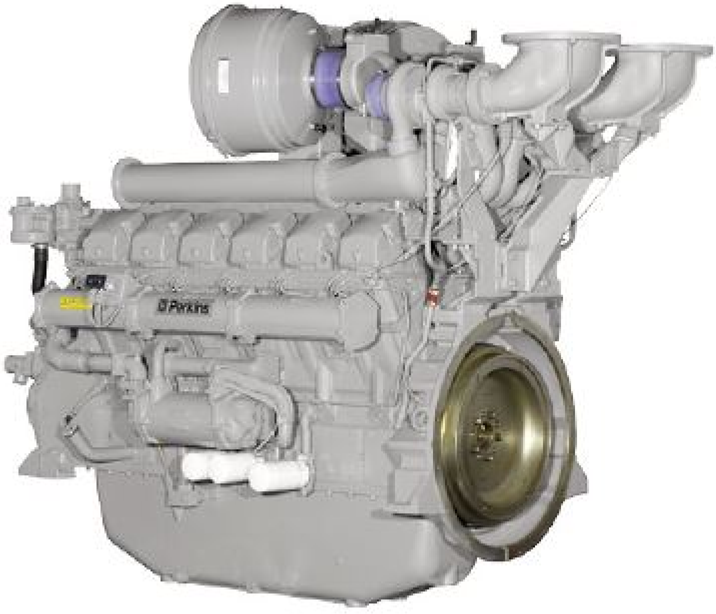
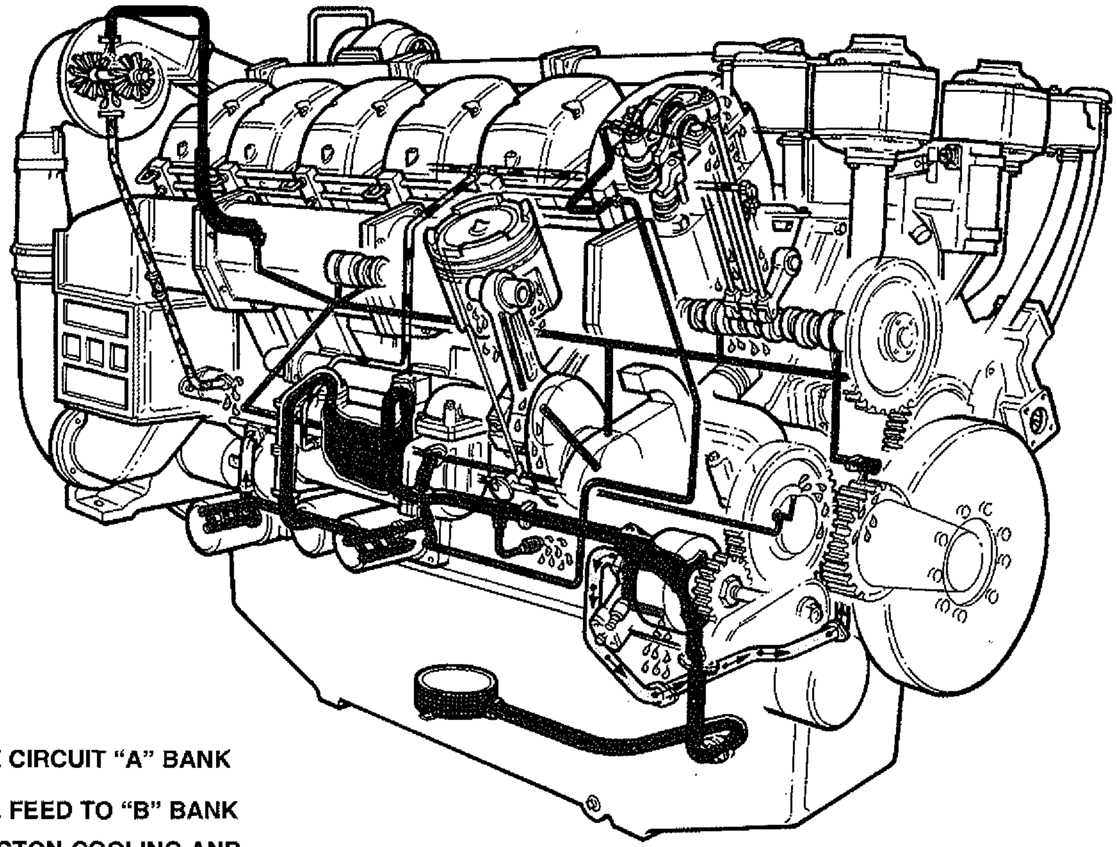
Perkins



# WORKSHOP MANUAL
# 4000 SERIES

4012 TAG1
4012 TAG2
4016 TAG1
4016 TAG2

# Perkins 4012/16 SERIES ENGINE LUBRICATING OIL DIAGRAM



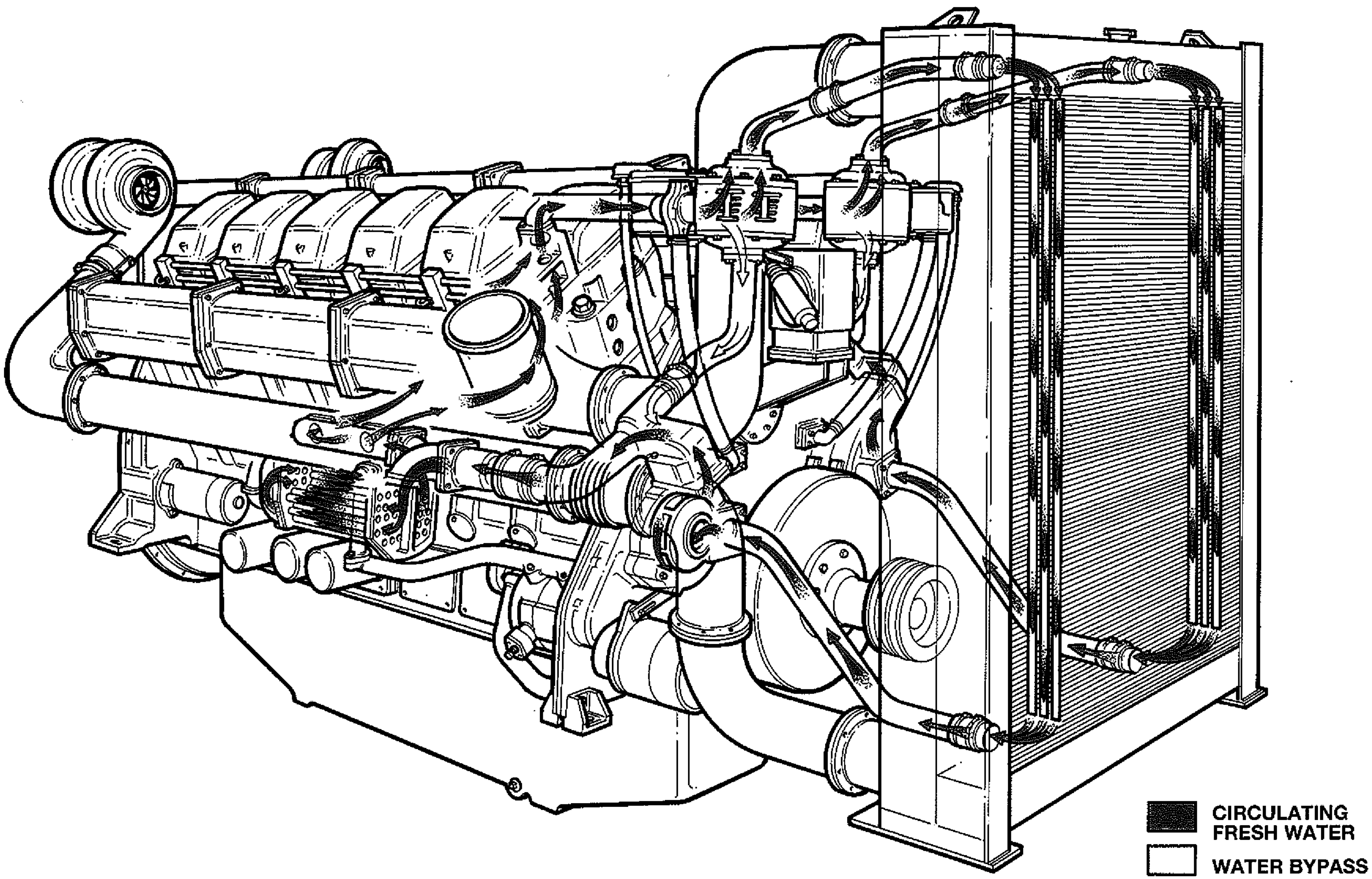
- OIL PRESSURE CIRCUIT "A" BANK
- OIL PRESSURE FEED TO "B" BANK
- OIL CIRCUIT PISTON COOLING AND CAM FOLLOWERS
- OIL RETURN TO SUMP
- OIL PRESSURE RELIEF

**PERKINS ENGINES (STAFFORD) LIMITED, TIXALL ROAD, STAFFORD ST16 3UB**

**Telephone: 01785 223141 Fax: 01785 215110 Telex: 36156**

PUBLICATION TP315 NOVEMBER 1994

# Perkins® 4012/16 TAG SERIES ENGINE (AIR COOLED CHARGE AIR COOLER) FRESH WATER CIRCULATION DIAGRAM





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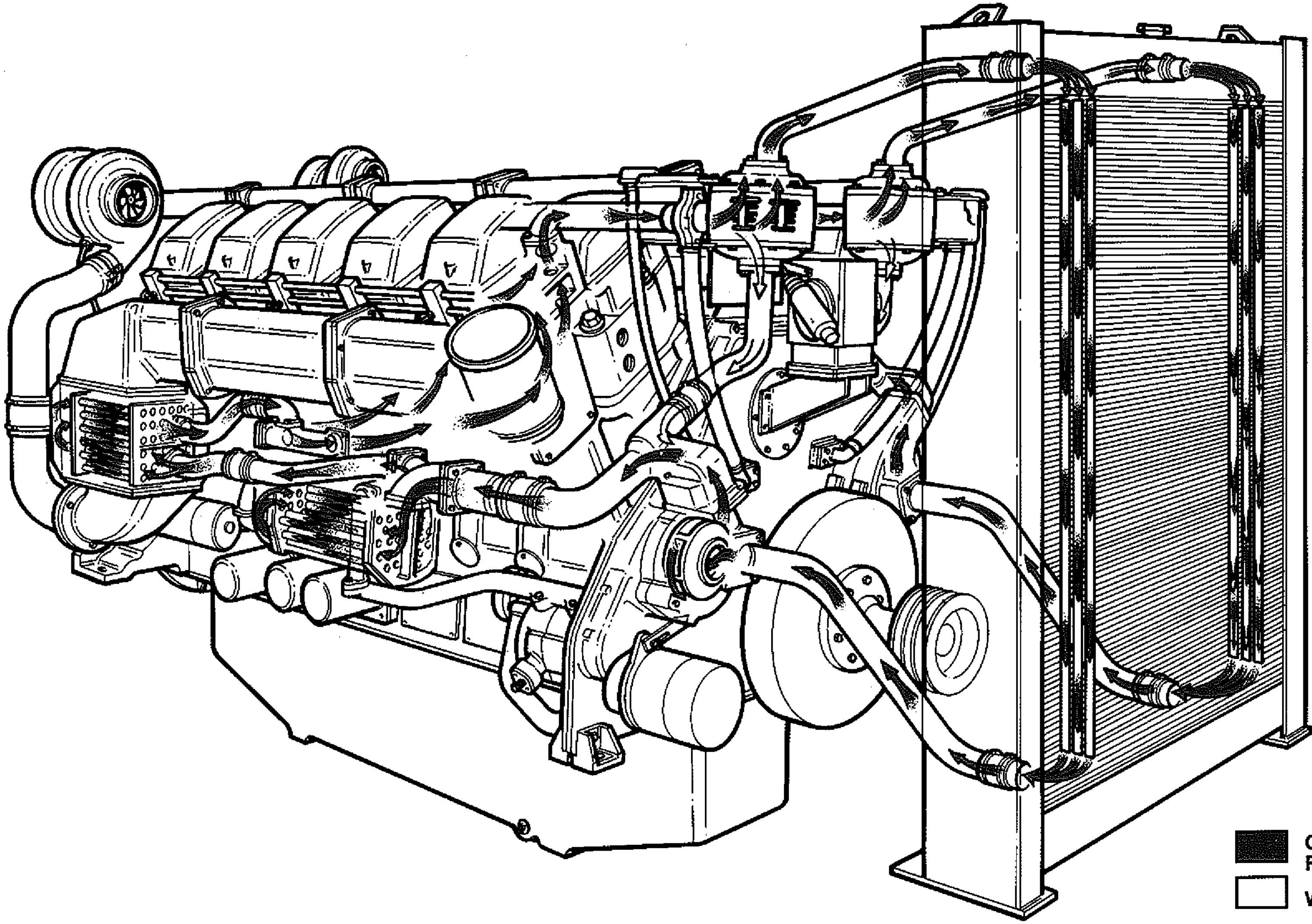
PUBLICATION TP372 NOVEMBER 1994

# Perkins® 4012/16 TWG SERIES ENGINE (WATER COOLED CHARGE AIR COOLER) FRESH WATER CIRCULATION DIAGRAM



CIRCULATING FRESH WATER

WATER BYPASS

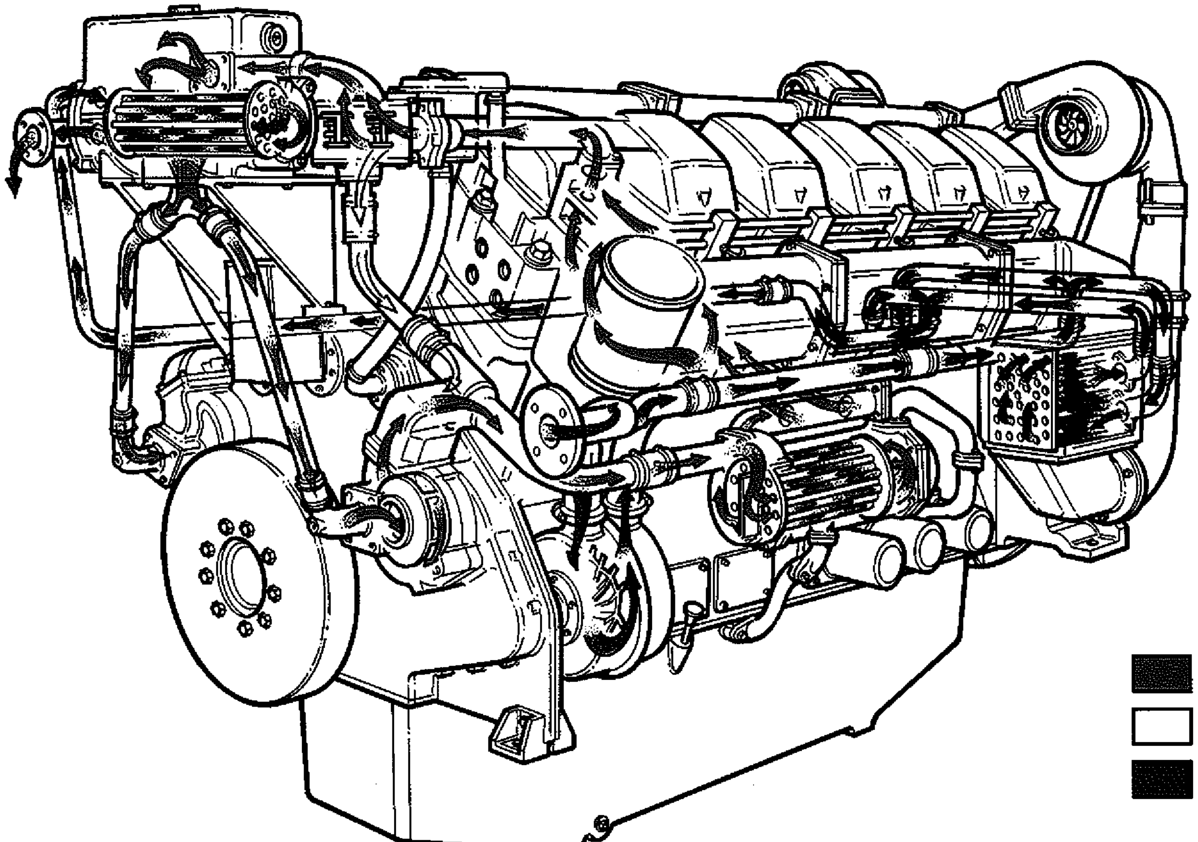
PERKINS ENGINES (STAFFORD) LIMITED, TIXALL ROAD, STAFFORD ST16 3UB

PUBLICATION TP373 NOVEMBER 1994

Telephone: 01785 223141 Fax: 01785 215110 Telex: 36156

# Perkins®

## 4012/16 TEG SERIES ENGINE (WATER COOLED CHARGE AIR COOLER) FRESH & RAW WATER CIRCULATION DIAGRAM



CIRCULATING FRESH WATER

WATER BYPASS

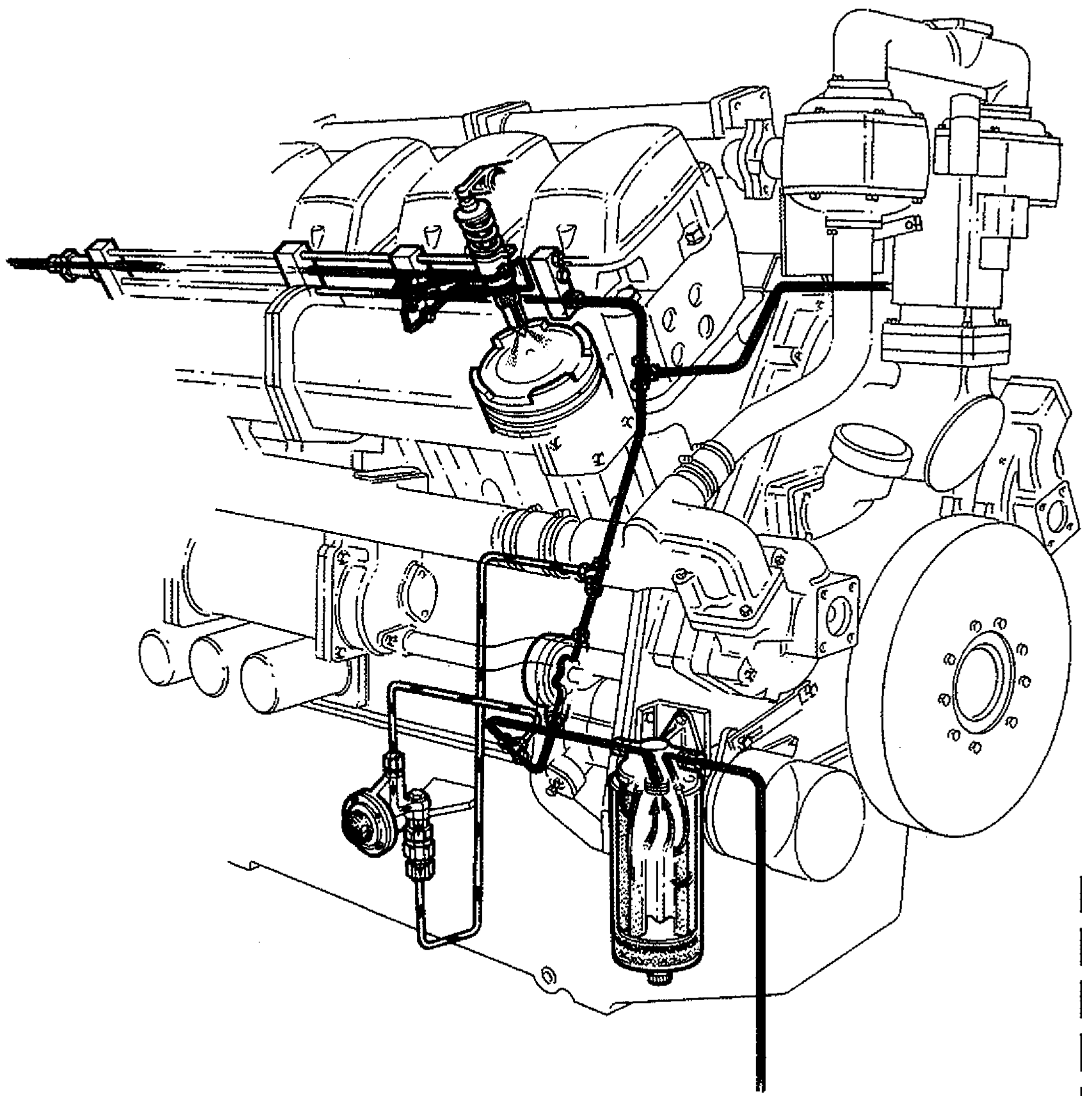
CIRCULATING RAW WATER

PERKINS ENGINES (STAFFORD) LIMITED, TIXALL ROAD, STAFFORD ST16 3UB

Telephone: 01785 223141 Fax: 01785 215110 Telex: 36156

PUBLICATION TP374 NOVEMBER 1994

# Perkins® 4012 SERIES ENGINE FUEL OIL DIAGRAM



FUEL LOW PRESSURE

FUEL INJECTION PRESSURE

FUEL RETURN

FUEL CONTAMINATED WITH WATER

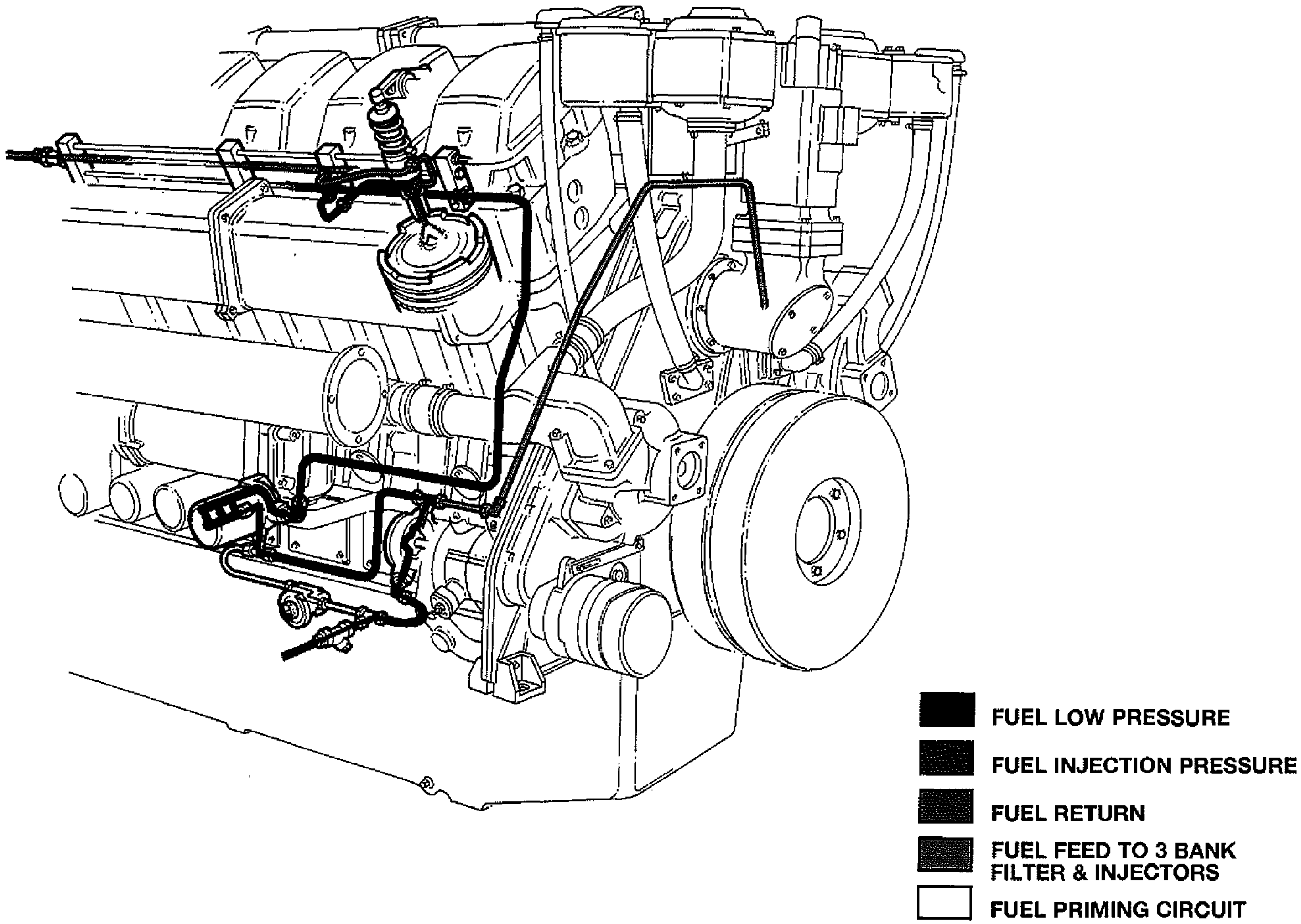
FUEL PRIMING CIRCUIT

**PERKINS ENGINES (STAFFORD) LIMITED, TIXALL ROAD, STAFFORD ST16 3UB**

**Telephone: 01785 223141 Fax: 01785 215110 Telex: 36156**

PUBLICATION TP321 NOVEMBER 1994

# Perkins® 4016 SERIES ENGINE FUEL OIL DIAGRAM




PERKINS ENGINES (STAFFORD) LIMITED, TIXALL ROAD, STAFFORD ST16 3UB
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PUBLICATION TP375 NOVEMBER 1994

## CALIFORNIA
## Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

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**Perkins**

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WARNING

READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS MENTIONED IN THIS MANUAL.
IMPROPER OPERATION OR MAINTENANCE PROCEDURES COULD RESULT IN A SERIOUS ACCIDENT OR DAMAGE TO THE EQUIPMENT CAUSING INJURY OR DEATH.
NON-COMPLIANCE WITH THESE INSTRUCTIONS AND THOSE INCLUDED IN THE INSTALLATION MANUAL TSL4068 MAY INVALIDATE THE WARRANTY OFFERED WITH THE ENGINE.
MAKE QUITE CERTAIN THAT THE ENGINE CANNOT BE STARTED IN ANY WAY BEFORE UNDERTAKING ANY MAINTENANCE, PARTICULARLY IN THE CASE OF AUTOMATICALLY STARTING GENERATING SETS.

The purpose of this Manual is to enable the operator to carry out routine servicing of the engine.
Before undertaking any work on the engine the appropriate section in the **Manual** should be read fully and completely understood prior to starting work.
The information contained within the manual is based on such information as was available at the time of going to print. In line with Perkins Engines (Stafford) Limited policy of continual development and improvement that information may change at any time without notice. The engine user should therefore ensure that he has the latest information before starting work.
The instructions contained in this Manual will, provided that they are correctly carried out, ensure the safe operation of the equipment.
Users are respectfully advised that it is their responsibility to employ competent persons to operate, maintain and service the equipment in the interest of safety.
Certain overhaul operations are impracticable without the use of special tools, and those operators who are not equipped to undertake major repairs are urged to consult their Perkins distributor.
When not working on the engine, ensure that all covers, blank flanges, doors, etc., are refitted to openings to prevent the ingress of dirt, etc.
Please quote the engine type and serial number with all your enquiries. This will help us to help you. The type and serial number are on a plate fitted to the crankcase.
If any doubt exists regarding the installation, use or application of the engine, the Installation Manual should be consulted for further advice contact Applications Department at Perkins Engines (Stafford) Ltd.
Oil change intervals may be changed according to operating experience by agreement with Perkins Engines (Stafford) Limited and subject to oil analysis being carried out at regular intervals.
Please note that this 4000 Series manual also covers SE engines dispatched from the factory from 1 March 1996. A table of equivalent engine designations is given on **page 2**.

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**Perkins International - North America**
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Telex: 380658 PERKIT I
Fax: 031 24 90 92 / 031 56 41 45

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**A/S Perkins Engines (Denmark) Ltd**
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**Perkins Engines (Far East) Pte Ltd.**
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**In addition to the above companies, there are Perkins distributors in most countries. Perkins Engines (Peterborough) Limited or one of the above companies can provide details.**

**Publication TSL4165**
**Published by the Technical Publications Department, Stafford.**

| PERKINS ENGINES (STAFFORD) ENGINE DESIGNATIONS 4000 SERIES AND SE SERIES EQUIVALENT TERMS | |
|---|---|
| **4000 SERIES** | **SE SERIES** |
| 4012TWG | 12SETCR |
| 4012TWG2 | 12SETCR2 |
| 4012TAG | 12SETCA |
| 4012TAG1 | 12SETCA1 |
| 4012TAG2 | 12SETCA2 |
| 4012TEG | 12SETCW |
| 4012TEG2 | 12SETCW2 |
| 4016TWG | 12SETCR |
| 4016TWG2 | 16SETCR2 |
| 4016TAG | 16SETCA |
| 4016TAG1 | 16SETCA1 |
| 4016TAG2 | 16SETCA2 |
| 4016TEG | 16SETCW |
| 4016TEG2 | 16SETCW2 |

## CONTENTS

## CONTENTS

# ⚠ SAFETY PRECAUTIONS

For safe and reliable operation of the engine it is essential that the recommended procedures as outlined in the manual are adhered to, and where necessary the special tools are used. Improper operation or maintenance procedures are dangerous and could result in injury or death.

The operator should check before operation that all the basic safety precautions have been carried out to avoid an accident occurring.

Read and understand all safety precautions and warnings before operating or servicing the engine.

The safety precautions that must be adhered to when operating the engine or carrying out service work are listed below under separate headings together with the relative symbols:

| | |
|---|---|
| Ensure guards are fitted | (a) over exposed rotating parts<br>(b) over exposed hot surfaces<br>(c) over exposed air intakes<br>(d) over exposed belts<br>(e) over live electrical terminals, high and low tension |
| Ensure protection equipment: for hands, ears, eyes, feet etc. (1) (2) (3) (5) (4) | (a) (1) is worn when using inhibitors<br>(b) (1) is worn when using anti-freeze<br>(c) (1) is worn when taking pressure cap off radiator or heat exchanger filler<br>(d) (5) is worn when working on or underneath engine<br>(e) (3) is worn when using air pressure line<br>(f) (1) is worn when changing lubricating oil/filter<br>(g) (2) is worn when working in enclosed engine room<br>(h) (1) is worn when changing electrolyte in battery<br>(j) (4) is worn always when working on the engine |
| No smoking or naked flame | (a) when checking battery electrolyte<br>(b) when working in engine room<br>(c) when operating or servicing engine |
| Fuel/oil pipes | (a) check for leaks<br>(b) check for spilt oil (clean up)<br>(c) always use barrier cream on hands |
| Gas/air pipes | (a) check for gas/air mixture leaks<br>(b) never run gas engine with failed pressure disc<br>(c) that gas line and valves meet local safety standards<br>(d) that the gas line pressure is correct |
| Shutdown equipment | (a) for stopping engine in case of over speed, high water temperature or low oil pressure should be provided<br>(b) for heat sensors, methane and smoke detectors should be provided (if applicable)<br>(c) test that protection system is working correctly<br>(d) Always be in a position to stop engine (even remotely) |
| Start up | (a) disconnect battery or any other means in case of accidental start up when working on engine<br>(b) never start engine with governor linkage disconnected<br>(c) do not hold stop lever in run position when starting engine<br>(d) always hold stop lever in stop position when cranking only |
| Electrical equipment | (a) check that electrics are earthed to local safety standards<br>(b) disconnect electrical supply to water jacket heater (if fitted) before working on engine<br>(c) take care against electric shocks<br>(d) Never re-adjust settings of electronic equipment without reference to Operation Manual |

| | |
|---|---|
| Freezing or heating component | (a) Always wear heat resistant gloves and use correct handling equipment |
| Exhaust system | (a) check for leaks<br>(b) check for correct ventilation of engine room<br>(c) check that guards are fitted<br>(d) check that diesel exhaust is clear<br>(e) check that pipework allows gas to escape upwards<br>(f) check that pipework is supported |
| Stop the engine | (a) before changing lubricating oil<br>(b) before filling radiator or topping up with anti-freeze<br>(c) before repairing engine<br>(d) before adjusting belts<br>(e) before adjusting tappets<br>(f) before changing spark plugs/injectors<br>(g) before changing air/oil/fuel filters (non change-over)<br>(h) before tightening fixing bolts etc |
| Flammable fluids | (a) never store near engine<br>(b) never use near naked light |
| Clothing | (a) do not wear loose clothing, ties, jewellery etc.<br>(b) always wear steel toe cap shoes<br>(c) always wear head, eye and ear protection<br>(d) always wear overalls<br>(e) always replace spillage contaminated overall immediately |
| Lifting heavy components | (a) use correct lifting equipment<br>(b) do not work alone<br>(c) always wear helmet |
| Viton 'O' rings | (a) always wear both hand and eye protection when handling 'O' rings which have been exposed to very high temperatures (eg a fire) |
| De-scaling solution | (a) always wear both hand and eye protection whilst handling<br>(b) always wear overalls and proper footwear |
| Handling/cutting gaskets and joints containing asbestos | (a) always wear respiratory protection<br>(b) always provide dust extract system<br>(c) always dispose of waste in accordance with local/legislative requirement |
| Waste disposal | (a) do not leave oily rags on or near the engine<br>(b) do not leave loose items on or near the engine<br>(c) provide fireproof container for oily rags |

Most accidents are caused by failure to observe basic precautions, and can be avoided by recognising potentially dangerous situations before an accident occurs.

Stop and isolate the engine, and ensure it cannot be restarted whilst servicing the engine.

Improper operation of the engine is dangerous and could result in injury or death.

Warnings are outlined in the operation manual and on the engine and are identified by the following symbol.

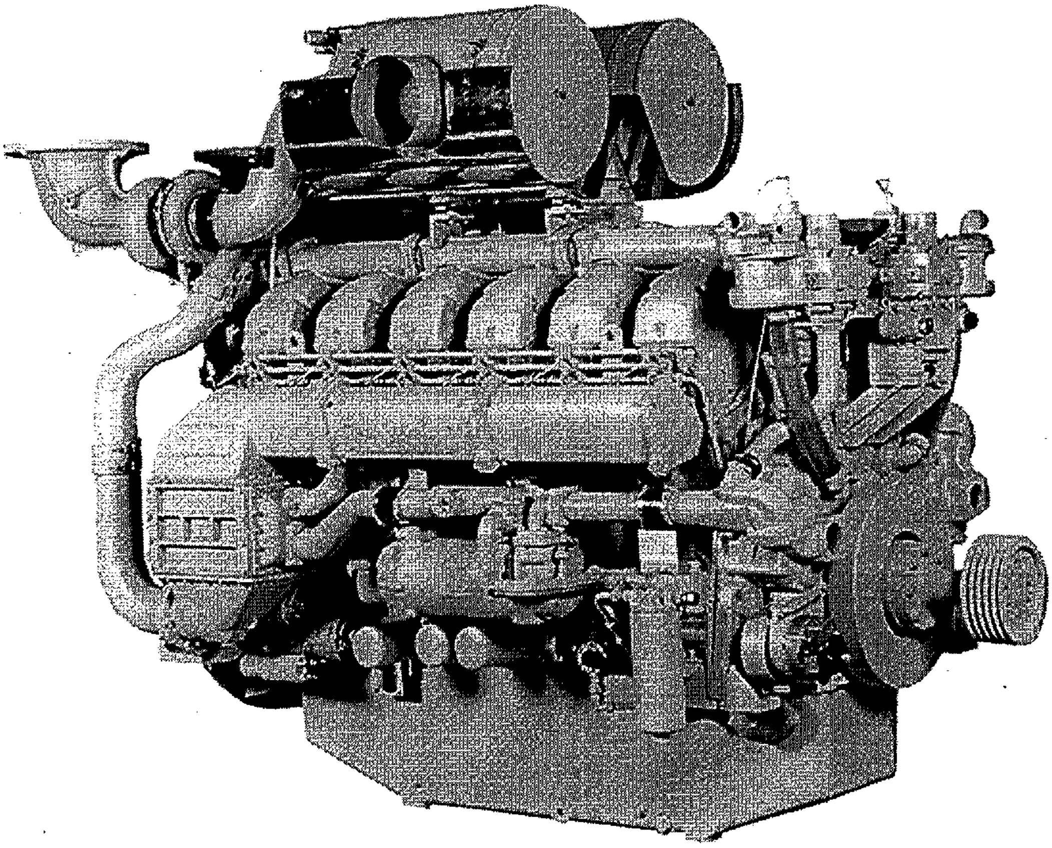
**WARNING** △ USE APPROPRIATE SYMBOL

There are many potential hazards that can occur during operation of the engine which cannot always be anticipated. Therefore a warning cannot be included in the manual for every possible circumstance that might involve a potential hazard.

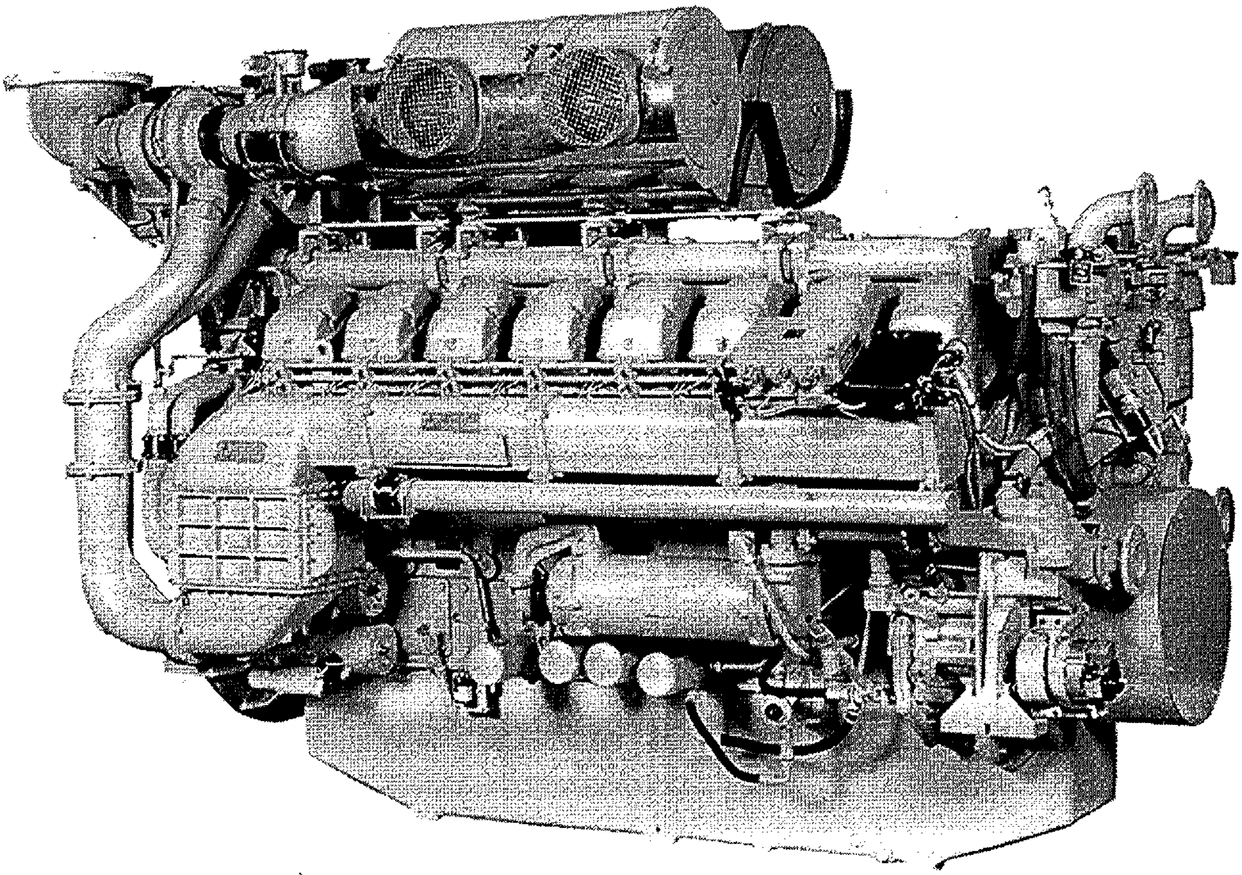
Should a procedure be used not specially recommended then you must satisfy yourself that it is safe and will not damage the engine.

| KEY TO SYMBOLS THAT MAY BE FOUND IN THE MANUAL | | |
|---|---|---|
| WARNING | NO SMOKING | WEAR EYE PROTECTION |
| HIGHLY FLAMMABLE | NO NAKED LIGHT | USE EAR PROTECTORS |
| DANGER LIVE WIRES | EMERGENCY STOP | PROTECTIVE FOOTWEAR MUST BE BE WORN |
| DANGER HOT SURFACE | GUARDS MUST BE FITTED BEFORE STARTING | WEAR HELMET |
| STAND CLEAR SUSPENDED LOADS | DANGER BATTERY ACID | HAND PROTECTION MUST BE WORN |

TP345
dated
JUNE 91



**4012TWG**



**4016TEG**

| | |
|---|---|
| **4012TWG** | 12 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), jacket water cooled charge air coolers and oil coolers in engine cooling circuit. Earlier engines with vertical air cleaners, later engines with horizontal air cleaners. |
| **4012TWG2** | Up rated version of the 4012TWG 12 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), jacket water cooled charge air coolers and oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4012TAG** | 12 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), air cooled charge air intercooler in radiator. Oil coolers in engine cooling circuit. Earlier engines with vertical air cleaners, later engines with horizontal air cleaners. |
| **4012TAG1** | Up rated version of the 4012TAG 12 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers) air cooled charge air intercooler in radiator. Oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4012TAG2** | Up rated version of the 4012TAG1 12 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), air cooled charge air intercooler in radiator. Oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4012TEG** | 12 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), raw water cooled charge air coolers with separate water pump and cooling circuit. Oil coolers in engine cooling circuit. Earlier engines with vertical air cleaners, later engines with horizontal air cleaners. |
| **4012TEG2** | 12 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), raw water cooled charge air coolers with separate water pump and cooling circuit. Oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4016TWG** | 16 cylinder "V" form diesel engine, water cooled, turbocharged (four turbochargers), jacket water cooled air cooiers and oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4016TWG2** | Up rated version of the 4016TWG 16 cylinder "V" form diesel engine, water cooled, turbocharged (four turbochargers), jacket water cooled charge air coolers and oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4016TAG** | 16 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), air cooled charge air intercooier in radiator. Oil coolers in engine cooling circuit. Earlier engines with vertical air cleaners, later engines with horizontal air cleaners. |
| **4016TAG1** | Up rated version of the 4016TAG 16 cylinder "V" form diesel engine, water cooled, turbocharged (four turbochargers) air cooled charge air intercooler in radiator. Oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4016TAG2** | Up rated version of the 4016TAG 16 cylinder "V" form diesel engine, water cooled, turbocharged (four turbochargers) air cooled charge air intercooier in radiator. Oil coolers in engine cooling circuit. Horizontal air cleaners. |
| **4016TEG** | 16 cylinder "V" form diesel engine, water cooled, turbocharged (twin turbochargers), raw water cooled charge air coolers with separate water pump and cooling circuit. Oil coolers in engine cooling circuit. Earlier engines with vertical air cleaners, later engines with horizontal air cleaners. |
| **4016TEG1 AND 4016TEG2** | Uprated versions of the 4016TEG 16 cylinder "V" form diesel engine, water cooled, turbocharged (four turbochargers), raw water cooled charge air coolers with separate pump and cooling circuit. Oil cooler in engine cooling circuit. Horizontal air cleaners. |

## SAFETY

### Engine lift equipment

Use only the lift equipment which is designed for the engine.

Use lift equipment or obtain assistance to lift heavy engine components such as the cylinder block, cylinder head, flywheel housing, crankshaft and flywheel.

Check the engine lift brackets for security before the engine is lifted.

### Asbestos joints

Some joints and gaskets contain compressed asbestos fibres see **Warning label Fig. A** in a rubber compound or in a metal outer cover. The 'white' asbestos (Chrysotile) which is used is a safer type of asbestos and the danger of damage to health is extremely small.

Contact with asbestos particles normally occurs at joint edges or where a joint is damaged during removal, or where a joint is removed by an abrasive method.

To ensure that the risk is kept to a minimum, the procedures given below must be followed when an engine which has asbestos joints is dismantled or assembled.

- Work in an area with good ventilation.
- Do NOT smoke.
- Use a hand scraper to remove the joints - do NOT use a rotary wire brush.
- Ensure that the joint to be removed is wet with oil or water to contain any loose particles.
- Spray all asbestos debris with water and place it in a closed container which can be sealed for safe disposal.

### Dangers from used engine oils

Prolonged and repeated contact with mineral oil will result in the removal of natural oils from the skin, leading to dryness, irritation and dermatitis. The oil also contains potentially harmful contaminants which may result in skin cancer.

Adequate means of skin protection and washing facilities should be readily available.

**Fig. A** 1085.2

The following is a list of 'Health Protection Precautions', suggested to minimise the risk of contamination.

1 Avoid prolonged and repeated contact with used engine oils.

2 Wear protective clothing, including impervious gloves where applicable.

3 Do not put oily rags into pockets.

4 Avoid contaminating clothes, particularly underwear, with oil.

5 Overalls must be cleaned regularly. Discard unwashable clothing and oil impregnated footwear.

6 First aid treatment should be obtained immediately for open cuts and wounds.

7 Apply barrier creams before each period of work to aid the removal of mineral oil from the skin.

8 Wash with soap and hot water, or alternatively use a skin cleanser and a nail brush, to ensure that all oil is removed from the skin. Preparations containing lanolin will help replace the natural skin oils which have been removed.

9 Do NOT use petrol, kerosene, diesel fuel, gas oil, thinners or solvents for washing the skin.

10 If skin disorder appears, medical advice must be taken.

11 Degrease components before handling if practicable.

12 Where there is the possibility of a risk to the eyes, goggles or a face shield should be worn. An eye wash facility should be readily available.

### Environmental protection

There is legislation to protect the environment from the incorrect disposal of used lubricating oil. To ensure that the environment is protected, consult your Local Authority who can give advice.

### Viton seals

Some seals used in engines and in components fitted to engines are made from Viton.

Viton is used by many manufacturers and is a safe material under normal conditions of operation.

If Viton is burned, a product of this burnt material is an acid which is extremely dangerous. Never allow this burnt material to come into contact with the skin or with the eyes.

If it is necessary to come into contact with components which have been burnt, ensure that the precautions which follow are used:

- Ensure that the components have cooled.
- Use Neoprene gloves and discard the gloves safely after use.
- Wash the area with a calcium hydroxide solution and then with clean water.
- Disposal of gloves and components which are contaminated, must be in accordance with local regulations.

If there is contamination of the skin or eyes, wash the affected area with a continuous supply of clean water or with a calcium hydroxide solution for 15-60 minutes. Obtain immediate medical attention.

**WARNING** ⚠ IT IS ESSENTIAL WHEN HANDLING INHIBITORS THAT PROTECTIVE EQUIPMENT IS WORN i.e. GOGGLES, GLOVES, ETC., TO AVOID EYE AND SKIN CONTACT AND INGESTION.

**STANDARD EX-WORKS TREATMENT LEVEL A**

For UK/European shipment giving up to 6 months shipping and storage protection when transported by container or lorry.

1. The oil and fuel used on engine test give satisfactory protection for 6 months. After test the oil is drained from the sump.
2. The water cooling system is flushed through with a Shell corrosion inhibited anti-freeze at 50% dilution with water.
3. After spray painting to the appropriate standard, ail bright surfaces and unpainted metal are treated with Valvoline Tectyl 506 preservative, brushing quality (this includes control linkages, etc.).
4. All openings in the engine (including points where pipework has been removed and air cleaner inlets, etc.), are sealed with plugs or blank flanges.

**SPECIAL PRESERVATION LEVEL B**

For overseas shipment giving 12 months shipping and storage protection under normal enclosed storage conditions of -15°C to +55°C and up to 90% relative humidity for up to 12 months.

1. The oil used on engine test confers satisfactory protection for 12 months after despatch from the works.
2. The entire fuel system is drained including filters, pump injectors and fuel tank, and replaced by one of the following fluids:-

SHELL 4113 (CONFORMS TO ISO 4113)
GULF DIESEL FLUID 34
CASTROL H91/61
ESSO IL1047

3. The engine is run for ten minutes at idling speed, until the preserving fluid emerges from the injector return connection.
4. During this period two brief accelerations to maximum speed (no load) are made to ensure complete circulation of the preserving fluid, which then remains in the fuel system after the engine has stopped and no further rotation of the engine takes place.
5. The engine oil is then drained from the sump.
6. The water cooling system is flushed through with a Shell corrosion inhibited anti-freeze at 50% dilution with water.
7. After spray painting to the appropriate standard, all bright surfaces and unpainted metal are treated with Valvoline Tectyl 506 preservative, brushing quality (this includes control linkages, etc.).
8. All openings in the engine (including points where pipework has been removed and air cleaner inlets, etc.), are sealed with plugs or blank flanges.

## SPECIAL PRESERVATION LEVEL C

For UK or overseas shipment when prolonged storage and protection is required for up to 5 years in temperate, tropical or arctic climates.

Also meets preservation to MOD NES 724 Level J for UK/NW Europe when stored in unheated buildings, or in the open under water-proof covers.

1. After engine test the oil is drained from the sump, filters and oil coolers.
2. The engine is refilled with Crodafluid PQ11 engine preserving oil.
3. The entire fuel system is drained including filters, pump injectors and fuel tank, and replaced by one of the following fluids:-

   SHELL 4113 (CONFORMS TO ISO 4113)
   GULF DIESEL FLUID 34
   CASTROL H91/61
   ESSO IL1047
4. The engine is then run for ten minutes at idling speed until the preserving fluid emerges from the injector return connection.
5. During this period, two brief accelerations to a maximum speed (no load) are made to ensure complete circulation of the preserving fluid, which then remains in the fuel system after the engine has stopped. No further rotation of the engine takes place.
6. The engine oil is then drained from the sump.
7. The water cooling system is flushed through with a shell corrosion inhibited anti-freeze at 50% dilution with water.
8. The water pump impellers are sprayed with Crodafluid PM47 oil film rust preventative.
9. After spray painting to the appropriate standard, all bright surfaces and unpainted metal are treated with Valvoline Tectyl 506 preservative brushing quality (this includes control linkages, etc.).
10. Inlet and exhaust manifolds have 5 - 15 milligrammes (depending on engine size) of Shell VPI 260 vapour phase inhibitor placed in them before sealing normally.
11. Air filter bodies are sprayed inside with Crodafluid PQ11 reserving oil.
12. Plastic plugs are fitted to fuel entry points, water connections, spare instrument holes in panels and air filter inlets.
13. Exhaust outlets are fitted with steel blanking plates.
14. Water hoses are treated with silicone grease and wrapped or sleeved with black polythene (silicone rubber hoses need not be treated).
15. Drive belts are removed, wrapped in wax paper, and packed in black polythene with silica gel as desiccant.
16. Starters, alternator, switches, instruments, sensors and wiring are sprayed with ambersil MS4 silicone grease.
17. Pulleys, flywheel, starter ring, pinion, etc., are protected by dipping or painting with Crodafluid PM47 oil film rust preventative.
18. The flywheel housing is fitted with a steel blanking plate.
19. Control panels have desiccants placed inside.
20. The complete engine assembly is sprayed with Crodafluid PW10 wax film rust preventative.

**(FOR FURTHER INFORMATION REFER TO INSTALLATION MANUAL TSL4068)**

## FOUNDATION

The foundation put down to accommodate a unit powered by a diesel engine is of great importance as it must:

i) Support the static weight of the units and any dynamic loads due to the running engine's out-of-balance forces.
ii) Be sufficiently rigid and stable so that distortion will not take place which would affect the alignment of the engine and driven unit.
iii) Absorb vibrations originating from the running units and prevent them being transmitted to the engine room floor, walls, etc.

## COOLING SYSTEM

For the satisfactory running of a diesel engine it is essential that the cooling system is efficient and of the correct type for the installation being considered.

The most common system is the utilisation of a mechanically driven water pump to force the coolant through the oil cooler, water jackets, cylinder heads and, in some cases, through a water cooled exhaust manifold.

The hot water from the engine unit enters the header tank of a radiator, passing through its tubes and out to the suction side of the water pump. A pressure of 0.5 to 0.7 bar is maintained in the system by the thermostats.

Water passing through the radiator is cooled by pushing air through the matrix by an engine driven fan. (See the appropriate **Engine Water Circulation diagram**).

To obtain extra power from a turbocharged engine, the hot air delivered from the turbo compressor is cooled before entering the engine cylinders.

When this compressed air is cooled by the ambient air, an additional radiator is fitted between the normal water radiator and the fan, which pushes the air through the charge air radiator first and then the water radiator. Large bore pipes connect the turbochargers to the charge air radiator and from it to the inlet manifolds. (See the appropriate **Engine Water Circulation diagram**).

When the charge air is cooled by the engine coolant, the engine driven water pump circulates the coolant through engine mounted charge air coolers, before the air enters the inlet manifolds. (See the appropriate **Engine Water Circulation diagram**).

When the charge air is cooled by raw water, an additional pump is fitted to circulate raw water through the engine mounted charge air coolers, before the air enters the inlet manifolds (see the installation variations of the above including remote mounted radiators, break tanks, cooling towers, heat exchangers and special radiators as described in the **Installation Manual TL4068.**)

## EXHAUST SYSTEM

The primary function of the exhaust system is to pipe the exhaust gases from the engine and discharge them, at an acceptable noise level, outside the engine room at a height sufficient to ensure their proper dispersal.

## BACK PRESSURE LIMITATION

Diesel engines give optimum performance when the resistance to exhaust gas flow is below a certain limit. Starting at the engine exhaust outlet flange the total exhaust system should not impose back pressure on the engine greater than that recommended. Excessive back pressure will cause incomplete combustion and deterioration in the scavenging of the cylinders. The result will be loss of power, high exhaust temperature and the formation of soot. The soot, if oily, can also affect the turbine of a turbocharger. The oily soot can build up on the turbine blades, harden and, if pieces of carbon break off, the turbine can become unbalanced and cause failure of seals and bearings.

**THE MAXIMUM EXHAUST BACK PRESSURE FIGURES FOR 4012/16 ENGINES CAN BE FOUND IN THE PRODUCT INFORMATION MANUAL AND ALSO IN ENGINE DATA SECTION OF THIS MANUAL.**

## INSTALLATION OF THE EXHAUST SYSTEM

The exhaust system should be planned at the outset of the installation. The main objectives must be to:

i) Ensure that the back pressure of the complete system is below the maximum limit.
ii) Keep weight off the engine manifolds and turbochargers by supporting the system.
iii) Allow for thermal expansion and contraction.
iv) Provide flexibility if the engine set is on anti-vibration mountings.
   If the engine is on anti-vibration mountings, there will be lateral movement of the engine exhaust outlet flanges when the engine starts and stops. Flexible elements should therefore be fitted as near to the outlet flanges as is practicable.
v) In a closed engine room or canopy, the exhaust system and silencer must be lagged to reduce heat radiation.
vi) Each engine must have its own separate exhaust system.

## ENGINE BREATHER

All engines are fitted with a breather system which prevents a build up of pressure in the crankcase, due to blow-by from the pistons. These fumes contain contaminants from the combustion process and minute globules of oil, so they are passed through a mesh filter which removes most of the oil before the gases are released to atmosphere.

## BREATHER INSTALLATION

Breather discharge gases should be ducted out of the engine room, which will be adequately ventilated. The pipe diameter should be equal to or larger than the discharge hose provided with the breather, in order to prevent the crankcase pressure from exceeding 25mm water gauge.

## FUEL SYSTEM

There are two basic systems for the installation of the fuel supply. The system chosen will depend on the amount of fuel required per day and if labour is available to carry out simple daily routine jobs.

**FUEL TANK - DAILY SERVICE**

The tank is usually sized to that the usable fuel content will be 9500/10500 litres. With a generating set having a full load of electrical output of 1200 kW such an amount would last for 20/24 hours with a reserve of approximately 10 hours.

It is preferred that the fuel tank be installed adjacent to the engine on a stand or bulk-head. It is recommended that the tank be so positioned that the minimum level of fuel be higher than the engine injector rail in order to create a positive head and gravity feed to the engine.

WARNING ⚠ SHOULD THE MAXIMUM FUEL LEVEL IN THE TANK BE HIGHER THAN 1.0 m (1.1 $lb/in^2$) ABOVE THE LEVEL OF THE INJECTORS, THEN AN ISOLATING SOLENOID VALVE MUST BE FITTED IN THE FUEL FEED LINE TO OPEN ON CRANKING, WITH DELAYED CLOSURE ON SHUT DOWN, TO PREVENT FUEL STARVATION.

**BULK STORAGE TANK**

Large engines or multi-engine installations require a large amount of fuel per hour and to contain the fuel a bulk storage tank is sited near to the engine room.

It may be arranged for the day tank to be manually filled by operating valves and using gravity to transfer the fuel from the bulk tank. However, to be sure that the day tank is regularly being filled, even through a night run, it is usual to have the transfer of fuel done automatically. The capacity of the day tank must be sufficient i.e. a minimum of 14000/18000 litre (3000/4000 gal) for 12/16 cylinder engines respectively, to avoid overheating the fuel in the tank by the excess returning from the engine, which contains 5 - 10 kW of heat, (maximum permissible fuel temperature is 57°C). If this is not possible, the fuel returning from the injectors must be piped directly to the bulk tank.

**NOTE:** Fuel injection equipment is particularly vulnerable to the effects of water and other contaminants. Fit a primary fuel filter/water separator in the fuel feed line to the engine and incorporate sediment traps in the bulk tanks and day tanks.

**SOUND INSULATION**

WARNING ⚠ ALWAYS WEAR EYE AND EAR PROTECTION WHEN WORKING NEAR OR IN AN ENGINE ROOM.

**NOISE LEVEL**

Noise levels are measured in decibels dB - through a frequency range of 31.5 to 16000 Hz and at each octave band centre frequency i.e. 31.5, 63, 125, 250 Hz, etc.

The human ear is responsive to noise levels in the frequency range of 63 to 8000 Hz.

The noise level in dB can be weighted A,B,C and D to suit different requirements.

The accepted norm is the 'A' Weighting as such an overall noise level closely reproduces the response of the human ear. The most commonly accepted readings are 'Sound Pressure Level'.

## RECOMMENDATIONS TO CONTAIN NOISE

In an engine room installation where noise levels to the outside have to be controlled, the following factors must be considered:

I) **BUILDING CONSTRUCTION**

Outside walls - should be double brick with a cavity.

Windows - double glazed with an approximate gap of 200 mm between panes.

Doors - double door air-lock or a single door with a wall built outside the door as a noise barrier, to absorb and reflect the noise when the door is opened.

II) **VENTILATION**

Air inlets for engine combustion and cooling air and the air outlet from the radiator fan or extractor fan should be fitted with noise attenuating splitters. These are proprietary items and should be discussed with the manufacturer. Ensure that the splitters do not restrict the air flow, as this puts excessive resistance on the fans.

With the amount of cooling air required on the larger engines, the splitters should be of generous proportions and the building should be adapted so that they fit correctly.

III) The engine set should be mounted on anti-vibration mountings, to prevent vibration being transmitted to the walls, other pieces of equipment, etc. These vibrations often generate noise.

## TORSIONAL VIBRATION ANALYSIS

## CRITICAL SPEED

Torsional vibrations occur in any rotating system. When fitting driven equipment to an engine, particularly single or twin bearing alternators, it is very important to investigate the torsional vibration characteristics of the complete unit.

At certain speeds in the engine running range, these vibrations may be sufficient to fracture the engine crankshaft, flywheel bolts, strip teeth off gear wheels, etc.

The point in the speed range where any of the above hazards can occur is called the '**CRITICAL SPEED**'.

The object of the torsional analysis is to calculate the critical speed points from the magnitude and frequency of the disturbing forces, and ensure that damaging critical speeds are outside the operating range of the engine, and particularly that all is clear within +10% to -5% of the synchronous speed.

There may be some critical speeds in the speed range from starting speed to 95% of synchronous speed, but these may be judged as 'safe', because the critical speed is passed through in a second or so.

However, if due to the application the requirement is an 'all speed' range, then all critical speeds have to be controlled within safe limits.

## GENERAL TORQUE LOADINGS

The following torque loadings are general for metric coarse threads and for grade 8.8 steel, but do not supersede the figures quoted above.

| THREAD | lbf ft | Nm |
|---|---|---|
| M5 | 5 | 7 |
| M6 | 9 | 12 |
| M8 | 21 | 28 |
| M10 | 41 | 56 |
| M12 | 72 | 98 |
| M16 | 180 | 244 |
| M20 | 351 | 476 |
| M24 | 606 | 822 |

**GENERAL NOTE:**

| | | |
|---|---|---|
| M10 - 12.9 Steel | 50 | 70 |

**TIGHTENING TORQUES**

These are based on 85% of the proof loads designated in BS3692.

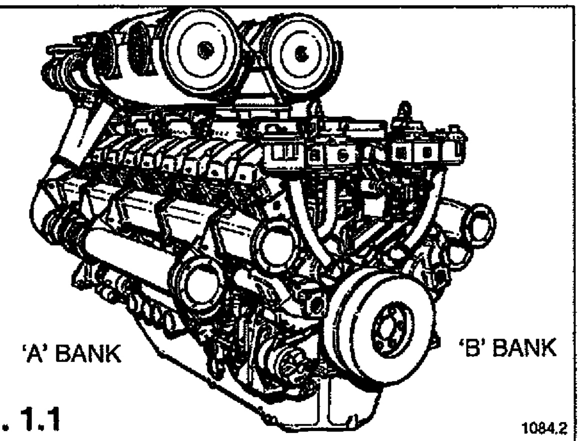



**Fig. 1.1**

For full technical data please refer to the **Product Information Manual.**

**Type:** Water-cooled, turbocharged, charge cooled, industrial diesel engine.

| **RANGE** | **4012** | **4016** |
|---|---|---|
| Cycle | 4 stroke | 4 stroke |
| No. of cylinders | 12 | 16 |
| Configuration | V-form | V-form |
| Bore | 160 mm | 160 mm |
| Stroke | 190 mm | 190 mm |
| Total swept volume | 45.84 litres | 61.123 litres |
| Compression ratio | 13.6:1 | 13.6:1 |
| Rotation | Anti-clockwise looking on flywheel end | |
| Firing order | 1A-6B-5A-2B-3A-4B-6A-1B-2A-5B-4A-3B | 1A-1B-3A-3B-7A-7B-5A-5B-8A-8B-6A-6B-2A-2B-4A-4B |
| Valve Timing | inlet valve opens 60° BTDC<br>inlet valve closes 46° ABDC | exh valve opens 46° BBDC<br>exh valve closes 60° ATDC |
| | | |
| Cylinder numbering | Cylinder 1 furthest from flywheel | |
| Cylinders designated A are on the right hand side of the engine, when viewed from the fly-wheel end and cylinders designated B are on the left hand side of the engine. | | |
| | | |
| Valve Clearances | exhaust | 0.40 mm (0.016") |
| (Engine cold) | inlet | 0.40 mm (0.016") |
| Valve dia. (mm) inlet and exhaust | 48 | 48 |
| | (52 on 4012TAG1/2 AND 4016TAG1/2) | |
| Valve Timing | See Workshop Manual **Sections U4 & U5** | |
| Injection Timing | See engine nameplate | |
| Piston Speeds | Engine r/min | m/s (ft/min) |
| | 1000 | 6.33 (1247) |
| | 1200 | 7.60 (1496) |
| | 1500 | 9.50 (1870) |
| | 1800 | 11.40 (2244) |

# TYPICAL COOLING SYSTEM

| | 4012 | 4016 |
|---|---|---|
| Approved Coolants) | See page 28 | |

| Total water capacity | Ltrs | Gals | Spec | Ltrs | Gals | Spec |
|---|---|---|---|---|---|---|
| | 200 | 44 | TAG | 255 | 56.1 | TAG |
| | 232 | 51 | TAG1 | 316 | 70 | TAG1 |
| | 232 | 51 | TAG2 | 316 | 70 | TAG2 |
| | 185 | 40 | TWG | 95 | 21 | TWG* |
| | 205 | 45 | TWG2 | 95 | 21 | TWG2* |
| | 82 | 18 | TEG** | 108 | 23.7 | TEG** |

* Engine only
** Engine with heat exchanger

| | |
|---|---|
| Max radiator top tank temperature | 93°C |
| Max water temperature into engine | 80°C |
| Thermostat opening temperature | 71°C |
| System pressure | 0.5 to 0.7 bar |

# FUEL SYSTEM

| | 4012 | 4016 |
|---|---|---|
| Approved fuels | See page 20 | |
| Minimum size fuel tank | 14,000 litres (3,000 gal.) | 18,000 litres (4,000 gal.) |
| Relief valve setting | 310 kPA (45 psi) | |
| Inferior nozzle pressure | 225-235 atm | |
| Injection equipment | Lucas-Bryce unit injector | |
| Filter/water separator | Spin-on expandable canister(s) | |
| Fuel lift pump | Maximum suction lift 1 metre | |
| Fuel flow | 20.457 litre/min. (4.5 gpm) @ 1800 r/min | |

# GOVERNORS

| | 4012 | 4016 |
|---|---|---|
| Type | Electronic | Electronic |
| Type | Hydraulic | Hydraulic |

# LUBRICATION SYSTEM

| | 4012 | 4016 |
|---|---|---|
| Recommended oil | See pages 17 & 18 | |
| Type of system | Wet sump, external engine mounted oil pump | |
| Total oil capacity (including cooler and filter) | 178 litre (39.2 gal) | 238 litre (53 gal) |
| Sump capacity (dipstick) | | |
| Min. | 136 litre (30 gal) | 147 litre (33 gal) |
| Max. | 159 litre (35 gal) | 214 litre (47 gal) |
| Crankcase pressure (max) | 25 mm (1") water gauge | |
| Lubricating oil temperature max. to bearings | 105°C | |
| Lubricating oil pressure at 80°C temp. to bearings | 0.34 mPa | |
| Max. oil temperature in sump | 115°C | |
| Min. oil pressure (1500 rpm)(at filter head) | 200 kPa (30 lb/in²) | |
| Oil filter | Disposable canister type | |
| Oil pump location | 'A' Bank | |

# INDUCTION SYSTEM

| | 4012 | 4016 |
|---|---|---|
| Air cleaners (earlier)<br>(current) | Twin vertical air cleaners<br>Twin horizontal air cleaners | |
| Type | Paper element | |
| Air restriction indicator setting | 380 mm $H_20$ | |
| Turbochargers | x2 off | x4 off |

# EXHAUST SYSTEM

| | 4012 | 4016 |
|---|---|---|
| Manifold type | Dry or water cooled | |
| Exhaust outlet flange | Vertical (Twin) | |
| Mating flange | See **Installation Manual** | |
| Max. exhaust back pressure | See **Product Information Manual** | |
| Max. exhaust temperature | | |

# FLYWHEEL

| | 4012 | 4016 |
|---|---|---|
| Drive size | SAE 18" | |
| | SAE 21" Optional | |

# FLYWHEEL HOUSING

| | 4012 | 4016 |
|---|---|---|
| SAE size | 00 | |

## TYPICAL DRY WEIGHT

| | 4012 | 4016 |
|---|---|---|
| Dry weight (engine) | 4360 kg 4012TAG | 5500 kg 4016TAG |
| | 4360 kg 4012TAG1 | 5750 kg 4016TAG1 |
| | 4400 kg 4012TAG2 | 5750 kg 4016TAG2 |
| | 4975 kg 4012TWG | 5940 kg 4016TWG/2 |
| | 5315 kg 4012TWG2 | 5820 kg 4016TEG |
| | 4680 kg 4012TEG2 | |
| | | |
| Dry weight engine & tropical radiator | 5280 kg 4012TAG | 6900 kg 4016TAG |
| | 5760 kg 4012TAG1 | 8010 kg 4016TAG1 |
| | 5800 kg 4012TAG2 | 8010 kg 4016TAG2 |
| | 4995 kg 4012TWG | |
| | 5315 kg 4012TWG/2 | |
| | | |
| Dry weight engine & heat exchanger | 4860 kg 4012TEG | 6000 kg 4016TEG |

## HOLDING DOWN BOLT HOLES

| | 4012 | 4016 |
|---|---|---|
| Hole dia. (Engine feet) | 22 mm | |
| No. off | 8 | |
| Hole dia. (Radiator feet) | 18 mm x 6 4012TAG | 22 mm x 6 4016TAG/2 |
| Turbochargers | 22 mm x 6 4012TAG2 | |
| | 22 mm x 6 4012TWG/1 | |

## ELECTRICAL SYSTEM

| | 4012 | 4016 |
|---|---|---|
| Voltage | 24V | |
| Alternator | Belt Driven | |
| Alternator output | 30A | |
| Starter motor | Single CAV (Earlier Engines) Twin Prestolite (Current Engines) | Twin Prestolite |
| No. of teeth (gear ring) | 144 (Early Engines) 156 (Current Engines) | 156 |
| No. of teeth (starter pinion) | 12 | |
| Battery (lead acid) | 24V DC (2 x 12V) | |
| Capacity down to 0°C (32°F) | 286 Ah | |

## PROTECTION EQUIPMENT

Before resetting protection equipment, it must be established whether special settings (for that individual engine) have been specified in the engine sales contract. This is particularly important with ALL high water temperature settings, and ALL Cogen applications.

Standard settings for protection equipment are as follows:-

| | Alarm | Shutdown |
|---|---|---|
| High Oil temperature (in sump) | 110°C | 115°C |
| Low oil pressure | 2.06 bar (30 lb/in²) | 1.93 bar (28 lb/in²) |
| High water temperature | | |
| 71°C Thermostat | 91°C | 96°C |
| 85°C Thermostat | 96°C | 101°C |
| 96°C Thermostat | 100°C | 105°C |

**Caution:** The above standard settings do not supersede any settings specified in the engine sales contract.

| | |
|---|---|
| Overspeed | 15% above max. running speed<br>(Except 1800 r/min which is 7%) |

## AIR STARTING

| | 4012 | 4016 |
|---|---|---|
| Air starter | See **Installation Manual** | |
| Air starter pressure | 150 lb/in² (10.34 bar) | |
| Compressed air supply | 170 lb/in² (11.72 bar) | |

## INSTRUMENT PANEL (ENGINE MOUNTED)

| | Normal Operation |
|---|---|
| Oil pressure | Between 276-413 kPa (40-60 lb/in²) |
| Oil temperature | Between 80-90°C (176-194°F) |
| Water temperature | Between 65-85°C (149-185°F) |
| Exhaust temperature | See **Product Information Manual** |

## COOLANT JACKET HEATING

| | 4012 | 4016 |
|---|---|---|
| Heater | 2 x 4 kW | |
| Voltage | 210-250V ac | |

**COMMISSIONING CHECK LIST**
**PLEASE REFER TO THE APPROPRIATE SECTION IN THIS MANUAL**

**1. INSTALLATION**

a) Ventilation inlet and outlet apertures to be of adequate size and unobstructed.

b) 1. The exhaust system must be of adequate size to avoid back pressure and be supported independently of the engine, with flexible sections.
2. The system must be suitably lagged to reduce the radiation of heat.
3. The outlet through the wall from the engine room must be satisfactorily sleeved.

c) Suitable anti-vibration mountings should be provided and be properly aligned.

d) Fuel System
The feed and return pipes must be adequate and the joints must be well made.
The sediment bowl must be clear.
The vent pipe must be unrestricted.

**2. AFTER LONG TERM STORAGE OR A LONG INOPERATIVE PERIOD (Refer to pages 13 & 14)**

1. Examine the air cleaners, exhaust manifolds and turbocharger outlets.
2. Remove the sump plug and drain the oil. Fill with new oil.
3. Remove the rocker covers.
4. With the fuel turned off, bar the engine over by hand, rocking gently at first to free the water pump impellers and piston rings.
5. Clean and reset the pump injectors, refit them and ensure that the linkage is correct.
6. Check the bridge piece settings and rocker clearances.
7. Lubricate the valve gear with new engine oil and refit the rocker covers.
8. Check the governor and stop linkages for freedom of action and oil them.
9. Crank the engine over on the starter with the stop lever in the 'stop' position, until the oil pressure registers on the gauge.
10. Bleed any air from the fuel system.
11. Check the cooling system and the radiator. Bleed any air from the system.
12. Check the oil and water levels.

**3. STATIC CHECK**

a) Fan belt tension.
b) Barring over by hand.
c) Oil grade and type.
d) Oil level, prime the filters and turbochargers.
e) Anti-freeze or inhibitor concentration and level in radiator or heat exchanger.
f) Battery acid level and specific gravity.
g) Air receiver pressure (air starters only).
h) Tightness of electric cable connections.

## 4. RUNNING CHECKS

**WARNING** ⚠ THE OPERATOR SHOULD CHECK BEFORE OPERATION THAT ALL THE BASIC SAFETY PRECAUTIONS HAVE BEEN OBSERVED

a) Bleed the fuel system at the pumps and filters (if necessary).
b) Bleed the jacket water pipes at the highest points.
c) Check the governed speed, frequency and voltage.
d) Check
   1. Oil pressure and temperature.
   2. Water temperature.
   3. Exhaust temperature.
e) Check for oil, water or fuel leaks.
f) Check air manifolds and air cleaners.
g) Check exhaust joints.
h) Check for vibration.
i) Check stop solenoid linkage adjustment. Set protection equipment Low Oil Pressure, High Water Temperature and overspeed.
   Air shut-off valves.
j) Check power output, overload, governor droop.
k) Record stable temperatures and pressures, etc.
l) Check automatic start system (Automatic Mains Failure).
m) Check battery charging equipment or air start equipment (to maker's recommendations).

## 5. DERATING THE ENGINE FOR ACTUAL SITE CONDITIONS

Should the site conditions exceed the following limits:

Ambient temperature (at the air inlet) above 27°C.
Barometric pressure below 100 kPa

The engine must be derated in accordance with the engine derating chart (see **Product Information Manual**), unless the engine has already been derated at the factory as stated on the label attached to the engine.

**EXAMPLES**

a) A 4012TAG1 running at 1500 r/min and operating at 2000 metre above sea level in an ambient temperature of 52°C should be derated by 24%.
b) A 4012TEG operating at 1000 metre above sea level in an ambient temperature of 45°C with cooling water at 40°C into the charge cooler should be derated by 19%.

**NOTE:** The maximum ambient temperature is the temperature that can occur during any day of the year according to records for the site.

Now check power stated on test certificate and if necessary derate this power by the appropriate figure.

Apply the reduced load to the engine or generator and adjust the fuel setting as per the derating procedure on **page 18**.

Conversion figures 100 kPa = 1 bar = 1 atmosphere = 110 metre altitude above sea level.

## QUANTITY OF OIL

| | |
|---|---|
| The maximum sump capacity | 159.0 litre (35 gal) 4012 series |
| The maximum sump capacity | 214.0 litre (47 gal) 4016 series |
| The minimum dipstick mark indicates | 136.0 litre (30 gal) 4012 series |
| The minimum dipstick mark indicates | 147.0 litre (32.5 gal) 4016 series |

## TYPE OF OIL

The industrial diesel engine should be lubricated with a good quality oil conforming to API CD or CCMC D4 specifications. All the major oil companies formulate oils to the above specifications.

## VISCOSITY

Use oil of:

| | | |
|---|---|---|
| SAE10W/30 | in starting temperatures below -15°C (without sump heater) | |
| SAE15W/40 | in starting temperatures from -15°C to 0°C | |
| SAE30 | in starting temperatures from 0°C to 32°C | or Mobil Delvac |
| SAE40 | in starting temperatures above 32°C | 1300 SAE 15W/40 |

## OIL CHANGE PERIODS

For normal operation of the engine the oil should be changed every 250 hours or annually whichever is the soonest.

Under certain circumstances where a centrifugal oil filter is fitted to the engine and an oil analysis programme has been carried out with the oil supplier over a period of 1000 hours of engine operation, it may be possible to extend the oil change period up to maximum of 350 hours.

To achieve the extended oil change period, a centrifugal oil filter must be fitted and cleaned every 150/200 hours between routine oil changes, and at every oil change point i.e. 350 hours maximum.

As the oil deteriorates it is essential that the following parameters must not be exceeded at the oil change point:

1. The viscosity of the oil must not increase by more than 10cSt at 100°C.
2. The total base number of the oil should not reduce to less than 50% of the value of new oil.
3. The flash point of the oil should exceed 180°C.
4. The water content of the oil must not exceed 1%.
5. The fuel content of the oil must not exceed 1%.
6. Oil samples should be taken from the mean sump oil level of the engine.

## ENGINE OPERATION

Excessive periods of idling or repeated cold starts should be avoided, as they will cause excessive dilution of the oil by fuel, requiring more frequent oil changes and dangerously lowering the flash point of the oil.

Should there be a lubricating oil supply problem, or if the fuel being used contains more than 0.5% sulphur, Perkins Engines (Stafford) Limited must be consulted to give advice in selecting a suitable grade.

The following list gives details of some of the oils that meet the required specifications. Note that the brand names may change as oils are upgraded or reformulated.

An up-to-date list is maintained by Perkins Engines (Stafford) Limited of major oil companies products and information, which can be obtained from Perkins Engines (Stafford) Service Department.

WARNING

WARNING FAILURE TO COMPLY WITH THESE INSTRUCTIONS WILL INVALIDATE THE WARRANTY OFFERED WITH THE ENGINE, AS IT MAY RESULT IN DAMAGE TO THE ENGINE.

## APPROVED INDUSTRIAL OIL

(Suitable for fuel to Class A1 or A2 specifications BS2869)

| Oil Company | Type |
|---|---|
| CASTROL | CRH/RX Super |
| ELF | Multiperfo XC |
| KUWAIT OIL Co | Q8 T400 |
| MOBIL | Delvac 13 |
| MOBIL | Delvac Super 1300 (15W/40) |
| SHELL | Rimula X |
| ESSO | Essolube XD 3+ |
| TEXACO | Ursa Super LA |

**WARNING** ⚠ ALWAYS STOP THE ENGINE AND ALLOW THE PRESSURISED SYSTEM TO COOL BEFORE REMOVING FILLER CAP. AVOID SKIN CONTACT WITH ANTIFREEZE BY WEARING HAND, ETC.

## ENGINE COOLING SYSTEM

The cooling system of an engine contains many different materials e.g. cast iron, aluminium, copper, solder, rubber (various types). To prevent deterioration of these materials, it is essential to use a very good quality coolant. **Untreated water is not suitable.** It is essential that the water is treated with an additive that gives the necessary protection.

## WATER QUALITY

The water to be mixed with the additive must have the following characteristics:
Chloride less than 80 PPMV
(PPMV = parts per million by volume)
Sulphates less than 80 PPMV
Total hardness less than 200 PPMV
pH of water between 7 to 7.5 (neutral to slightly alkaline)

## ADDITIVES TO WATER

Due to the complexity of the cooling system it is necessary to use an additive that contains a balanced package of corrosion inhibitors.
To achieve the required solution a 50/50 mix of Shell Safe Premium antifreeze with water should be used at all times, even in areas where frost is unlikely.**
The 50/50 mixture will give frost protection down to -35°C. In areas where Shell Safe Premium is not available contact Perkins Engines (Stafford) Limited for advice on a recommended alternative.

Under no circumstances should an additive containing nitrites, borates, phosphates, chromates, nitrates, or silicates be used, as they are not compatible with the materials used in the cooling system.
When mixing the antifreeze with the water always follow the manufacturer's recommendation and add the antifreeze to the water to the correct concentration before adding to the engine cooling system.
Mixing water to antifreeze can lead to the formation of a gel in the mixture, which can lead to blockage of water passages and subsequent local overheating.

## MAINTENANCE OF COOLANT

The water and antifreeze mixture should be regularly replaced in operating engines at least once a year. In engines used for standby duty it is essential to maintain the water and antifreeze mixture at the correct alkalinity level i.e. the pH should not increase above 7.5. A hydrometer only shows the proportion of ethylene glycol, not the degree of corrosion protection.

**WARNING** ⚠ FAILURE TO FOLLOW THE ABOVE RECOMMENDATIONS MAY RESULT IN DAMAGE TO THE ENGINE, AND WILL INVALIDATE THE ENGINE WARRANTY.

** An exception to this rule is where the 4016TWG2 is used in tropical conditions, where the coolant in the charge cooler section should contain no more than 10% antifreeze because of its reduced heat transfer coefficient.

Fuel should be wholly hydrocarbon oil derived from petroleum, with which small quantities of additives may be incorporated for the improvement of ignition or other characteristics and should conform to British Standard Specification 2869. Class A1 or A2.
If fuels other than the above classes are considered, the operator must consult Perkins Engines (Stafford) Limited, and ensure that a suitable grade of lubricating oil is used.

**BS2869 REQUIREMENTS FOR ENGINE FUEL**

| Property | | Class A1 | Class A2 |
|---|---|---|---|
| Viscosity, kinematic at 40°C, cSt * | | | |
| Min. | | 1.5 | 1.5 |
| Max. | | 5.0 | 5.5 |
| Cetane number, min. | | 50 | 45 |
| Carbon residue, Ramsbottom on 10% residue, % (m/m), max. | | 0.20 | 0.20 |
| Distillation, recovery at 350°C, % (V/V), min. | | 56°C | 56°C |
| Water content, % (V/V), max. | | 0.05 | 0.05 |
| Sediment, % (m/m), max. | | 0.01 | 0.01 |
| Ash, %(m/m), max. | | 0.01 | 0.01 |
| Sulphur content, % (m/m), max. | | 0.30++ | 0.50++ |
| Copper corrosion test, max. | | 1 | 1 |
| Cold filter plugging point °C, max. | | | |
| Summer (March/September inclusive) | Northern | -4 | -4 |
| Winter (October/February inclusive) | Hemisphere | -15 | -12 |

*1cSt = 1 mm 2 /s.
++This limit is set in accordance with the legislative requirements for gas oil of the 'Council Directive (75/716/EEC of the European Economic Community) on the approximation of the laws of Member States relating to the sulphur content of certain liquid fuels'.
In countries where this legislation does not apply, it is permissible to run 4000 series engines on fuels with up to 1.0% sulphur. (See **page 26-27**).

**ENGINE FUELS**

1 The two classes of fuel specified in the table are marketed specifically as oil engine fuels. Class A1 is of higher quality and is intended primarily as an automotive diesel fuel, whilst Class **A2** is intended as a general purpose diesel fuel. Classes A1 and A2 are distillate grades and are so specified as to prevent the inclusion of residuum.
2 The specifications for Classes A1 and A2 include limits for cold filter plugging point chosen to cover seasonal requirements in the United Kingdom.
3 Ignition quality is specified in terms of cetane number, but the calculated cetane index is referred to as an alternative for routine purposes with fuels not containing ignition improver additives.

**NOTE:** If local supply problems dictate that fuels which fall outside the above specification are to be used, our Service Department must be consulted prior to use.

The following notes are intended to supplement the servicing and maintenance operations described elsewhere in this manual.

## LIFTING

> **WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT. DO NOT WORK ALONE. ALWAYS WEAR PROTECTIVE GLOVES,

When lifting the larger engine components, it is essential that slings or straps, whether of wire, webbing or ordinary rope construction, have a tested safe working load well above the weight of the item to be lifted. Use eyebolts or shackles where possible and rope slings when in contact with machined surfaces. Observe safety precautions regarding suspended loads, etc.

## PROTECTION AGAINST CORROSION

Where engines have been dismantled for inspection, ferrous parts must be protected against rusting. Care must also be exercised in the handling of parts with highly finished surfaces since these surfaces can be corroded by finger marks, especially in countries with a humid atmosphere.

After cleaning parts should be protected by dipping or spraying with clean engine oil, or preferably with a de-watering fluid such as Shell Ensis Fluid 252 (one week's protection) or 254 for longer periods. When using a de-watering fluid, the parts should be cleaned in a water based solvent to remove ail grease or oil, and the fluid applied by dipping or spraying.

When the engine is rebuilt, the parts should be degreased, re-oiled and fitted. Protect all apertures against the ingress of foreign matter.

## MARKINGS

Certain engine components are marked for matching and timing operations and others are associated when re-assembling components. All new replacement parts, if not previously marked, must be indelibly marked on a non-rubbing or sealing surface by etching or other means.

It is recommended when refitting such components as inlet and exhaust valves, and valve rockers, that these are fitted into their original locations during rebuild. These components should be marked before removal.

> **WARNING** ⚠ GASKETS AND JOINTS MAY CONTAIN ASBESTOS. BREATHING ASBESTOS DUST IS DANGEROUS TO HEALTH. WHEN FITTING OR HANDLING GASKETS AND JOINTS, SEE SAFETY PRECAUTIONS.

## GASKETS AND JOINTS

Use new gaskets, joints and 'O' rings throughout.

## PIPES, UNIONS, ETC.

Carefully examine all pipes for cracking and chafing, especially at bends and clips. Additionally, examine pipes for cracked union nuts and dirt on seatings of nipples. Never strain a pipe when attempting to connect it, but find out why it will not meet the other component.

**WARNING** ⚠ DO NOT USE WOOL BASED CLOTHS FOR CLEANING. USE LINT FREE MATERIALS.

## CLEANLINESS

Always observe scrupulous cleanliness when rebuilding and assembling the engine, and thoroughly flush all oilways, pipes, etc., clear of sludge and dirty oil. Machined surfaces should be oiled to provide initial lubrication and protection against corrosion. Do not use cotton waste or dirty rag for wiping parts before assembly, since fibres may become detached and find their way into oilways and between moving parts. For this same reason DO NOT USE WOOL BASED CLOTHS FOR CLEANING.
Filings or scrapings must be prevented from entering oilways or ports. Rough ragged edges should be removed from all moving parts oilways and ports etc.
New parts should be kept in their protective wrappings or coatings until required.

## CLEARANCES AND WEAR LIMITS (SEE PAGES 41 & 42)

When assembling new parts, ensure that the correct fit is obtained. **Clearances and Wear Limits see pages 41 & 42** is provided for all engine parts where a close running fit between mating surfaces is a feature of the design. Maximum permissible clearances are quoted, which, when exceeded, call for the replacement of one or both parts.

## ENGINE SERVICING

**NOTE:** Personnel employed upon servicing these engines should become familiar with all design features particularly the cooling system, fuel system and the protection system etc.

## 'V'-BELTS

'V'- belts must always be at the correct tension. Belts that are too tight will cause excessive bearing stresses, and those without sufficient tension will slip and fail prematurely. A belt in correct tension can be depressed by an amount equal to its own thickness for each 48" (1220 mm) of unsupported length.
Never replace individual belts in a multiple drive, always fit a complete matched set.

## CLEANING

Where possible a water based solvent cleaner should always be used.

If a low volatile hydrocarbon solvent is used the manufacturers instructions must be strictly adhered to.

**NOTE:** Solvents should be recycled where possible.

All surfaces to be treated with 'Loctite' must be free from oil and grease or detergent residues. Apply cleaners generously to the surface to be degreased and then remove as much as possible. To remove hard spots of contamination use a clean paper towel as an oily one will only introduce a further contamination. Make a final application of cleaner, if possible in a vertical plane and allow the surface to dry naturally. If using a solvent which is slow to evaporate, it is permissible to remove the excess with a clean paper towel.

Before cleaning, all thick deposits of carbon or sediment should be removed by hand scraping, care being taken to avoid scratching machined surfaces.

Oil holes should be pricked through with wire, thoroughly washed, and then blown through with compressed air to ensure freedom from obstruction.

After cleaning, all bright parts should be smeared with oil, grease or dipped in de-watering fluid to prevent rusting.

## SEALANT AND JOINTING COMPOUNDS

**WARNING** ⚠ JOINTING PRODUCTS AND 'LOCTITE' COMPOUNDS SHOULD NOT BE USED IN CLOSE PROXIMITY TO EACH OTHER. THEY DO NOT HAVE TO TOUCH FOR CHEMICAL REACTIONS TO TAKE PLACE AND TOXIC FUMES TO BE EVOLVED.

The use of gasket cements, jointing pastes or mastics is not recommended as this can lead to oilways becoming blocked by solidified globules of excess material.

However, anaerobic sealants and retainers e.g. the 'Loctite' range of products, are recommended as they are unlikely to cause this kind of problem even if they are used too generously.

'Loctite' products must not come into contact with either liquid or gaseous oxygen.
Closely follow the manufacturers instructions when using 'Loctite' products.

**'LOCTITE' SEALING COMPOUND 518 (RED)**
This compound is suitable for use with gaskets on metal to metal surfaces (e.g. flywheel housing to crankcase face).
The compound gives a satisfactory seal under all conditions of transmitted vibration, slight movement and/or rapid variations of temperature. The joint seal will not shrink, tear, crack or relax. When necessary, joints can be readily dismantled and the old sealing material simply removed. No special treatment of the faces is required before assembly as the product is re-applied directly to one of the faces.
Any excess of the compound may be wiped away without the use of any special cleaning solvent.

**'LOCTITE' HYDRAULIC SEAL 542 (RED)**
This compound is suitable for sealing pipe fittings and threaded connectors up to 19 mm diamater. The connections can be readily unscrewed and the old material simply removed.
No special treatment of the threads is required before assembly and the compound is applied directly to the thread.
The compound remains liquid whilst in contact with air but hardens automatically when confined between closely fitting metal parts. This self-hardening property gives the products the ability to lock, retain or seal metal parts. When cured the product should not be subjected to temperatures exceeding 150°C.
Any excess of the compound is simply wiped away without the use of any special clean-up solvent.

**'LOCTITE' LOCKING AND SEALING COMPOUND 577 (YELLOW)**
The above product has been found suitable for sealing gas pipe fittings and threaded connectors of larger size. The compound is applied, after thoroughly cleaning the mating threads and allowing them to dry. Any excess compound is simply wiped away, and the joint may be easily dismantled whenever necessary.
When cured the product should not be subject to temperature exceeding 125°C. Any excess of the compound is simply wiped away without the use of any special clean-up solvent.

**'LOCTITE' HIGH STRENGTH RETAINER 638 (GREEN)**

The above compound has been found suitable for fixing the water pump outrigger bearing for the alternator pulley drive, oil filler and dipstick tubes. The compound is capable of high static and torsional strength and withstands fatigue due to cyclic loading and allows parts to be slip-fitted into place, instead of being forced together, to give a total seal.

**'LOCTITE' STUDLOCK COMPOUND 270 (GREEN)**

The above compound has been found suitable for fixing core plugs and cup plugs which do not normally require dismantling.
The compound is capable of high strength locking and sealing, but still allows for the plug to be removed.

**USE OF LIQUID NITROGEN IN A FREEZING BATH**

> **WARNING** ⚠ LIQUID OXYGEN MUST NOT BE USED OWING TO ITS DANGEROUS COMBINATION WITH OIL, WHEN A POTENTIALLY EXPLOSIVE MIXTURE WILL RESULT.

Certain sub-assemblies contain components which need their external dimensions temporarily reduced before fitting. This may be achieved by submerging the component in liquid nitrogen until the component reaches the same temperature (-196°C). **It is strongly recommended that the customer fit service exchange assemblies where this applies.**

These assemblies are:

Cylinder heads (valve seat, inserts, bridge piece guide)

Oil pumps (fuel lift pump drive dog-diesel engines only)

Cam followers (roller bushes)

For those who wish to repair the above sub-assemblies themselves, it is essential to follow the safety precautions and working practices given below.

1. A supply of clean fresh running water should be available, sufficient to irrigate an area of frostbite, or eye contact, for at least 15 minutes.
2. Liquid nitrogen should only be used in well ventilated area, and neither liquid or gaseous nitrogen disposed of into areas (eg sewers) where a build up of gas is possible. This is because nitrogen gas is an asphyxiant, and is particularly dangerous since a victim may be unaware of a problem until lack of mobility or unconsciousness results.
3. Only use approved containers, designed and supplied for the purpose of contaminating liquid nitrogen.
4. Liquid nitrogen containers should not be exposed to fire or other heat sources, since exposure to excessive heat may cause containers to rupture or explode.
5. Fire extinguishers should be readily available.
6. Only liquid nitrogen should be used, liquid oxygen is particularly dangerous, since oxygen is an oxidising chemical, which may combine with other substances (eg oil) to form dangerously explosive or highly inflammable mixtures.
7. Read, understand and comply with the suppliers Safety Data Sheets.

(a) Components should be placed in and removed from the bath using a hooked tool or a pair of tongs whichever is the more suitable.
(b) Insulating gloves must be worn to avoid frost burn.
(c) Eye protection against splashing must be worn.
(d) Components immediately on removal from the bath are brittle and should handled accordingly.
(e) The bath should be insulated, deep and only of sufficient diameter to accept the largest component. This will reduce the evaporation rate. Only sufficient liquid to cover the component to be frozen should be used.
(f) The make-up supply of liquid nitrogen should be kept in an insulated flask with a narrow neck open to atmosphere.

**WARNING** ⚠ IT IS ESSENTIAL WHEN HANDLING THE ABOVE PRODUCTS THAT PROTECTIVE EQUIPMENT IS WORN i.e. GLOVES, GOGGLES, AND OVERALLS, TO AVOID EYE AND SKIN CONTACT AND INGESTION.

**(I) REMOVAL OF SCALE AND CORROSION DEPOSITS: REFER TO BS4959: 3.1.3.3**

Scale and corrosion deposit removal is usually carried out using an inhibited acid solution, heated and circulated. In most instances, inhibited sulphamic acid (or Housemans Chemtreat 253) will be appropriate. The strength of solution and recirculation time will depend on the deposit composition. Neutralisatlon of the spent acid must be ensured prior to effluent discharge.

In practice, a dosage rate of 1 kg per 9 litres of water can be used and the process repeated if necessary. Thorough flushing of the cleaned system completes this procedure.

Housemans product Chemtreat 253 is based on inhibited and sulphamic acid. (This used to be called HTL5).

**(II) REMOVAL OF OIL: REFERS TO BS4959: 3.1.3.2**

If inspection indicates oil contamination the degreasing should be carried out prior to any acid cleaning. Depending on the severity of contamination, mechanical removal, heavy duty industrial degreasants or an oil dispersant will be appropriate. Housemans HD1 is a non-caustic powder degreasant. Typical usage rates are a 5% strength solution. Their Cooltreat 45 is an oil dispersant, designed for om-line cleaning of cooling systems. Dosage rates are normally 10% by volume, as an initial treatment, but a lighter dosage may be sufficient depending on degree of contamination.

**WARNING** ⚠ BEFORE ATTEMPTING ANY WORK ON ENGINE DISCONNECT AND REMOVE STARTER BATTERIES OR ANY OTHER MEANS OF STARTING.

When undertaking a major overhaul the first step will be to systematically strip the engine down into its component parts. Care should be taken to segregate components into their respective groups, e.g. cylinder head, lubrication parts, crankshaft associated components, etc. After cleaning, the component groups can be placed in separate containers ready for inspection, repair or replacement and reassembly. If the above procedure is followed, much time will be saved during the rebuilding.

Apart from reference to the '**Wear and Renewal Limits**', each Maintenance Section is complete in itself, dealing with dismantling, checking, replacement and assembly.

## ENGINE REMOVAL FROM INSTALLATION

1. Turn off the fuel at the tank or supply point. Disconnect the fuel supply to the inlet side of the lift pump. Drain the water and oil. Disconnect the capillaries, the wiring and the oil pipe to the remote instrument panel (if fitted). Isolate the water supply to the raw water pump (if fitted).
2. If a sump drain pipe is fitted below or through the engine baseframe, this should be removed after draining the oil from the sump and before lifting the engine, to avoid damage to the sump.
3. Disconnect the exhaust pipe from the exhaust outlet.
4. Remove the fan belt guards, slacken off the belt tensioner and remove the 'V'-belts.
5. Remove any radiator stays, water pipes and air pipes (if fitted), then remove the radiator.
6. Disconnect the engine, if possible, from any driven equipment, e.g. free-standing or close-coupled alternator, pump, etc.
7. Disconnect the engine from its mountings and remove it from the baseframe.
8. Thoroughly clean the engine externally before starting to dismantle it.

## ENGINE DISMANTLING SEQUENCE

1. The pump injectors should be removed first and put aside to await any specialised attention which they may require. (But see 6 below).
2. Remove all external equipment: i.e. air cleaners, fuel and oil filters, alternator, starter(s) and instrument panel.
3. Remove the turbochargers and associated pipework.
4. Remove the air inlet manifolds and exhaust manifolds.
5. The basic engine can now be dismantled in group order.
6. It may be advisable when carrying out a major overhaul to remove the flywheel and crankshaft pulley before removing the cylinder heads. This is in order to utilize the engine compression when undoing the flywheel and pulley retaining bolts.
7. It is advisable to label and store all components in their relative group order to ensure correct replacement on the engine.
8. It is most important that mating components (e.g. pistons, gudgeon pins, rings and cylinder liners) are kept in sets.

## ENGINE REBUILDING SEQUENCE

**NOTE:** When aluminium or other soft metals are securred by nuts and bolts, a double turn spring washer should be fitted. If these are not available, a single turn spring washer may be fitted together with a plain washer between the spring washer and the component.

1. After they are fitted, the cylinder liners should be secured in position by means of keepers across the lip of the crankcase. Then invert the crankcase, support it on a suitable trestle and fit the crankshaft.
2. Turn the engine onto its side and fit the piston and connecting rod assemblies.
3. Again invert the crankcase, fit the camshaft and timing gears, fuel control shafts and governor to control shaft links, then the flywheel housing, gearcase and seal, and sump.
4. Fit the oil pump and external oil pipes.
5. The crankcase should now be turned upright and the rebuild continued by refitting:
   - i) Tappet assemblies, cylinder heads and push rods.
   - ii) Rocker boxes, pump injectors and linkages, rockers and rocker shafts.
   - iii) Camshaft oil feeds.
   - iv) Jacket water pumps, raw water pump and oil coolers.
   - v) Inlet manifolds, water rails and exhaust manifolds.
   - vi) Fuel and oil filters.
   - vii) Fuel pipes and oil pipes.
   - viii) Turbochargers and air cleaners.
   - ix) Alternator and starter motors.

**WARNING** ⚠ IT IS ESSENTIAL THAT THE CORRECT LENGTH OF SCREW OR BOLT IS USED. INSUFFICIENT LENGTH MAY RESULT IN THE THREAD BEING STRIPPED, WHEREAS TOO LONG A THREAD MAY RESULT IN BOTTOMING IN A BLIND HOLE, OR CATCHING ON ADJACENT COMPONENTS.

**NOTE:** * Bolt heads and threads must be lubricated with clean engine oil.
** Cylinder head bolts to be lubricated under the heads, under the washers and on the threads with PBC (Poly-Butyl-Cuprysil) grease. **Important:** See **Workshop Manual Section R11** before fitting. However, **dry threads** are required for connecting rod bolts and the raw water pump shaft nut, but all other threads only to be lubricated with clean engine oil and care must be taken **NOT** to oil the heads or faces.

## TORQUE SETTINGS

| **CYLINDER HEAD GROUP** | | **lbf.ft** | **Nm** |
|---|---|---|---|
| Cylinder head bolt ** (early type) | M24 | 550 | 750 |
| Cylinder head bolt ** (later waisted type) | M24 | 530 | 720 |
| Rocker shaft capscrew/nut | M16 | 90 | 120 |
| Rocker adjuster nuts inlet/exhaust | M12 | 35 | 50 |
| Rocker adjuster nuts pump injectors | M14 | 50 | 70 |
| Injector clamp capscrews | M12 | 70 | 95 |
| Bridge piece adjuster nuts | M10 | 25 | 35 |
| Injector clamp to cylinder head capscrews | M12 | 70 | 95 |
| Rocker box bolts | M10 | 35 | 50 |
| Air manifold bolt | M10 | 35 | 50 |
| Exhaust manifold bolts | M10 | 50 | 70 |
| Exhaust bellows to exhaust manifold (16 cyl only) prevailing torque bolts / nuts | M10 | 45 | 60 |
| Exhaust Y piece (16 cyl only) prevailing torque bolts | M10 | 38 | 50 |
| Schwitzer turbocharger 'V'-band clamp nuts | M8 | 8 | 11 |
| Sandwich plate retaining capscrews | M10 | 35 | 50 |

| **CRANKCASE AND CRANKSHAFT GROUPS** | | | |
|---|---|---|---|
| Main bearing bolts * — See **Section W4** for sequence | M24 | 580 | 786 |
| Lateral capscrews, main bearing caps — See **Section W4** for sequence | M16 | 124 | 168 |
| Bolts sump to crankcase | M10 | 40 | 54 |
| New connecting rod bolts (must be fitted with **dry threads**) | M16 | 210 | 285 |
| Inspection covers | M10 | 35 | 50 |
| Viscous damper bolts | M16 | 250 | 340 |
| Flywheel bolts See **Section X3** for sequence | M16 | 250 | 340 |
| Front drive adaptor bolts (12 cylinder engines only) | M16 | 250 | 340 |
| Front drive adaptor bolts (16 cylinder engines only) | M20 | 380 | 520 |
| Balance weight bolts | M16 | 250 | 340 |
| Crankshaft pulley bolts | M16 | 250 | 340 |
| Piston cooling jet screws | M10 | 20 | 27 |
| Flywheel housing bolts | M10 | 35 | 50 |
| Lifting bracket Durlock screws | M10 | 50 | 70 |

| | | lbf ft | Nm |
|---|---|---|---|
| **LUBRICATING OIL** | | | |
| Bolts, pump housing to gearcase plate | M10 | 35 | 50 |
| Thin nut, gear to drive shaft | M30 | 175 | 237 |
| **CAMSHAFT GROUP** | | | |
| Camshaft gear bolt | M12 | 110 | 150 |
| Camshaft thrust plate bolt | M10 | 35 | 50 |
| Camshaft follower housing bolt | M10 | 35 | 50 |
| Idler gear hub bolts | M10 | 35 | 50 |
| **WATER PUMP** | | | |
| Water pump gear nut | M24 | 170 | 230 |
| Water header to oil cooler bolts | M10 | 35 | 50 |
| Water pump to gearcase bolts | M10 | 35 | 50 |
| Raw water pump gear securing nut, **dry thread** | M35 | 180 | 244 |
| **ENGINE FEET** | | | |
| Engine feet to base frame bolts | M20 | 350 | 475 |
| Engine feet to cushion feet bolts | M16 | 160 | 215 |
| Engine feet to gearcase and suspension plate bolt | M12 | 70 | 95 |
| **GOVERNOR** | | | |
| Control shaft mounting plate bolt | M10 | 35 | 50 |
| **FAN** | | | |
| Fan driven pulley taper lock bush screws | $^1/_2$" BSW | 35 | 50 |
| Fan driven pulley taper lock bush screws | $^5/_8$" BSW | 65 | 90 |
| **ALTERNATOR** | | | |
| Drive pulley taper lock bush screw | $^3/_8$" BSW | 15 | 20 |
| **FUEL PUMP/INJECTORS** | | | |
| Injector capscrew clamp to cylinder head, early engines | M10 | 50 | 70 |
| Injector capscrew clamp to cylinder head, later engines | M12 | 70 | 95 |
| Injector nozzle nut to holder | M27 | 150 | 203 |
| Fuel pump control linkage screw | 2BA | 6 | 8 |
| Unit injector control lever capscrews | M5 | 6 | 8 |
| **FLEXIBLE COUPLING** | | | |
| Flexible coupling cover screw | M12 or $^1/_2$" UNC | 47 | 64 |
| Coupling driving flange screws (coupling size 2.15) | M12 or $^1/_2$" UNC | 47 | 64 |
| Coupling driving flange screws (coupling size 3.86) | M16 or $^5/_8$" UNC | 114 | 155 |

## GENERAL TORQUE LOADINGS

The following torque loadings are general for metric coarse threads and for grade 8.8 steel, but do not supersede the figures quoted above.

| THREAD | lbf ft | Nm |
|---|---|---|
| M5 | 5 | 7 |
| M6 | 9 | 12 |
| M8 | 21 | 28 |
| M10 | 41 | 56 |
| M12 | 72 | 98 |
| M16 | 180 | 244 |
| M20 | 351 | 476 |
| M24 | 606 | 822 |

## GENERAL NOTE:

| | | |
|---|---|---|
| M10 - 12.9 Steel | 50 | 70 |

## TIGHTENING TORQUES

These are based on 85% of the proof loads designated in BS3692.

**KEY**

**COLUMN I**

Description of components.

**COLUMN II**

Design size of components.

**COLUMN III**

This column gives the limiting wear dimension of a component outside of which it must be renewed, or as in the case of the crankshaft, must be reground to the next undersize dimension.

**COLUMN IV**

Design working clearance between parts.

**COLUMN V**

If during a major or top overhaul it is necessary to refit worn components, the maximum clearance between the mating parts must not exceed the figure given in this column if a further 10000 hours running is required, or in the case of a top overhaul, a further 2500 hours.

If the clearance between parts exceeds this figure, a satisfactory running clearance may be obtained by a combination of a new part and its corresponding component worn to the limiting dimensions stated in Column III. Generally, however, the fitting of new components to components already worn to their limiting dimensions is not recommended.

| COLUMN I | COLUMN II | COLUMN III | COLUMN IV | COLUMN V |
|---|---|---|---|---|
| DESCRIPTION | Design Dimension mm (in) | Limiting Dimensions mm (in) | Design Clearance mm (in) | Max Worn Clearance mm (in) |
| Piston Ring - Top, parallel type<br>Gap - Top, keystone type | 0.75(0.030)<br>0.5(0.020) | 0.75(0.030)<br>0.75(0.030) | NA<br>NA | 1.27(0.050)<br>1.27(0.050) |
| Piston Ring Gap - Second | 0.75(0.030)<br>0.5(0.020) | 0.75(0.030) | NA | 1.27(0.050) |
| Piston Ring Gap - Oil Control | 0.75(0.030)<br>0.5(0.020) | 0.75(0.030) | NA | 1.27(0.050) |
| Ring Groove Width - Top, parallel<br>- Top keystone | 3.590(0.141)<br>3.565(0.140) | NA | NA | 0.2 (0.008) |
| Ring Groove Width - Second | 3.565(0.140)<br>3.540(0.139) | NA | NA | 0.18(0.007) |
| Ring Groove Width - Oil Control | 6.065(0.2388)<br>6.040(0.2378) | NA | NA | 0.18(0.007) |
| Cylinder Liner Bore | 160.025(6.300)<br>160.000(6.299) | 160.15(6.305) | NA | 160.15 (6.305) |
| Gudgeon Pin Diameter | 63.500(2.500)<br>63.492(2.4997) | NA | 0.084(0.0033)<br>0.058(0.0022) | 0.15(0.0059) |
| Small End Bush Bore (fitted) | 63.576(2.503)<br>63.550(2.502) | NA | | |
| Crankshaft Main journal Diameter | 140.02(5.5125)<br>140.00(5.5112) | 139.849(5.506) | 0.170(0.0067)<br>0.093(0.0037) | 0.240(0.010) |
| Inlet and Exhaust Valve Stem Diameter | 11.0236(0.4340)<br>11.0109(0.4335) | NA | 0.109(0.0043)<br>0.066(0.0026) | 0.20(0.006) |
| Inlet and Exhaust Valve Guide Diameter | 11.120(0.4378)<br>11.090(0.4366) | NA | | |
| Valve Spring Fitting Length | 42.54(1.675) | Minimum Load at Fitted Length = 400N(90.616 lb) | | |
| Camshaft Journal Diameter | 91.925(3.619)<br>91.898(3.618) | NA | 0.233(0.0091)<br>0.168(0.0066) | 0.254(0.010) |
| Camshaft Bearing Bore | 92.131(3.627)<br>92.093(3.6257) | NA | | |

| COLUMN I mm (in) | COLUMN II Design Dimension | COLUMN III Limiting Dimensions | COLUMN IV Design Clearance | COLUMN V Max Worn Clearance |
|---|---|---|---|---|
| Camshaft End Float | NA | NA | 0.25(0.010)<br>0.10(0.004) | 0.30(0.012) |
| Exhaust and Inlet Cam Height | 78.905(3.1065)<br>78.855(3.1045) | 77.795(3.0628) | NA | NA |
| Fuel Cam Height | 78.905(3.1065)<br>78.855(3.1045) | 78.473(3.0895) | NA | NA |
| Idler Gear End Float | NA | NA | 0.254(0.010)<br>0.152(0.006) | 0.30(0.012) |
| Idler Gear to Camshaft Gear | NA | NA | 0.45(0.018)<br>0.125(0.005) | 0.63(0.025) |
| Idler, Camshaft, Oil Pump and Water Pump Gear Backlash | NA | NA | 0.375(0.015)<br>0.125(0.005) | 0.50(0.020) |
| Main Bearing Bore Diameter | 140.170(5.5185)<br>140.113(5.5160) | See Crankshaft Main Journal diameter and clearances | | |
| Undersize Bearings | 63.500(2.500)<br>63.492(2.4997) | | | |
| Crankpin Diameter | 118.013(4.6462)<br>117.993(4.6454) | Min. Diameter<br>117.932(4.643) | 0.127(0.005)<br>0.073(0.0029) | 0.203(0.008) |
| Big End Bearing Bore | 118.127(4.651)<br>118.086(4.649) | See Crankpin diameter and clearance | | |
| Undersize Bearings | 0.254(0.010)<br>0.508(0.020) | | | |
| Crankshaft End Float | NA | NA | 0.51(0.020)<br>0.13(0.005) | 0.55(0.022) |
| Oil Pump End Float | NA | NA | 0.2(0.008)<br>0.1(0.004) | 0.30(0.012) |
| | 4012 & OLD 4016 | LATER 4016 | | |
| Rotor Width | 76.150(2.9979)<br>76.124(2.9967) | 88.900(3.5004)<br>88.874(3.4992) | 0.11<br>0.26 | 0.30 |
| Depth of Housing | 76.11(2.9963)<br>76.07(2.9947) | 88.86(3.4988)<br>88.82(3.4972) | | |
| Oil Pump Housing/Cover Gasket Thickness | 0.30(0.012)<br>0.20(0.006) | | | |
| Water Pump Gear Backlash-Meshing with driving gear | NA | NA | 0.294(0.012)<br>0.152(0.006) | |
| Pump Shaft<br>Size of Shaft for Impeller | 25.100(0.9882)<br>25.087(0.877) | | 0.100(0.004)<br>0.066(0.0026) | Interference |
| Impeller<br>Bore of Impeller | 25.021(0.9851)<br>25.000(0.9843) | | | |
| Governor Drive<br>Bevel Gears | NA | NA | 0.15(0.006)<br>0.05(0.002) | 0.25(0.010) |

## SE671D BASIC 4000 SERIES TOOL KIT

| REF No. | PART No. | DESCRIPTION | No. Off |
|---|---|---|---|
| 1 | 477/1 | Screwdriver (Rocker cover and rocker clearance adjustment) | 1 |
| 2 | 699/2 | Feeler Gauge Set (Rocker clearance adjustment) | 1 |
| 3 | 483/28 | 19 mm a/f Combination Spanner (M12 Valve adjuster locknut) | 1 |
| 4 | 483/31 | 22 mm a/f Combination Spanner (M14 Injector adjuster locknut) | 1 |
| 5 | 483/25 | Strap Wrench (Oil and fuel filter bowls) | 1 |
| 6 | 483/35 | 30 mm a/f Combination Spanner (Sump drain plug) | 1 |
| 7 | T6253/177 | Calibration gauge (Pump injectors) | 1 |
| 8 | 483/34 | 8mm a/f combination spanner (Pump injector linkage adjustment) | 2 |
| 9 | 483/19 | 17mm a/f combination spanner (Bridge piece adjuster locknut) | 1 |
| 10 | 587/1 | Tool box | 1 |

The above tools permit the removal of the rocker covers for the setting of bridge pieces, adjustment of valve clearances, injector callibration, the servicing of fuel and oil filters and the draining of oil from the sump.

## SE671D BASIC 4000 SERIES TOOL KIT

| REF No. | PART No. | DESCRIPTION | No. Off |
|---|---|---|---|
| 1 | 491/23 | Tee Bar 1/2" Square Drive | 1 |
| 2 | 481/8 | 5" Extension 1/2" Square Drive | 1 |
| 3 | 481/11 | Adaptor 1/2" Square female x 3/8" Square male | 1 |
| 4 | 481/15 | Bit Holder 3/8" Square Drive | 1 |
| 5 | 481/10 | 4 mm Hexagon Bit (Pump injector lever screw) | 1 |
| 6 | 481/16 | Bit Holder for 481/13 1/2" Square Drive | 1 |
| 7 | 481/13 | 8 mm Hexagon Bit (Pump injector clamp capscrew) | 1 |
| 8 | 481/17 | Bit Holder for 481/14 1/2" Square Drive | 1 |
| 9 | 481/14 | 14 mm Hexagon Bit (Rocker shaft capscrew) | 1 |
| 10 | 484/28 | 24 mm a/f Socket 1/2" Square Drive (M16 Flywheel bolts & rocker shaft) | 1 |
| 11 | 484/37 | 17 mm a/f Socket 1/2" Square Drive (M10 Rocker box bolts) | 1 |
| 12 | 484/36 | 19 mm a/f Socket 3/4" Square Drive (M12 bolts) | 1 |
| 13 | 484/35 | 22 mm a/f Socket 3/4" Square Drive (M16 Durlok screws) | 1 |
| 14 | 484/43 | 27 mm a/f Socket 1" Square Drive (M24 Cylinder head bolts) | 1 |
| 15 | Y87/00001 | Adaptor 3/4" Square female x 1/2" Square male (HVT5000 to 1/2' sq.) | 1 |
| 16 | HVT5000 | Torque Wrench 3/4" Square Drive 100-410 lb.ft. | 1 |
| 17 | GVT8400 | Torque Wrench 1" Square Drive 350-700 lb.ft. | 1 |
| 18 | 489/89 | 15 mm a/f Combination Spanner (M10 Durlok screws) | 1 |
| 19 | 489/91 | 24 x 27 mm a/f Open Ended Spanner (M16 bolts and fuel pipes) | 1 |

The above tools permit removal of injectors, rockers, air and exhaust manifolds, water pipes and cylinder heads.

| REF No. | PART No. | DESCRIPTION | No. Off |
|---|---|---|---|
| | | For Major Overhauls | |
| 1 | - | Tool Kit Comprising Items 2 to 51 | |
| 2 | T6253/140 | Rear Oil Seal Insertion Kit | 1 |
| 3 | T6253/141 | Front Oil Seal Insertion Kit (4012 engines) | 1 |
| 4 | T6253/141A | Front Oil Seal Insertion Kit (4016 engines) | 1 |
| 5 | T6253/236 | Lifting Eye for Gearcase M12 | 1 |
| 6 | T6253/149 | Mandrel for inserting 14 mm Core Plugs | 1 |
| 7 | T6253/237 | Cylinder Head Lifting Tool | 1 |
| 8 | T9142/8 | Cup Plug Mandrel | 1 |
| 9 | T6253/199 | Camshaft Bearing Removal and Refitting Kit | 1 |
| 10 | T6253/152 | Liner Extractor | 1 |
| 11 | t85002/4/ | Valve Seat inserting Tool (Non-Uprate) | 1 |
| 12 | T85117/3 | Valve Seat Inserting Tool (Uprate) | 1 |
| 13 | T6253/209 | Crankshaft Pulley Extractor | 1 |
| 14 | T6253/159 | Small End Bush Inserter & Extractor | 1 |
| 15 | T6253/200 | Liner Clamp Kit | 1 |
| 16 | T85002/3 | Valve Guide Inserting Tool | 1 |
| 17 | T85002/2 | Injector Bush Inserting Tool | 1 |
| 18 | T85002/14B | Injector Bush Depth Gauge | 1 |
| 19 | T85002/6 | Injector Bush Expanding Tool (lower) | 1 |
| 20 | T85002/8 | Injector Bush Expanding Tool (upper) | 1 |
| 21 | T85002/7 | Injector Bush Facing Cutter | 1 |
| 22 | T6253/240 | Valve Seat Grinder Kit | 1 |
| 23 | T6253/139 | Piston Slip Ring Compressing Tool | 1 |
| 24 | T6253/157 | Support Studs | 1 |
| 25 | T6253/145 | Fuel Injector Extractor | 2 |
| 26 | T6253/156 | Injector Bush Coning | 1 |
| 27 | T6253/146A | Injector Clamp and Fuel Feed Adaptor | 1 |
| 28 | T6253/146B | Set of Spare 'O'-Rings (Fuel Feed Adaptor) | 1 |
| 29 | T6253/202 | Injector Nozzle Cleaning Tool Kit | 1 |
| 30 | T6253/203 | Nozzle Needle Gauge | 1 |
| 31 | T6253/147 | injector Compressor Kit | 12 or 16 |
| 32 | T6253/138 | Dummy Fuel Injector | 12 or 16 |
| 33 | T6253/172 | Fuel Setting Tool (early engines) | 1 |
| 34 | T6253/204 | Nozzle Multiclean | 1 |
| 35 | T6253/208 | Nozzle Testmaster | 1 |
| 36 | T6253/211 | Allen Key (Starter Motor Removal) Early Engines | 1 |
| 37 | T6253/142 | Camshaft Guide Tube | 1 |
| 38 | T6253/238 | Circlip Pliers (Internal) | 1 |
| 39 | T6253/144 | Timing Disc | 1 |
| 40 | T6253/243 | Valve Spring Compressor | 1 |

| REF No. | PART No. | DESCRIPTION | No. Off |
|---|---|---|---|
| 41 | T6253/245A | Valve Seat Cutter Holder | 1 |
| 42 | T6253/245B | Valve Seat Cutter | 1 |
| 43 | T6253/256 | Piston Ring Pliers | 1 |
| 44 | T6253/295 | Pump Action Suction Tool (Piston Removal) | 1 |
| 45 | T85001/33 | Crankshaft Gear Spacing Tool | 1 |
| 46 | T6253/214 | Torsional Vibration Damper Lifting Tool | 1 |
| 47 | T6253/307 | Valve Guide Removal Tool | 1 |
| 48 | T6253/241 | Heinzmann PG 01 Test Unit | 1 |
| 49 | T6253/292 | Centrifugal oil filter dismantling tool | 1 |
| 50 | T6253/293 | Centrifugal oil filter extraction tool | 1 |
| 51 | 848/3 | 5/8" a/f Allen key (Early sump drain plugs) | 1 |

**WARNING** ⚠ CHECK GUARDS ARE FITTED OVER EXPOSED AIR INTAKES. STOP THE ENGINE WHEN CHANGING THE AIR CLEANER ELEMENTS.

## DESCRIPTION

The air cleaners as fitted on 4012/16 series engines has a disposable paper element type which must be serviced (See **Operators Handbook pages 39-40**), but must be thrown away when dirty and replaced with new elements.

## STANDARD AIR CLEANER AS FITTED ON THE EARLY 4012TAG, 4012TWG, 4012TEG, 4016TAG, 4016TWG AND 4016TEG ENGINES.

Twin air cleaners (1) are fitted vertically on the engine and mounted on a carrier plate (10) via adaptor pipes (2) and flanged air stub pipes (3).

The air cleaners are connected to the turbocharger intakes via rubber hose connections (4), clips (5) and air inlet elbows (6).

The carrier plate is fitted to support brackets (7) which are fixed to the flywheel housing.

The air intakes to the cleaners are protected against objects entering the intakes by mesh guards (8).

The air shut off valves (9) are fitted between the air cleaners and the turbocharger intakes (see **Fig. 1A**).

## HEAVY DUTY AIR CLEANERS

The heavy duty air cleaners incorporate additional cyclone units as pre-cleaners (11) fitted to the air intakes in place of the mesh guards (8). The pre-cleaners are fixed to brackets (12), otherwise the assembly is the same as with the standard air cleaners.

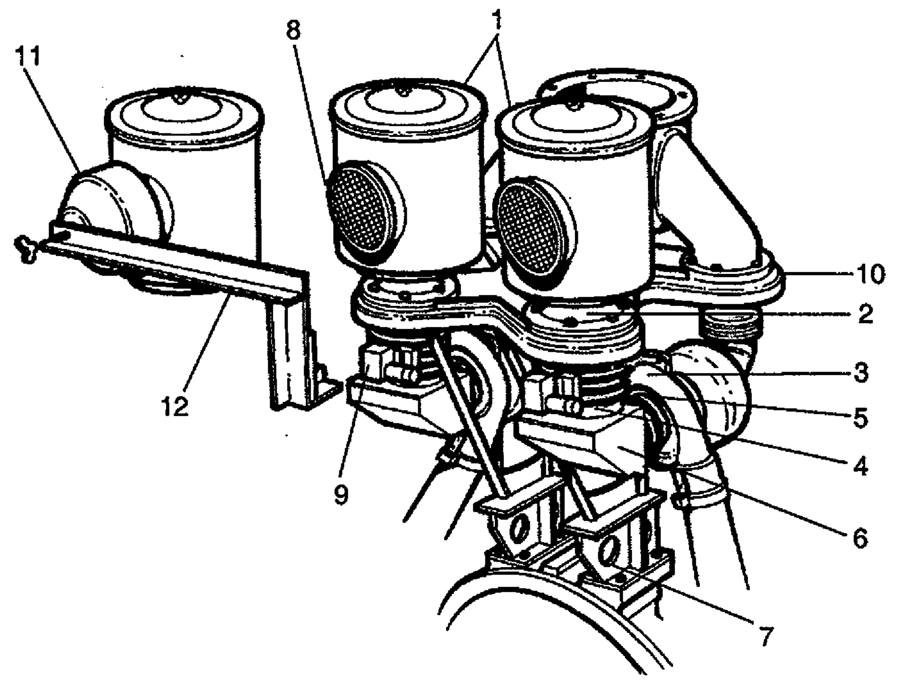



**Fig. 1A**

## STANDARD AIR CLEANERS AS CURRENTLY FITTED ON THE 4012TAG, 4012TWG, 4012TEG, 4016TAG, 4015TWG, 4016TEG, 4012TAG1, 4012TAG2 AND 4012TWG2 ENGINES

Twin air cleaners (1) are strapped (2) horizontally into a combined heat shield/ support bracket (3) fixed to the exhaust manifolds. The air cleaners are connected to the turbocharger intakes via rubber hose connections (4), clips (5) and air inlet bends (6).

The air intakes to the cleaner are protected against objects entering the intake by a mesh guard (7).

The air shut-off valve (8) is fitted between the air cleaner and the turbocharger intake (see **Fig. 2A**).

## HEAVY DUTY AIR CLEANERS

The heavy duty air cleaners incorporate additional cyclone units as pre-cleaners (9), fitted to the air intakes in place of the mesh guards (7). The pre-cleaners are fixed to bracket (10), otherwise the assembly is the same as with the standard air cleaners.

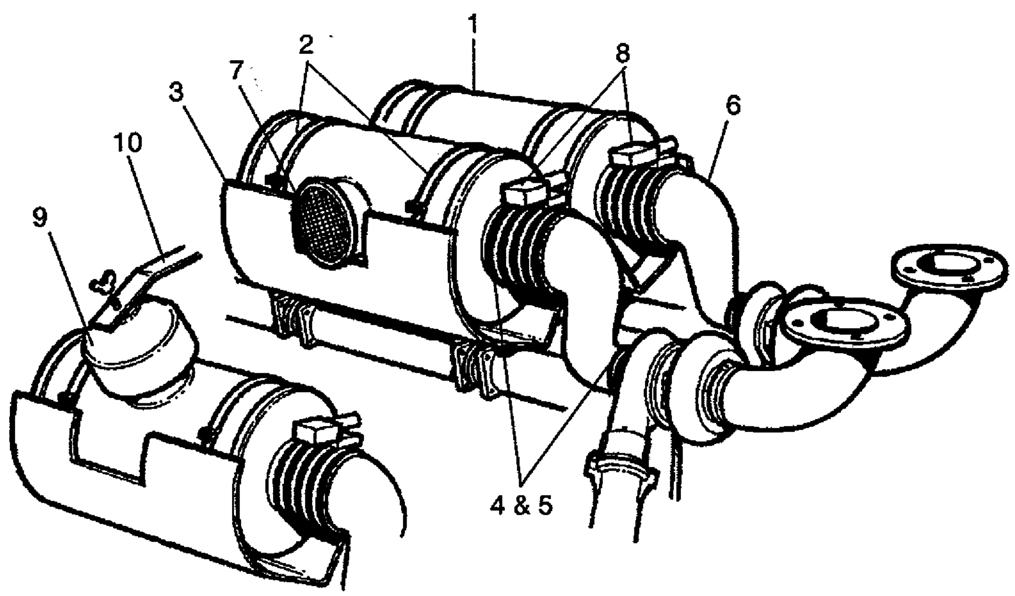



**Fig. 2A**

**AIR CLEANERS FITTED TO 4016TAG1, 4016TAG2, 4016TWG2, 4016TEG1 AND 4016TEG2**

These engines are fitted with four turbochargers and four air shut off valves connected to the two air cleaners by 'Y' shaped air pipes. See **Fig 3A**.

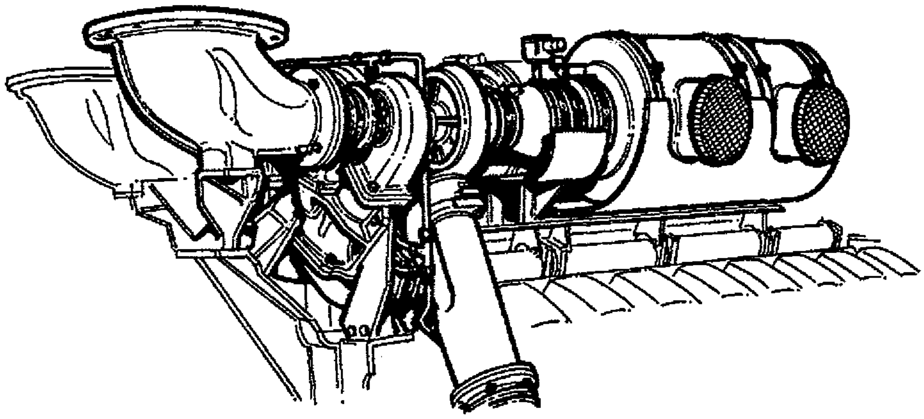


**Fig. 3A**

494.2

## RESTRICTION INDICATORS

The middle section of the restriction indicator 'A' will remain clear while the air cleaner is in servicable condition. When the filter reaches its contamination limit, the restriction indicator will sense the change in pressure and its middle section 'A' will change to red. At this point the air filters must be changed (see **Maintenance Schedule Operators Handbook page 61**). When the air filters have been changed reset the indicator to clear by pressing button 'B'.

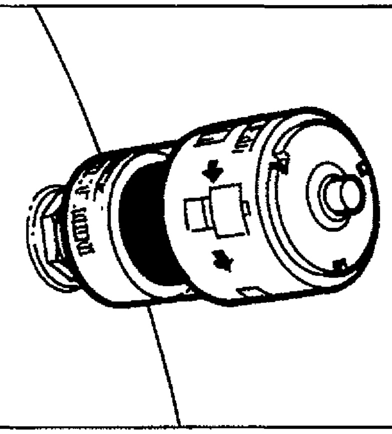


**Fig. 4A**

948.2

In the event of failure, service exchange alternators are normally supplied

## REMOVING THE ALTERNATOR (Disconnect Batteries)

**WARNING** ⚠ RUNNING THE ENGINE WITHOUT BATTERIES BEING CONNECTED MAY DAMAGE THE ALTERNATOR.

Disconnect the batteries. Remove the small metal guard around the alternator pulley. Slacken the lock nut on the pivot bolt, and take out the link bolt, which will release the tension from the drive belt allowing it to be removed. Take out the pivot bolt securing the alternator to its mounting bracket, and withdraw the alternator complete with pulley from the engine.

## REMOVING THE ALTERNATOR DRIVE PULLEY AND ALTERNATOR PULLEY

Remove the drive guard (drive pulley only). Both the grub screws should be removed, their threads and points oiled, and a grubscrew started into each jacking hole (there can be either one or two). Tighten the screw/s shown in **Fig. 2B** (alternately and evenly if there are two) until the bush is loosened and the assembly is free on the shaft **(see Fig.1U Section U1)**. The pulley and bush may now be removed from the shaft.

**NOTE:** The alternator pulley has another bush between the taperlock bush and alternator shaft. This may be removed by holding the alternator in the vice and tapping the bush off the shaft with a hammer and drift. Remove the spacing washer from behind the cooling fan on "Prestolite" alternators.

**Key**
**(Fig. 1B)**
**1** Link bolt
**2** Link
**3** Drive guard
**4** Mounting bracket & pivot bolt

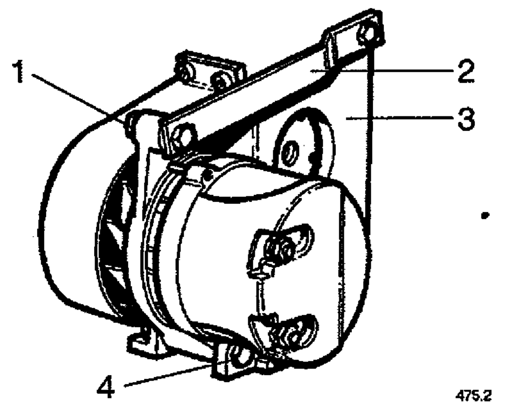



**Fig. 1B**

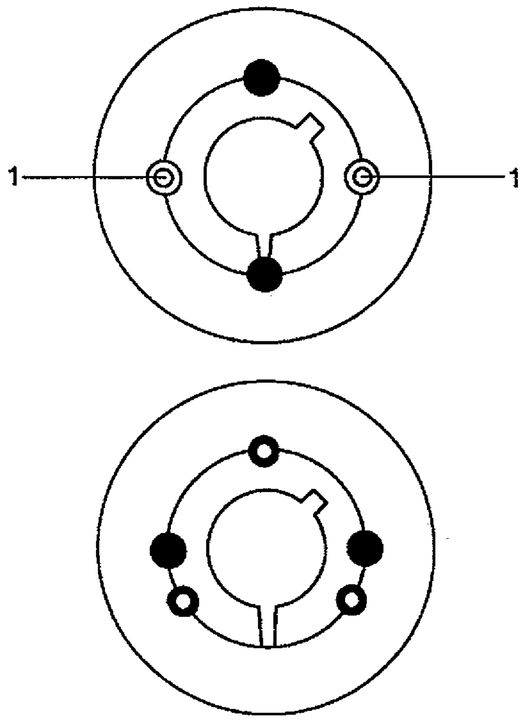



**Fig. 2B**

**Key**
**(Fig. 2B)**
**1** Locating screw

## REFITTING THE ALTERNATOR PULLEY

**NOTE:** Prestolite alternators have a spacer which must be fitted to the alternator drive shaft before anything else. if this spacer is omitted, the cooling fan will catch on the body of the alternator. Both types of alternator have a Woodruff key and an adaptor bush between the shaft and pulley assembly. The Woodruff key is simply tapped into the slot using a soft faced hammer and the adaptor bush started onto the shaft with the key in the slot and gently tapped into position with a tubular installing tool. The nut and spring washer should be started on the alternator shaft and tightened before fitting the taperlock bush and pulley assembly. From this point follow the procedure (given below) for refitting the alternator drive pulley.

## REFITTING THE ALTERNATOR DRIVE PULLEY

Fit the alternator drive pulley assembly onto the oil pump shaft, after fitting the taper lock bush in line with the following procedure:

Remove the protective coating (if new) from the bore and outside of bush, and bore of hub (if new). After ensuring that the mating tapered surfaces are completely clean and free from oil or dirt, insert the bush into the hub so that the holes line up.

Sparingly oil the threads and points of the grub screws, or threads and under the heads of the capscrews. Place the screws loosely in the holes threaded in the hub, shown thus ◎ in **Fig. 2B**.

Clean the shaft and fit the hub and bush to the shaft as one unit, locate in the position required to align with the alternator pulley, making an allowance of 1.5 mm for the movement of the hub as the bush nips the shaft first and then draws the hub onto the bush as it is tightened.

Using a hexagon wrench, tighten the screws gradually and alternately until they are tightened to the required torque (**see Torque Settings on pages 38-40**).

Hammer against the large end of bush, using a block or sleeve to prevent any damage. (This will ensure that the bush is seated squarely in the bore). The screws will now turn a little more. Repeat this alternate hammering and screw tightening once or twice to achieve the maximum grip on the shaft.

If a key is to be fitted, use a parallel key that is side fitting with top clearance.

After the drive has been running under load for a short time, stop and check the tightness of the screws.

Fill the empty holes with grease to exclude dirt. Check the tightness of the screws after a few hours of operation.

## REFITTING THE ALTERNATOR

Before fitting the alternator, rotate the pulley and driveshaft once or twice to ensure that the alternator turns freely.

The refitting of the alternator is a reversal of the removal procedure, taking care not to overtighten the drive belt and ensuring that the pulley on the alternator and the driving pulley are aligned with each other. Refit the guard.

Refer to the wiring diagram for correct connections.

## STARTER MOTORS TYPE S130L AND S152L

**WARNING** ⚠ ALL TERMINALS MUST NOT BE UNDONE. SLACKENING OF THESE NUTS CAN CAUSE INTERNAL DAMAGE TO THE CONNECTIONS. THE LABELS ON THE STARTERS ARE FOR IDENTIFICATION AND MUST NOT BE REMOVED.

**NOTE:** In the event of failure service exchange starters are normally supplied.

**REMOVING THE STARTER (Disconnect the batteries)**
Remove the nut from each main terminal and take off the leads. Also disconnect the leads from the smaller terminals, labelling them to ensure correct replacement.
Remove the retaining screws and withdraw the starter motor.

**REFITTING THE STARTER**
Insert the starter motor into the flywheel housing and refit the retaining screws in the mounting flange and tighten down evenly to ensure that the starter is correctly located.
Re-connect the leads to each main terminal and also the small leads to the correct terminals. (See **Fig. 1C**).
(Reconnect the batteries).

**Key**
**(Fig. 1C)**
**1** 24 volt batteries
**2** 381-4 Repeater relay
**3** Start button
**4** 2ST Relay
**5** S130 or S152 starter

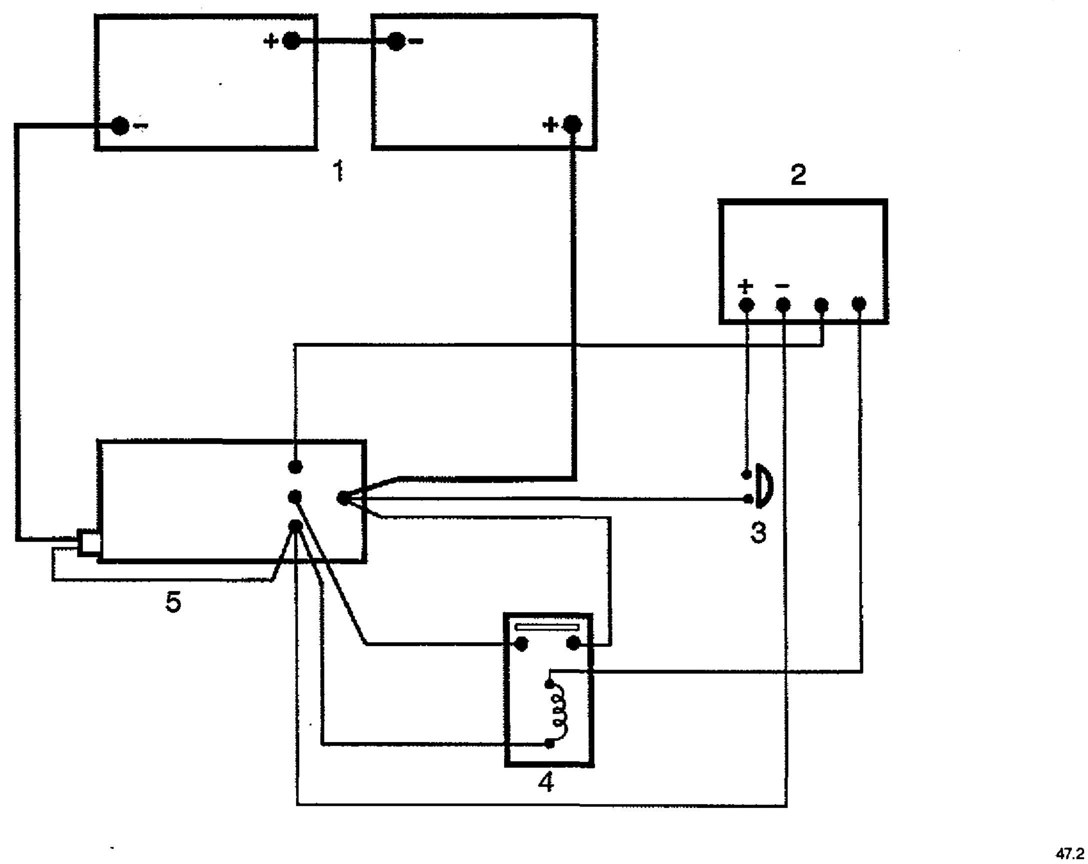



**Fig. 1C**

## MAINTENANCE

The starter mounting bolts and cables must be checked at 6 monthly intervals to ensure that the bolts are tight and the cable connections to the terminals are clean and tight.

Following any damage to the starter pinion, the ring gear should be checked.

**Avoid continuous cranking in excess of 60 seconds before investigating a failure to start.**

Continuous or intermittent cranking with insufficient cooling time can cause damage to the starter.

If the starter is permitted to over heat, or the battery cranking voltage allowed to drop below 16 volts, the damage to the starter may not be immediately apparent, but can cause subsequent failure or at least shorten its life.

## LUBRICATION

The drive end bearing is lubricated by a wick contained in the drive endshield oil reservoir. The reservoir requires no attention during routine maintenance, but should be refilled when the starter is dismantled at major overhauls every 2 years. This should by done by removing the starter and adding a supply of oil (Shell Tellus T27) through the oil filler in the drive end shield. The filler hole lies beneath a core plug which must be removed to gain access to the filler hole, (new plugs must be fitted CAV Part No. 6265/619 on the S130L starter using a special tool 6244-44) and care must be taken to ensure a positive fit in the filler hole otherwise they will fall out in service.

## FAULT TRACING GUIDE

### Single Starter - Installation Circuit

If the starter fails to operate when the start cycle is initiated or when the starter button is pressed, it will be necessary to check out in sequence the complete system using the following check list.

**NOTE:** Ensure that the batteries are fully charged and the complete circuit is correct to diagram.

| FAULT | REMEDY |
|---|---|
| When the starter is energised nothing happens | **1** Check the battery voltage.<br>**2** Check the supply to terminals 'S'.<br>**3** Fit a new starter. |
| Starter 'clicks' and does not engage the pinion or rotate | **1** Check the battery voltage and connections.<br>**2** Fit a new starter. |
| Starter rotates the pinion against the ring gear | Fit a new starter.<br>**NOTE: In the event of a damaged pinion, the ring gear must be examined and any burrs removed** |
| Starter engages but fails to crank or cranks slowly | **1** Check that the engine is free to rotate.<br>**2** Battery voltage is too low. |
| Starter repeatedly attempts rapid engagements | **1** Pinion is not able to engage. Examine the pinion teeth and ring gear.<br>**2** Faulty 381 repeater relay (if fitted). |
| Starter continues running after switching off | **1** Stop by disconnecting the battery. Check that the pinion has disengaged. If not, disengage the pinion and try the starter again.<br>**2** Check the repeater relay (if fitted) see **Section GG1.**<br>**3** Fit a new starter. |

## 2ST RELAY OR 33RA RELAY

1. Remove the lead to terminal 'S' on starter and energise the circuit.
2. Check the positive supply from the control panel to the 2ST or 33RA solenoid coil or, when fitted, to 'S' terminal of the 381 repeater relay.
3. If there is no supply, check the control panel.
4. If the supply is available check the 2ST or 33RA relay, an audible 'click' will be heard when it is energised and the lead to terminal 'S' should become live. If there is no response, fit a new unit.

## 381-4A REPEATER RELAY (See Section GG1)

Disconnect the lead to terminal 'S' on the starter and energise the circuit. The repeater relay should pulse approximately once a second until a positive supply is applied to terminal 'A' when pulsing should cease. If the relay does not operate as described, fit a new unit.

## STARTER MOTORS TYPE MS1/108 MS7 AND MS7/5

**WARNING** ⚠ ALL TERMINALS MUST NOT BE UNDONE. SLACKENING OF THESE NUTS CAN CAUSE INTERNAL DAMAGE TO THE CONNECTIONS.

**NOTE:** In the event of failure service exchange starters are normally supplied.

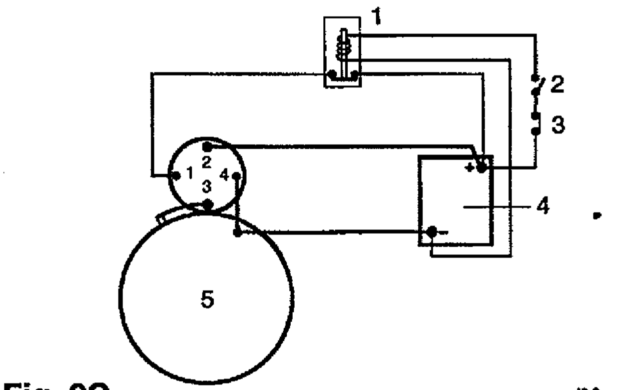



Fig. 2C

### REMOVING THE STARTER (DISCONNECT THE BATTERIES)

Remove the nut from each terminal and remove the leads, labelling them to ensure correct replacement.
Remove the retaining screws and withdraw the starter motor.

### REFITTING THE STARTER

Insert the starter motor into the flywheel housing, refit the retaining screws in the mounting flange and tighten down evenly to ensure the starter is correctly located. Re-connect the leads to each terminal, and tighten the nuts (see **Fig. 2C**).

### MAINTENANCE

To ensure maximum life and trouble-free starting, it is recommended that maintenance procedures should be undertaken at regular intervals, the length of which are dependent upon service conditions. The starter mounting bolts and cables must be checked at 6 monthly intervals to ensure that the bolts are tight, and the cable connections and the terminals are clean and tight.

**Avoid continuous cranking in excess of 60 seconds before investigating a failure to start.**

Continuous or intermittent cranking with insufficient cooling time can cause damage to the starter.

If the starter is permitted to overheat, or the battery cranking voltage allowed to drop below 16 volts, the damage to starter may not be immediately apparant, but it can cause subsequent failure or at least shorten its life.

Annually the starter should be removed from the engine and the bushes lubricated with SAE 5W/20 engine oil in each of the wick type lubricators located in the nose housing, the commutator end plate and the shift housing. Clean the splines of the drive shaft with suitable solvent and lubricate with Aeroshell grease No. 7 DID5598 or equivalent.

The commutator and brushes should be examined and if the brushes are worn below a length of 15.88 mm (0.62") they must be renewed. To renew the brushes remove the opening band complete. Remove the screws which secure the eight brush tabs, and slacken the remainder, pivot the lock-washers to one side and, using a suitable tool, lift up the brush springs and remove the brushes.

**Key**
**(Fig. 2C)**

1 Relay
2 Starter switch
3 Starter inter lock
4 Battery
5 Starter motor

## FAULT TRACING

**NOTE:** Ensure that the batteries are fully charged and the complete circuit is correct to diagram.

**Single starter installation (see Fig. 2C for circuit)**
If the starter fails to operate when the start cycle is initiated or when the starter button is pressed, it will be necessary to check out in sequence the complete system using the following check list.
**Twin Starter Installations (see Operators Handbook for circuits).**

| FAULT | REMEDY |
|---|---|
| When the starter is energised nothing happens | 1 Check the battery voltage.<br>2 Check supply to solenoid and starter terminals.<br>3 Fit new starter. |
| Starter 'clicks' and does not engage the pinion or rotate | 1 Check the battery voltage and connections.<br>2 Fit new starter. |
| Starter rotates the pinion against the ring gear | Fit new starter.<br>**NOTE: In the event of a damaged pinion, the ring gear must be examined and any burrs removed** |
| Starter engages but fails to crank or cranks slowly | 1 Check that the engine is free to rotate.<br>2 Battery voltage is too low. |
| Starter repeatedly attempts rapid engagements | 1 Pinion is not able to engage. Examine the pinion teeth and ring gear.<br>2 Faulty TSL5 repeater relay (if fitted). |
| Starter continues running after switching off | 1 Stop by disconnecting the battery. Check that the pinion has disengaged. If not, disengage the pinion and try the starter again.<br>2 Check the repeater relay (if fitted).<br>3 Fit new starter. |

## SR1 RELAY

1. Remove the lead to terminal '1' on starter and energise the circuit.
2. Check the positive supply from the control panel to the SR1 relay.
3. If there is no supply, check the control panel.
4. If the supply is available check the SR1 relay, an audible 'click' will be heard when it is energised and the lead to terminal '1' should become live. If there is no response, fit a new unit.

## TSL5 REPEATER RELAY

Disconnect lead terminal '2' on repeater relay and energise the circuit. The repeater relay should pulse approximately once a second until a positive supply is applied to terminal '2' when pulsing should cease. If the relay does not operate as described, fit a new unit.

## STARTER MOTOR TYPE SS815
## AIR STARTING SYSTEM

**WARNING** ⚠ THE STARTER ON PRESSURES GREATER THAN 10.34 bar (150lb/in²) OR LESS THAN 4.8 bar (70lb/in²).

The air starter motor operates at a pressure of 1034 kPa (150 lb/in²) from a compressed air supply pressure of 1172 kPa (170 lb/in²) minimum at air receiver (see **Fig. 3C**).

**Key**
**(Fig. 3C)**
1 Air supply
2 Oil reservoir
3 Relay valve
4 Inlet
5 Air strainer
6 HDLI Lubricator
7 Exhaust muffler
8 Starter control valve
9 Air starter

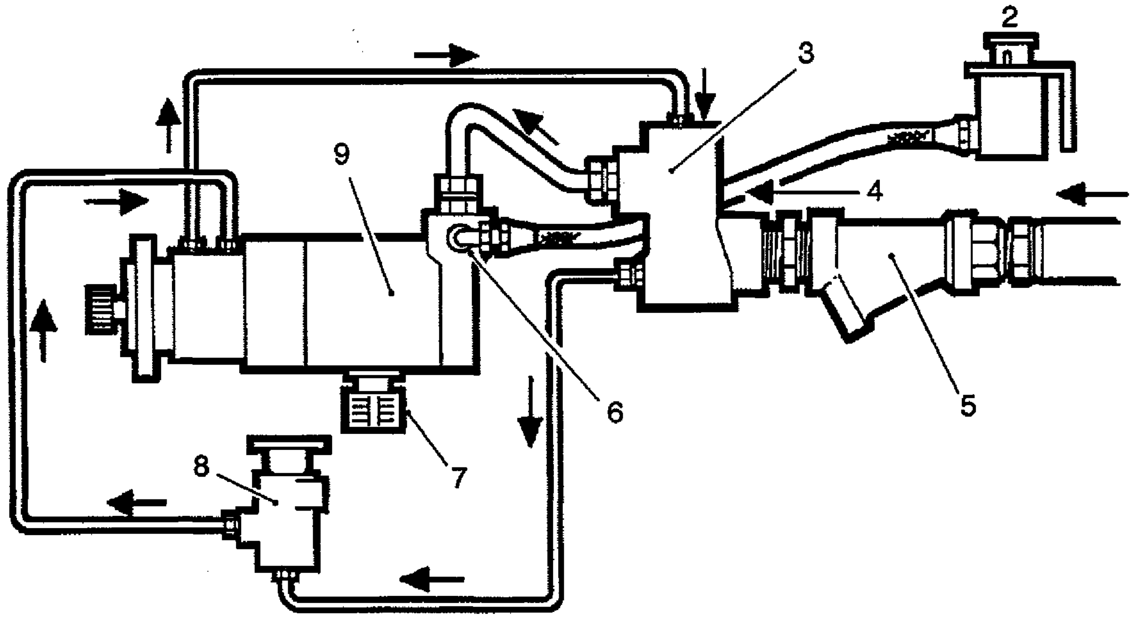



**Fig. 3C**

## OPERATION

When the control valve is opened, air is admitted through the rear port of the starter to actuate a piston which forces the drive pinion forward for flywheel engagement prior to air admission to the motor. No rotation is imparted to the pinion by the motor at this stage.

When the pinion is fully engaged, the forward port is uncovered allowing the air to the relay valve inlet (see **Fig. 4C**).

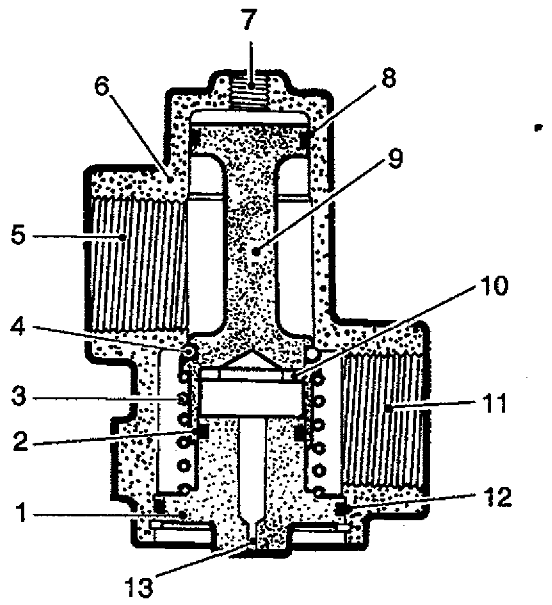


**Fig. 4C**

**Key**
**(Fig. 4C)**

**1** End cap
**2** Small end cap seal
**3** Piston return spring
**4** Piston seat
**5** Outlet
**6** Valve housing
**7** Relay valve inlet
**8** Piston seal
**9** Piston
**10** Piston buffer
**11** Inlet
**12** Large end cap seal
**13** Vent

Air is admitted through the relay valve inlet, depressing the piston against the piston return spring. Air trapped at the lower end of the piston is exhausted through the small vent in the end cap.

As the piston is depressed, air is admitted from the inlet side of the valve and flows around the piston to the starter, which starts the cranking cycle.

Since the starter control valve is actually a 3-way normally vented valve, as soon as it is released or closed, the air on top of the piston is dumped and the piston snaps back to shut off air to the starter.

Hence the relay valve responds quickly to the control valve to assure air starter disengagement and prevent damage to the pinion and/or flywheel gear ring. (See **Fig. 4C**).

## MAINTENANCE

Providing that the air starter motor is properly installed and maintained it is unlikely to give any problems in service.

In the event of failure, service exchange starters are normally supplied, as the high cost of the special equipment and the facilities necessary make it uneconomical for individual operators to repair them. For those operators who still wish to repair their own starters, the special equipment and technical information may be obtained from the manufacturer.

## LUBRICATION

Proper lubrication of the starter is essential for top performance and maximum durability.

The air starter motor is fitted with a type HDLI lubricator, which is self-priming, and is supplied with lubricant from a separate reservoir, mounted on the engine.

For temperatures above 0°C (32°F) use SAE10 non-detergent oil.

For temperatures below 0°C (32°F) use diesel fuel.

Reservoir capacity 500 cc.

**CAUTION:** The oil supply line pressure should not be greater than 34 kPa (5 lb/in$^2$).

## REMOVING THE STARTER

Ensure that the air supply to the starter is turned off and locked. Disconnect the batteries in the case of a dual start system.

The starter should always be removed as a unit from the engine whenever repairs are necessary.

Disconnect the flexible hose at the starter motor air inlet connection (1½" NPT), also the pipes from the inlet and outlet control ports (¼" NPT).

Remove the retaining screws in the starter motor mounting flange, and withdraw the starter motor.

## REFITTING THE STARTER

Insert the starter motor into the flywheel housing, and refit the retaining setscrews in the mounting flange and tighten down evenly, to ensure the starter is correctly positioned.

Re-connect the flexible air supply pipe to the starter, together with the pipes to the inlet and outlet control ports.

Turn on the air supply and check for leaks.

## REMOTE OR AUTOMATIC OPERATION

For remote or automatic operation the manual starter control valve is replaced by a 3-way solenoid operated valve (see **Fig. 5C**).

**Key**
**(Fig. 5C)**

**1** Air supply (150 psi)
**2** Oil reservoir
**3** Relay valve
**4** Inlet
**5** Air strainer
**6** HDL Lubricator
**7** Outlet
**8** Conduit connection
**9** 3-Way solenoid operated valve
**10** Exhaust muffler
**11** Air starter

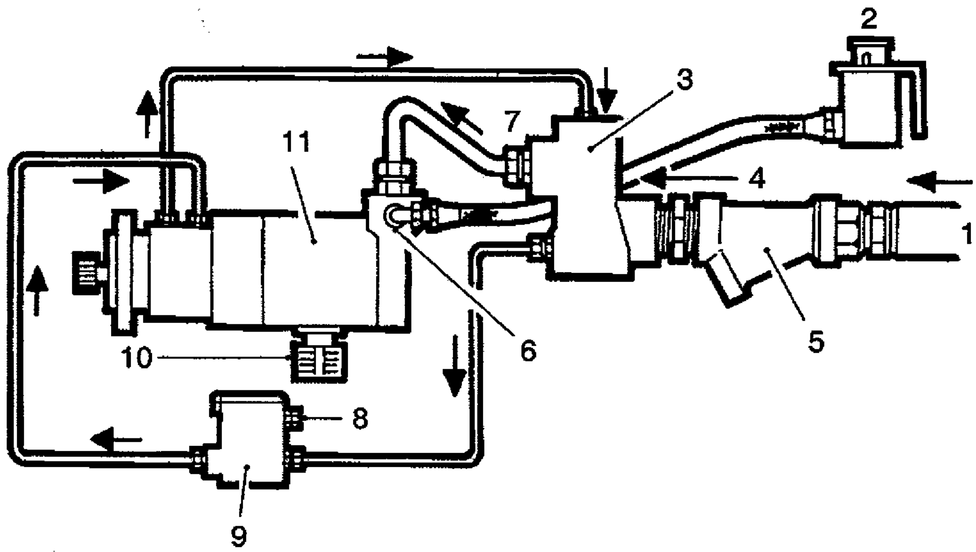



**Fig. 5C**

**WARNING** ⚠ THE WEIGHT OF THE PUMP MUST BE SUPPORTED BY A LIFTING SLING FITTED ROUND THE PUMP BODY.

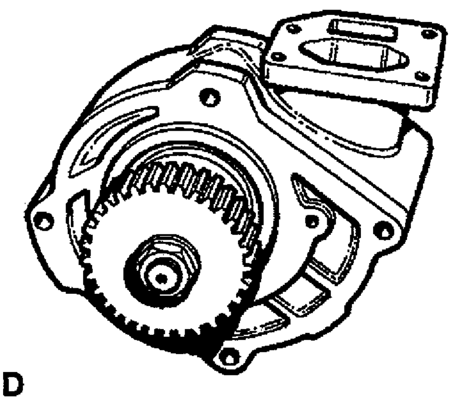



Fig. 1D

**NOTE:** In the event of failure, service exchange water pumps are normally supplied as the special equipment needed to remove and refit the impeller, drive gear and bearings is not generally found in the field. For those operators who have the facilities to repair their own water pumps, the special equipment may be obtained from Perkins Engines (Stafford) Ltd.

**REMOVING THE PUMP**

Drain the coolant system using the drain taps in the ends of the oil coolers, disconnect the hoses between the pump inlet (from radiator), pump/thermostat by pass and pump to oil cooler.

Remove the four through bolts fixing the pump casing to the gearcase and suspension plate, withdraw the pump assembly carefully from the gearcase. (See **Section U1**) The drive gear can be removed and refitted to the replacement pump providing that the wear is within the recommended tolerances. (See **Renewal Limits pages 41-42**).

**REFITTING THE PUMP**

Ensure that all joint faces are clean and free from old jointing material and that a new 'o' ring (2) (see **Fig. 2D**) is fitted in the recess in the bearing housing, lubricate with soft soap or petroleum jelly and fit the pump body making sure it seats evenly. Coat the drive gear with clean engine oil refit in reverse order using a new joint between the pump casing and gearcase.

**NOTE:** References to 'water' or 'fresh water' should be taken to mean potable water containing anti-freeze and/or corrosion inhibitors, as described in the **Operators Handbook** under the heading '**Coolant**'.

## TO DISMANTLE

A press capable of exerting a force of at least 5 tonne is required to remove and fit the impeller. See **Fig. 2D.**

Grip the drive gear (10) in a vice with protected jaws, remove the securing nut (8) and the retaining washer (9). Draw the gear off the shaft and remove the drive key (7).

Remove the bearing retaining circlip (11). Separate the pump body (1) from the bearing housing (3).

Mount the bearing housing (3) in a hydraulic press, impeller (15) uppermost, by supporting under the mounting face and allowing sufficient clearance below for the shaft (16).

Using a suitable dolly, press the shaft (16) out of the impeller (15). Arrangements should be made to catch the shaft and bearings (12).

Remove the carbon seal assembly (13) from the rear of the impeller (15) and ceramic counterface (14) from the bearing housing (3) and discard them both.

Check the condition of the bearings (12), before proceeding any further with dismantling.

Withdraw the oil seal (4) from the bearing housing (3) and discard it. **DO NOT RE-USE.**

Remove the bearing locating rings (5) from the bearing housing (3).

Withdraw the bearings (12) complete with the distance piece (6) from the shaft (16).

**Key**
**(Fig. 2D)**

1. Pump body
2. 'O' ring
3. Bearing housing
4. Oil seal
5. Bearlng retainers
6. Distance piece
7. Key
8. Securing nut
9. Retaining washer
10. Drive gear
11. Circlip
12. Bearings
13. Carbon seal assembly
14. Ceramic counterface
15. Impeller
16. Shaft

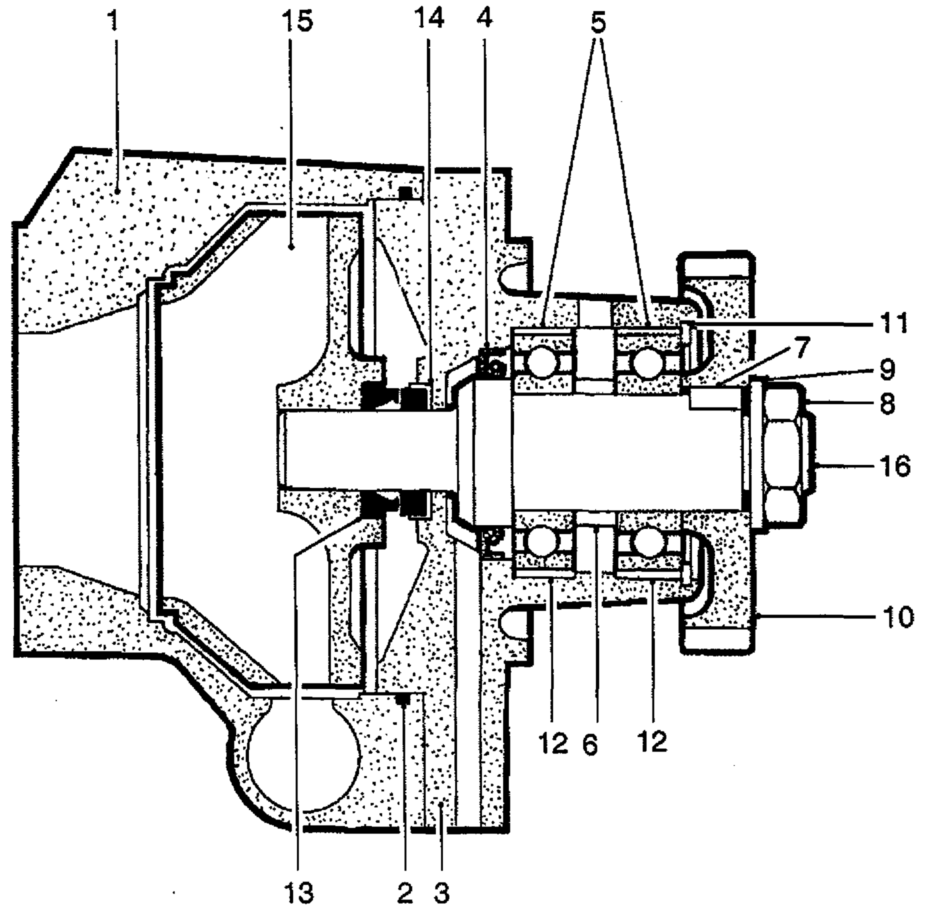



Fig. 2D

**TO INSPECT**

Before the removal of the shaft from the bearing housing, check the bearings for excessive play. A harsh gritty action is indicative of a damaged bearing which should be replaced.

Check the impeller for cracks, corrosion or damage. Check the bore for scoring. Lightly clean as necessary. Do not remove too much material as this will reduce the interference fit.

Examine the shaft for wear and grooving on the shoulder at the contact point of the oil seal, and the impeller seating area for scoring. Check the size of the shaft, and the bore of the impeller for correct fit (see **pages 41-42 Wear and Renewal Limits**). Lightly clean as necessary. Do not remove too much material as this will reduce the interference fit.

Check the drive gear teeth for ridging, pitting. Blend out any such marks with a fine oil stone.

**TO ASSEMBLE**

Press the bearings (12) and the spacer (6) onto the shaft (16) ensuring that the inner bearing fits firmly against the shaft shoulder. Pressure should only be exerted on the inner races.

Fit the oil seal (4) to the bearing housing (3) with the open side facing the bearing. Lubricate the sealing lip.

Place the bearing locating rings (5) in the bearing housing (3), and insert the shaft/ bearing assembly. Fit the bearing retaining circlip (11).

Fit the key (7) to the shaft, slide the drive gear (10) onto the shaft, and fit the retaining washer (9) with the securing nut (8). Grip the gear in a vice with protected jaws and tighten the securing nut to the correct torque. See **Torque Settings pages 38-40.**

Invert the housing and carefully press the ceramic counterface (14) into the bearing housing (3).

Moisten with water the rubber mounting of carbon seal assembly (13) and press it into position in the rear of the impeller (15).

Locate the impeller (15) on the shaft using a soft hammer to ensure that the impeller is positioned squarely on the shaft before pressing it on. Mount the bearing housing assembly (3) on a hydraulic press, solidly mounting the gear face to accept pressure. Do not allow the pressure to be exerted on the bearing housing. Apply the load to the impeller centre and press on the impeller (15) until flush with the end of the shaft (16).

Fit a new 'O'- ring (2) into the bearing housing groove, lubricate with soft soap or petroleum jelly and fit the pump body. Check for free rotation.

Using a new joint, fit the pump to the timing cover and secure.

Reconnect the hose between the pump elbow and delivery pipe.

Refit the pipe between the thermostat and pump elbow.

Refill the cooling system and check for water leaks.

## RAW WATER PUMP AS FITTED ON THE 4012/16 WATER COOLED CHARGE COOLER ENGINES

### GENERAL DESCRIPTION

The raw water pump is mounted via an adaptor plate on the rear of the timing gear cover, and is driven directly from the engine gear train, via a gear fixed to the pump shaft. The pump shaft support bearings are lubricated via an engine lubricated oil supply pipe (see **Fig. 4E**).

In the event of a raw water pump failure exchange pump are usually supplied.

**NOTE:** It is essential that the pump inlet and outlet connections remain in line (see **Fig. 1E**). If this alignment is disturbed the pump will not operate.

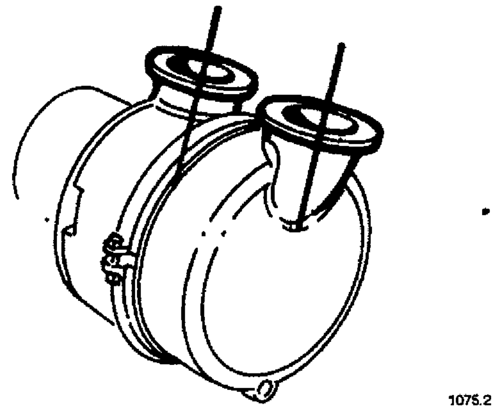



Fig. 1E

## RAW WATER CIRCUIT AS FITTED ON THE 4012TEG/2 AND 4016TEG/2 ENGINES

The raw water supply (2) is connected to the pump suction, and then piped from the pump delivery to the charge coolers (4), where the raw water is used to cool the combustion air from the turbochargers to the air inlet manifolds.

From the charge air coolers (4), the raw water flows through the heat exchanger (1) where it is used to cool the hot fresh water from the engine cooling circuit, i.e. engine oil coolers (3) and water jackets, before being piped away (5) (see **Fig. 2E Early Heat Exchanger and Oil Cooler Layout (4012TEG) or 5E**).

## RAW WATER CIRCUIT AS FITTED ON THE 4012TWG/2 AND 4016TWG/2 ENGINES

The raw water supply (2) is connected to the pump suction and then piped from the pump delivery to the heat exchanger (1). The raw water flows through the heat exchanger where it is used to cool the hot fresh water from the engine cooling circuit, i.e. engine oil coolers (3), charge air coolers (4) and water jackets. Before being piped away back to the source (5) (see **Fig. 3E Early Heat Exchanger and Oil Cooler Layout (4012TWG)**).

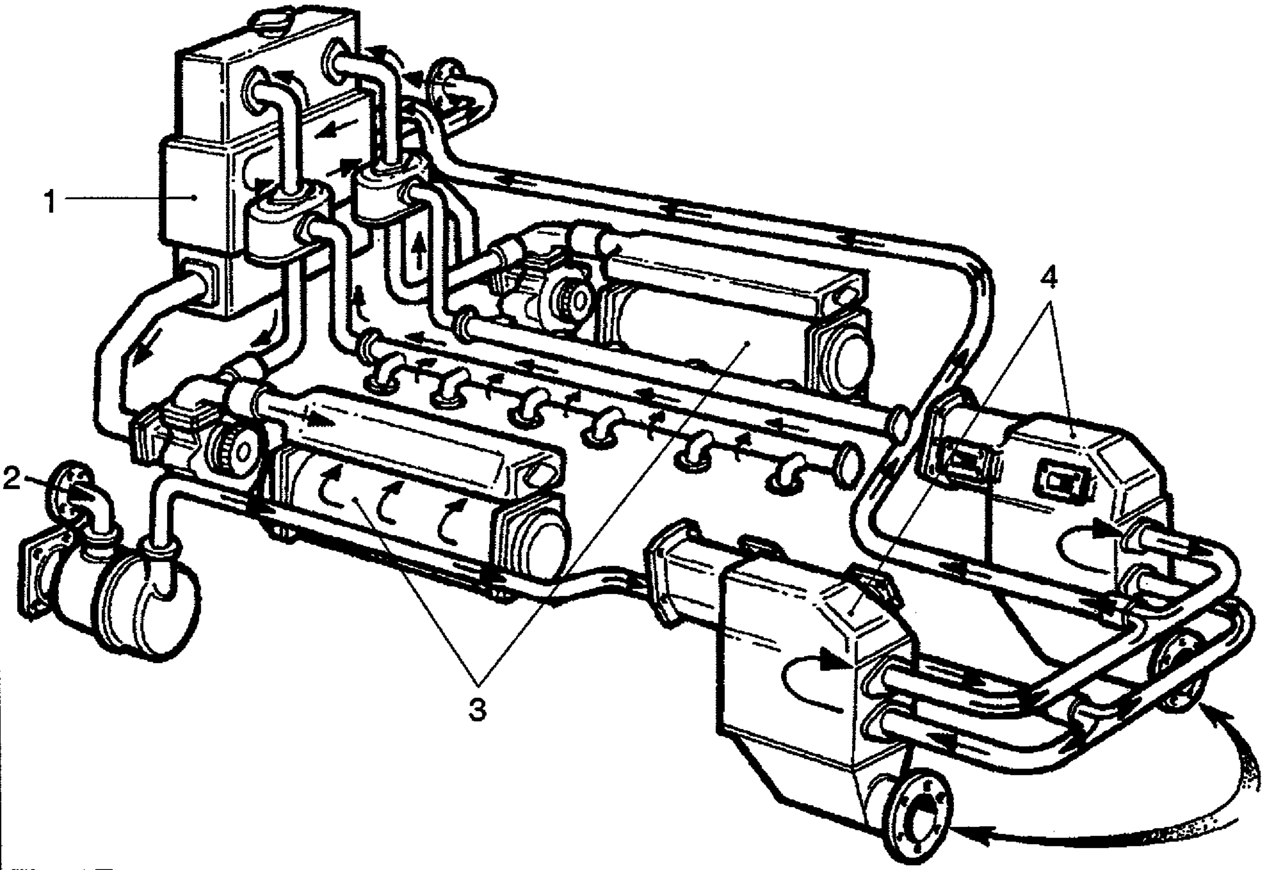



Fig. 2E

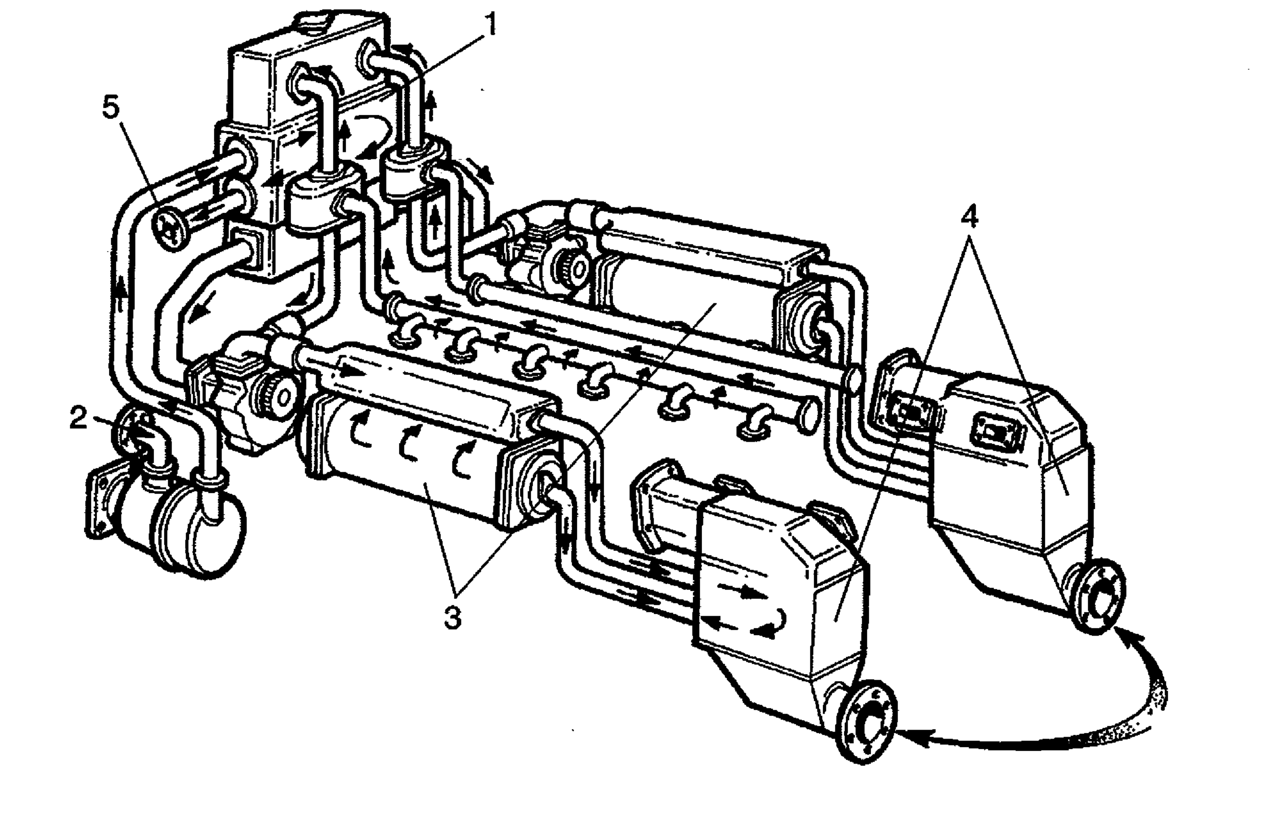



Fig. 3E

## REMOVING THE RAW WATER PUMP

**WARNING** ⚠ THE PUMP MUST BE SUPPORTED BY A LIFTING SLING FITTED ROUND THE PUMP BODY.

Isolate the raw water supply and drain the water from the tap in the external pipework.
Remove the 'V' band clamps (1) securing the inlet and outlet water pipes to the pump.
Disconnect the lubricating oil supply pipe at the union (2) fitted in the pump. This pipe should then be sealed to prevent oil leakage.
Remove the four screws (3) securing the pump to the engine adaptor plate (4), and carefully withdraw the pump.
Clean off any jointing material remaining on the adaptor plate and then seal or cover the aperture (see **Fig. 4E**).

## TO DISMANTLE THE RAW WATER PUMP

Grip the drive gear (6) in a vice with protected jaws, remove the securing nut (8), retaining washer (9), draw the gear off the shaft and remove the drive key (10).
Check the drive gear for ridging, pitting or plucking. Blend out any such marks with a fine oil stone.
Remove the union (2) from the pump casing.

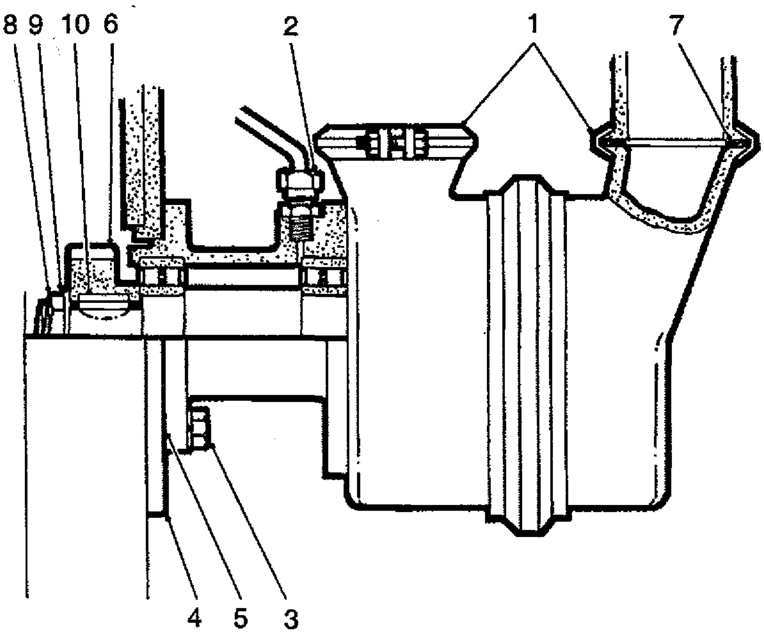



**Fig. 4E**

## REFITTING THE PUMP

Fit the key (10) to the shaft, slide the drive gear (6) onto the shaft, apply Loctite 542 to the thread, fit the retaining washer (9) and the securing nut (8). Grip the gear in a vice with protected jaws and tighten the securing nut the required torque (see **Torque Settings pages 38-40**). Fit the union (2) in the service exchange pump.

Fit a new joint (5) to the pump, the adaptor (4), coat the drive gear (6) with clean engine oil and fit the pump to the engine adaptor plate. Refit and tighten the retaining screws (3) evenly to pull the pump squarely onto the mounting plate. Reconnect the oil feed pipe. Fit the rubber sealing washers (7) between the water pipes and pump flanges, then very carefully fit and tighten evenly the 'V' band clamps (1) making sure that they hold the water pipes squarely to the pump. Refill the system.

## LATEST HEAT EXCHANGER AND OIL COOLER LAYOUT 4012/16TEG2 (TROPICAL)

**Key**
**(Fig. 5E)**
1. Raw water inlet
2. Raw water outlet
3. Heat exchanger
4. Oil coolers
5. Charge air coolers

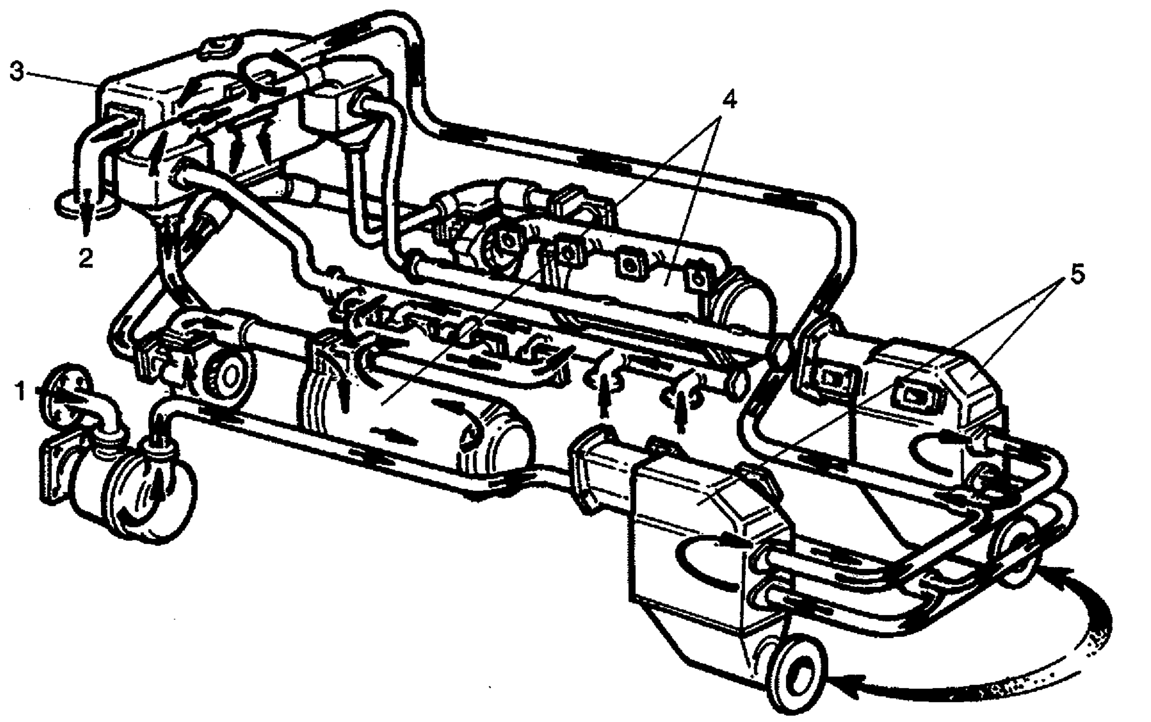



**Fig. 5E**

## LATEST HEAT EXCHANGER AND OIL COOLER LAYOUT 4012/16TWG2 (TEMPERATE)

**Key**
**(Fig. 6E)**
**1** Raw water inlet
**2** Raw water outlet
**3** Heat exchanger
**4** Oil coolers
**5** Charge coolers

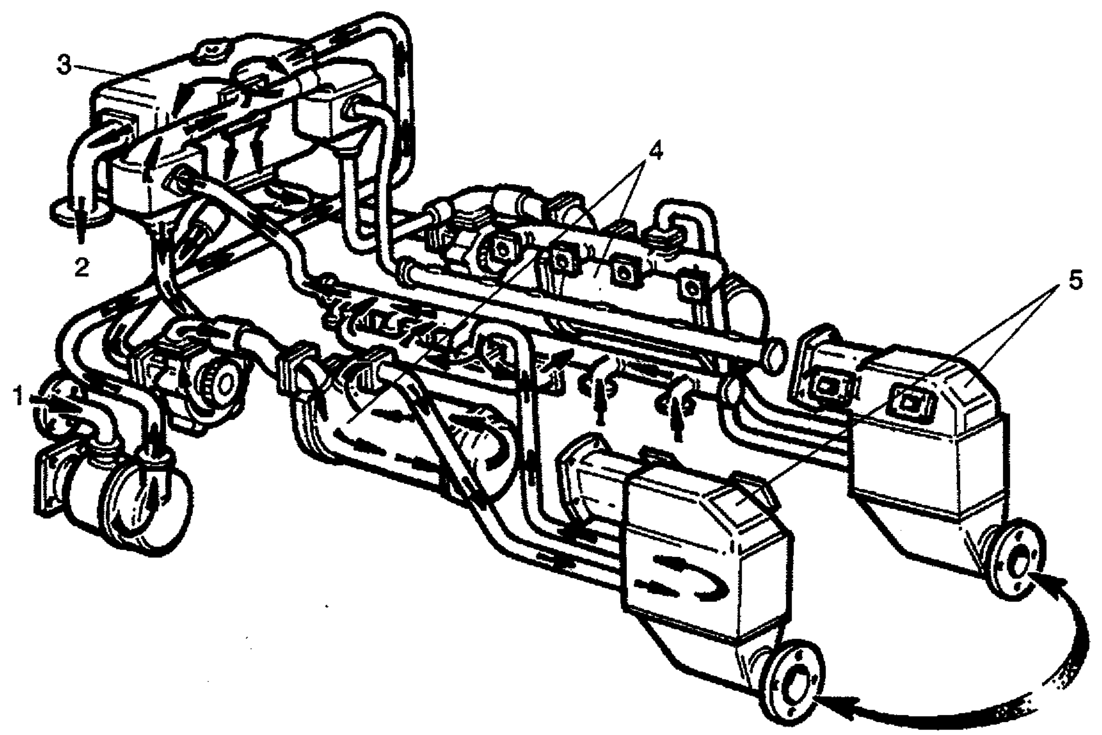



**Fig. 6E**

## GENERAL DESCRIPTION (RADIATOR COOLED)

### COOLING CIRCUIT AS FITTED ON THE 4012TWG & 4016TWG ENGINES (NOT THE 4016TWG2 AT AMBIENT TEMPERATURES IN EXCESS OF 38°C)

Coolant is circulated through the engine cooling system by two centrifugal pumps mounted on the front face of the timing cover and driven by the engine gear train. Coolant from the pumps flows through the oil coolers before entering into the crankcase water jackets. From both the cooling jackets around the cylinders and the charge air coolers, water flows upwards through the cylinder heads and water rails to the thermostat housings. The housings are fitted with two thermostat elements each, which determine the direction of coolant flow dependent upon temperature. When cold the flow is directed back via by-pass pipes to the water pump suctions to recirculate the system. When hot the thermostats open the coolant is allowed to enter the radiator and is cooled by air blowing over the single core cooling matrix. (See **Flow diagram in the Operators Handbook**).

### COOLING CIRCUIT AS FITTED ON THE 4012TAG & 4016TAG ENGINES

Coolant is circulated through the engine cooling system by two centrifugal pumps mounted on the front face of the timing cover and driven by the engine gear train. Coolant from the pumps flows through the oil coolers before entering the crankcase water jackets. From the cooling jackets around the cylinders the coolant flows upwards into the cylinder heads and water rails to the thermostat housings. The housings are fitted with two thermostat elements each, which determine the direction of coolant flow dependent upon temperature. When cold the flow is directed back via by-pass pipes to the water pump suctions to recirculate the system. When hot the thermostats open the coolant is allowed to enter the radiator, and is cooled by air blowing over the single core cooling matrix.

The hot charge air from the turbochargers is directed via large diameter air pipes to the radiator top, and after passing through a separate radiator is directed through large bore pipes to the engine air intake manifolds. The cooling of the charge air is achieved by putting this additional radiator behind the normal water cooling radiator. The single radiator fan pushes air through air through each matrix in series, i.e. the cooling air from the fan passes first through the charge air matrix and then through the water cooling section. (See **Flow diagram in the Operators Handbook**).

**GENERAL DESCRIPTION (HEAT EXCHANGER COOLED)**
**COOLING CIRCUIT AS FITTED ON THE 4012TEG, 4016TEG AND SOME 4016TWG2 (SEE ABOVE) ENGINES**

Coolant is circulated through the engine and intercoolers by two separate cooling systems, each system using independent water pumps. Coolant for the engine cooling system is circulated by two centrifugal pumps mounted on the face of the timing cover and driven by the engine gear train. The coolant for the intercooler system is circulated by a raw water pump mounted on the rear face of the timing cover and driven by the engine gear train. The water for the engine cooling system flows from the pumps through the oil coolers before entering the crankcase water jackets. From the cooling jackets around the cylinders the coolant flows upwards into the cylinder heads and water rails to the thermostat housings.

The housings are fitted with two thermostat elements each, which determine the direction of coolant flow dependent upon temperature. When cold the flow is directed back via by-pass pipes to the water pump suctions to recirculate the system. When hot the thermostats opened the coolant is allowed to enter the heat exchanger and circulate the outside of the tubes, to be cooled by raw water passing through the tubes, after circulating the intercoolers and returning to the external source.

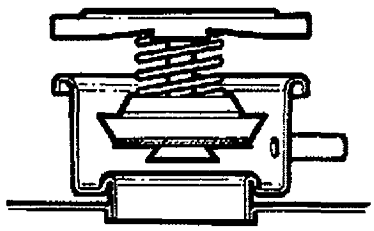


Fig. 1F

56.2

**GENERAL INFORMATION**

Cooling systems are pressurised to operate at between 0.5 to 0.7 bar, by fitting a pressure filler cap on the radiator or heat exchanger.

The filler cap requires a double action turning motion before it can be removed i.e. first turn to the stop to release the pressure and only then press and turn to remove the cap. The filler cap on the radiator/heat exchanger is fitted with a valve which is normally closed. When the pressure in the cooling system rises above 0.5 or 0.7 bar the valve opens. Surplus coolant escapes through the overflow pipe. When the pressure is relieved the valve closes.

The valve also incorporates a vacuum valve which when the main valve is closed allows air to be drawn into the top of the radiator or heat exchanger and prevents a vacuum forming in the top of the tank as the water level falls (see **Fig. 1F**).

**WARNING** ⚠ COOLING SYSTEM IS PRESSURISED. DO NOT REMOVE THE FILLER CAP FROM THE RADIATOR OR HEAT EXCHANGER WHILE THE ENGINE IS HOT. HAND PROTECTION MUST BE

The use of plain water is not recommended owing to chemical actions which can result in corrosion and furring-up of the cooling system. A solution of either water and universal anti-freeze or water and a corrosion preventive must be used (see **Operators Handbook**).

After installation and before the first start remove the radiator/heat exchanger cap and fill the cooling system with the required coolant. Run the engine off-load for one minute to ensure that the system is completely filled, then stop the engine and top up the system to within 25mm (1") of the overflow pipe.

**CAUTION:** In the case of remote radiators the standard thermostat should be replaced by a different design located nearer to the radiator (see **Installation Manual**).

## MAINTENANCE INSTRUCTIONS (RADIATOR)

It is essential to achieve efficient cooling, so the radiator should be inspected periodically to ensure that there is no significant build up of dust and dirt on the cooling matrices. It is suggested that inspection should be carried out at least every three months. The frequency of inspection should be increased when adverse site conditions exist.

**WARNING** ⚠ ALWAYS WEAR EYE PROTECTION WHEN USING COMPRESSED AIR.

If external fouling is evident the cooling surfaces should be cleaned. A low pressure (25 lbf./in$^2$ - 1.75 kg/cm$^2$) steam jet or compressed air is normally sufficient to clean the outside fins. Stubborn areas may need washing or hosing down with detergent and hot water. Shell Teepol is ideal for this, although there are many acceptable alternatives.

If recommended coolants have been used, there should be no appreciable limescale build up in the water tubes. If there is a limescale build up, it must be removed using a proprietary chemical de-scaling solution (one which will not attack the solder coated brass tubes of the radiator). See **page 33**. Where a proprietary de-scaling agent is used, the manufacturer's instructions for its use should be adhered to.

If there is any doubt about water leaks, limescale or carbon build up, replace the radiator or heat exchanger as the refitting of a faulty unit will lead to a drop in engine output, or engine damage in the case of water leaks.

## REMOVING THE RADIATOR

**WARNING** ⚠ DISCONNECT BATTERIES OR ANY OTHER MEANS OF STARTING ENGINE.

Drain the cooling system by removing the drain plug from the radiator bottom tank, having first removed the radiator filler cap.
Remove both the top and bottom hose connections by unscrewing the hose clips and sliding the hoses off the pipes of the radiator top and bottom tanks. Disconnect the air pipes in the case of the air cooled intercooler engines, by removing the screws in the radiator air pipe flange connections.
Remove belt guards, then slacken off the jockey pulley adjuster and pivot bolts (see **Figs. 32-33 in the Operators Handbook**) and remove fan belts from the fan pulley.
Remove the radiator holding down bolts, and lift the radiator away from the engine by using the lifting eyes fitted in the top of the radiator side members.

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT.

## REFITTING THE RADIATOR

Lift it up to the engine and, after aligning the fan pulley to the crankshaft pulley, refit and tighten the holding down bolts.
Fit the fan belts and adjust the tension of the belts as shown in **Figs. 32-33 in the Operators Handbook**. Grease the fan and jockey pulley bearings, and refit the belt guard.
Before refitting the air pipes, ensure that the mating flange faces are clean, and that no old joint material remains on these faces.
Using new joints between the air pipe flanges on the top and bottom tanks, tighten the retaining screws in a sequence that will pull the flanges square to each other without distortion.
Refit the top and bottom water hose connections to the pipes in the radiator top and bottom tanks, and tighten the hose clips to make water tight joints.
Refit the drain plug and fill the radiator as described in **Operators Handbook page 27**. Run the engine on light load for a few minutes, check for water leaks. Stop the engine, check the coolant level and top up accordingly.

## FAN DRIVEN PULLEY
The fan driven pulley is fixed to the radiator cooling fan drive shaft via a 'FENNER' taper lock bush, and is positioned on the shaft to line up with the jockey and crankshaft pulleys.

## REMOVING THE FAN PULLEY
REMOVE all screws insert screws in jacking holes after oiling thread and point of grub screws or thread and under head of cap screws.
Tighten screws alternately until bush is loosened in hub and pulley assembly is free on the fan drive shaft.
Remove assembly from shaft.

## REFITTING FAN DRIVEN PULLEY
Fit the fan driven pulley assembly onto the fan driven shaft, after fitting the taper lock bush in line with the following procedure:
Remove the protective coating from the bore and outside of bush, and bore of hub. After ensuring that the tapered surfaces are completely clean and free from oil or dirt, insert bush in hub so that holes line up.
Sparingly oil thread and point of grub screws, or thread and under head of caps screws. Place screws loosely in holes threaded in hub **Fig. 3F**. Clean shaft and fit hub and bush to shaft as one unit.
Using a hexagon wrench tighten screws gradually and alternately until all are tightened to the required torque (see **Torque Settings on pages 38-40 General Section**).
Hammer against large end of bush, using a block or sleeve to prevent damage. (This will ensure that the bush is seated squarely in the bore). Screws will now turn a little more. Repeat this alternate hammering and screw tightening once or twice to achieve maximum grip on the shaft.
If a key is to be fitted use a parallel key that is side fitting with top clearance. After the drive has been running under load for a short time stop and check tightness of screws.
Fill empty holes with grease to exclude dirt.
Check the tightness of the screws after a few hours operation.

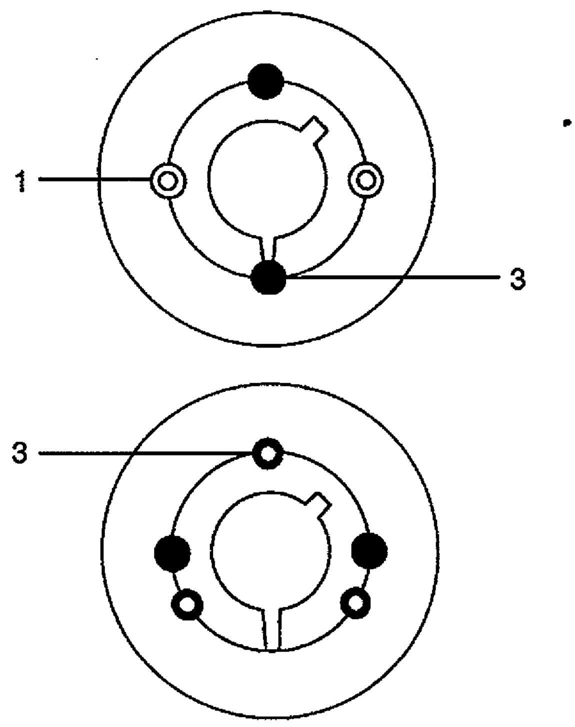



**Fig. 2F**

**Key**
**(Fig. 2F)**
1 Remove locating screws
2 Jacking holes
3 Screw fitting in jacking holes

## MAINTENANCE INSTRUCTIONS (HEAT EXCHANGER) (SEE FIG. 3F EARLY ENGINES)

The heat exchanger need only be removed for cleaning and inspection at a major overhaul, unless it has become blocked or developed a leak.

If the recommended coolant has been used and maintained, there should be no appreciable limescale build up around the water tubes. However, it may be necessary to de-scale the water tubes.

Clean out any limescale by using a suitable de-scaling chemical solution (one which will not attack the cupro-nickel tubes of the heat exchanger (see **page 35**).

Where a proprietary de-scaling agent is used, the manufacturers instructions for its use should be adhered to.

If there is any doubt about water leaks, limescale or carbon build up, replace the tube stack.

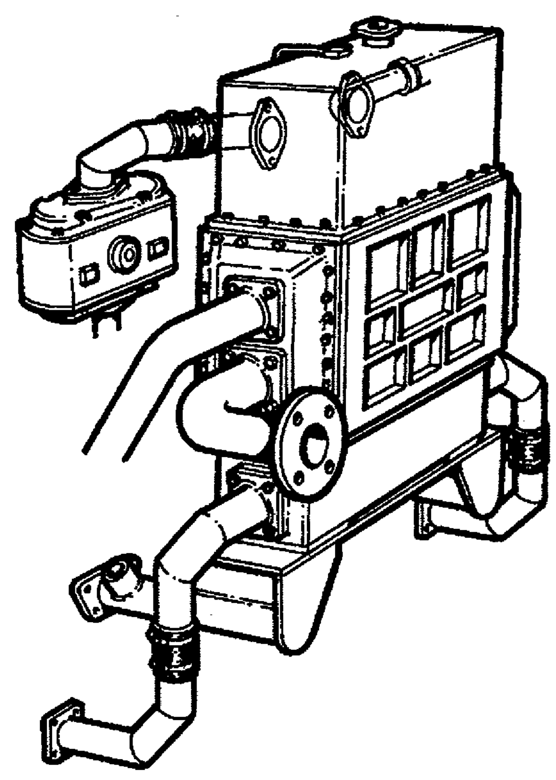


**Fig. 3F** 499.2

## REMOVING THE HEAT EXCHANGER (SEE FIG. 4F)

**WARNING** ⚠ DISCONNECT BATTERIES OR ANY OTHER MEANS OF STARTING THE ENGINE.

To remove that heat exchanger, first remove the filler cap (8) then drain the engine cooling system via a draln plug located at the underside of the engine coolant pump, alternatively a drain plug in the crankcase at the flywheel end under the inlet manifold.

Remove the four nuts and spring washers (9) and (10) in the fresh water inlet branch pipe, also the four nuts and spring washers (11) and (12) in the fresh water outlet branch pipe.

Disconnect the raw water inlet and outlet elbows (17) and the water branch bleed pipe (18).

**WARNING** ⚠ THE NEXT OPERATION MUST BE CARRIED OUT BY TWO SERVICE ENGINEERS. USE THE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT (100 kg).

Remove the two nuts and spring washers (14) and (15) and the two screws and spring washers (14) and (16) fixing the ehat exchanger (1) to the mounting bracket (2). While both service engineers take a firm grip of the unit, carefully lift it away from the engine.

## DISMANTLING FOR CLEANING

Remove the eight cap screws (6) in the heat exchanger end covers (5) and remove and discard the 'O' ring (4). The tube stack (3) is a push fit in the heat exchanger body, and should be an easy job to push out, if the inhibitor content of the cooling system has been maintained. Place oil cooler body vertically with the flange of the tube stack pointing downward. Support the heat exchanger body each side of the flange on blocks of wood, allowing sufficient clearance below the heat exchanger body for the removal of the tube stack. Place a block of wood on the end of the tube stack. The block should cover the entire face of the tube stack, as it has to spread the load evenly. Using another long piece of wood as a drift, very carefully drive the tube stack out of the body, making sure it does not foul the wooden blocks supporting the heat exchanger body.

Wash all components, removing any jointing material from the mating surfaces. Make sure the heat exchanger body and tube stack are clean. De-scale the water tubes as described.

## REASSEMBLING THE HEAT EXCHANGER

Refit the tube stack to the heat exchanger body, having fitted new 'O' rings to end covers. Fit the retaining socket screws tightening them evenly so the covers are pulled squarely to the heat exchanger body.

## REFITTING THE HEAT EXCHANGER

Two service engineers can now lift the heat exchanger up onto the mounting bracket and while both service engineers hold the heat exchanger to support it on the bracket fit the screws, nuts and spring washers and tighten them down fully.

Refit the water branch bleed pipe to the heat exchanger top tank.

Fit new joints to all the mating flanges in the heat exchanger body and refit the inlet and outlet pipes to the body and the raw water pipes to the end covers.

Ensure that the drain plugs are refitted, and refill the engine cooling system with the appropriate solution of water and inhibitor/antifreeze (see **Page 20 In the Operators Handbook**).

Reconnect the batteries or any other means of starting.

## RAW WATER CONNECTIONS

Ensure that these are properly connected before turning on the raw water supply. Bleed any trapped air from the charge coolers (see **Item 11 Fig. 1K**) and from the heat exchanger, by slackening off the top raw water connection. Retighten and check for leaks.

**CAUTION:** Untreated water is not suitable. See **page 21 Operators Handbook** for coolant specifications.

## COOLANT FILLING INSTRUCTIONS

After installation and before the first start remove the radiator heat/exchanger caps, and fill the cooling system. Run the engine off-load for one minute to ensure that the system is completely filled, then stop the engine and top up to within 25mm (1") below the top of the filler neck and replace the cap. Fill top pipe and expansion tank up to level of vent pipe.

Run engine for 1 minute off load, stop engine.

**WARNING** ⚠ TOP PIPE FILLER CAP AND EXPANSION TANK PRESSURE CAP MUST NOT BE INTERCHANGED. DO NOT REMOVE EITHER CAP UNTIL ENGINE IS COLD. HAND PROTECTION MUST BE WORN WHEN FILLING OR DRAINING SYSTEM.

**MAINTENANCE INSTRUCTIONS (HEAT EXCHANGER) (SEE FIG. 4F CURRENT ENGINES)**

The heat exchanger need only be removed for cleaning and inspection at a major overhaul, or if it has become blocked or developed a leak.

If the inhibitor content of the heater exchanger cooling system has been maintained, there should be no appreciable limescale build up around the water tubes, however depending on the source of the raw water it may be necessary to de-scale the water tubes.

Clean out any limescale build up by using a suitable proprietary de-scaling chemical solution, one which will not attack the cupro-nickel tubes of the heat exchanger (see **Operators Handbook page 21**).

Where a proprietary de-scaling agent is used, the manufacturers instructions for its use should be carefully followed.

If there is any doubt about water leaks, limescale or carbon build up, replace the tube stack, as the fitting of a faulty unit will lead to a drop in engine output or engine damage in the case of water leaks or overheating.

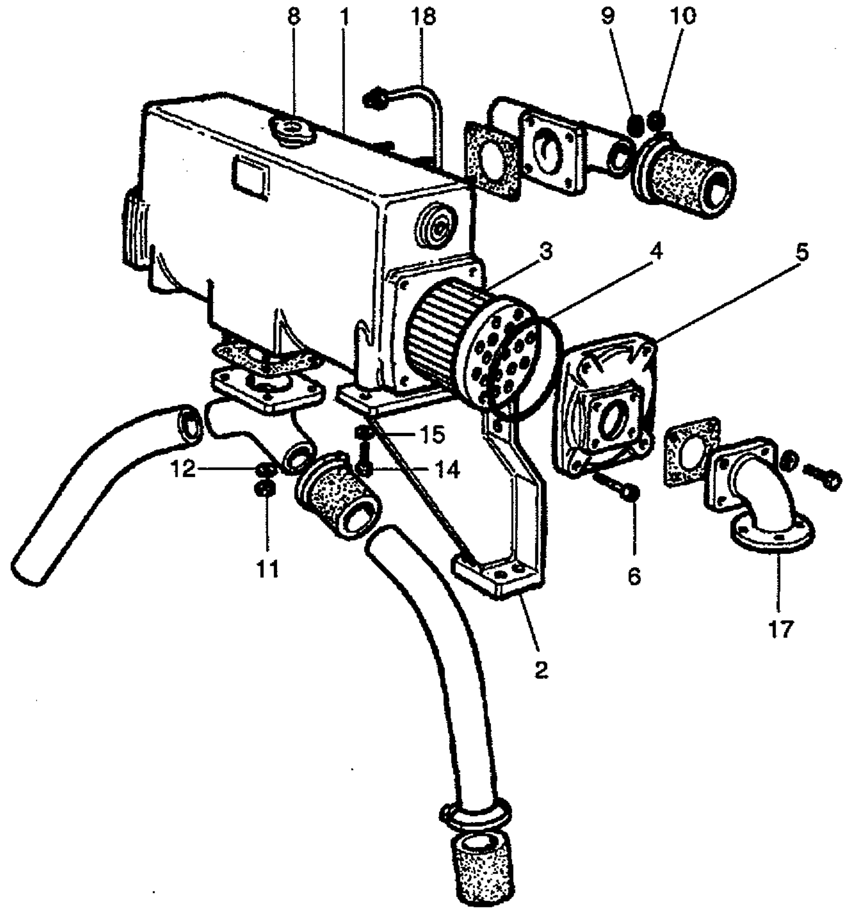



**Fig. 4F**

## DESCRIPTION OF CIRCUIT (SEE OPERATORS HANDBOOK OIL FLOW DIAGRAM)

Lubricating oil is drawn from the engine sump by a lobe rotor pump mounted on the rear of the suspension plate on the 'A' bank side of the engine and driven from the timing gear train. An adjustable relief valve built into the pump controls the system pressure.

On leaving the pump, the supply is split to supply each bank, that for 'A' bank being supplied direct, whilst the supply to 'B' bank is taken via a cross pipe through the sump.

The arrangement of oil cooler, filters and pipe work is similar on both sides of the engine, so the following description refers to one side only.

Oil from the pump is delivered to the oil cooler and then passes to the filter headers, the bearing supply header carrying two filters and the piston jet header one. Oil flows through the three full flow canister type lubricating oil filters which bypass the flow of oil if blocked. They are mounted directly to the filter header.

In the case of engines fitted with change over type filters, which may be remotely mounted, the oil flows from the filter header inlet gallery via pipes to and from the change over filters, returning to the outlet gallery in the filter header; one of the filter connections in the filter header is blanked off.

Oil from the piston jet filter is delivered to a crankcase side gallery running the full length of the engine to supply the piston cooling jets. Each jet directs a spray of oil upwards to a drilling in the piston, connecting with a cast in cooling gallery. After circulating the gallery, oil drains back to the sump via a second drilling in the piston.

Oil from the bearing supply filter header is delivered to a crankcase side gallery running to the front end of the engine, where an angled cross gallery transfers the oil to the main centre gallery. Vertical drillings convey oil from the centre gallery to the main and camshaft bearings. Drillings in the crankshaft and connecting rods convey the oil to the large-end and small-end bearings.

The vertical oilway supplying No. 1 main bearing also supplies oil to a jet lubricating the teeth of the timing gear train. The bearings for the two idler gears in the train are pressure lubricated from the side galleries via grooves in the crankcase end face.

The valve gear is lubricated by a supply piped from each filter header via the top rail connecting the cylinder heads. Oil is piped to each rocker box and conveyed to the rocker shaft via a recess around the fulcrum shaft securing stud, radial drillings in the shaft supplying oil to the rocker lever bearings.

The cam follower assemblies are lubricated by oil piped from the side galleries to jets in each cam follower housing. At the free-end the pipe supplies oil to the governor drive, the oil filling the bottom of the housing to form an oil bath for the governor drive gears.

The turbochargers are supplied with oil from the rear of the central gallery, draining into the crankcase.

**WARNING** THE WEIGHT OF THE PUMP MUST BE SUPPORTED BY A LIFTING SLING FITTED ROUND THE PUMP BODY.

## OIL PUMP, ORIGINAL AND CURRENT SIDE ENTRY TYPES

The oil pump (see **Fig. 1G Original Front Entry Oil Pump** and **2G Current Side Entry Oil Pump**) comprises two cast and machined housings. These are the body (1) and cover (2), in which is carried a drive shaft (3) running in replaceable plain bearings (4). The drive shaft, driven from the timing gears by a spur gear (7) keyed to the shaft, drives the pump rotors (5) and (6), alternator drive pulley, and fuel lift pump through a drive coupling (17). The inner rotor (5) keyed to the shaft by a parallel key (10), has external lobes which mesh with the internal lobes of the outer rotor (6) while turning on an eccentric pitch circle and thus both form the working components of the oil pump. The extended shaft, at the gear end, provides for mounting the alternator drive pulley, which is retained on the shaft by a taperlock bush. The relief valve (See **Fig. 5G**) comprising plunger (25), spring (24) and spring retainer (23) all enclosed within the pump cover (2), has a pressure adjustment screw (20) with locknut (21) incorporated in the retaining flange (19). This allows for adjustment to give the required output pressure from the oil pump. The retaining flange is secured to the pump cover by two screws. Rotor end float is determined by fitting a joint (15) of the correct thickness between the body (2) and pump cover (1).

With the pump shaft turning, oil entering through the lower orifice in the body is sucked into opening gaps between the turning rotor lobes, and carried by the turning rotors to the upper half of the body and pump cover.

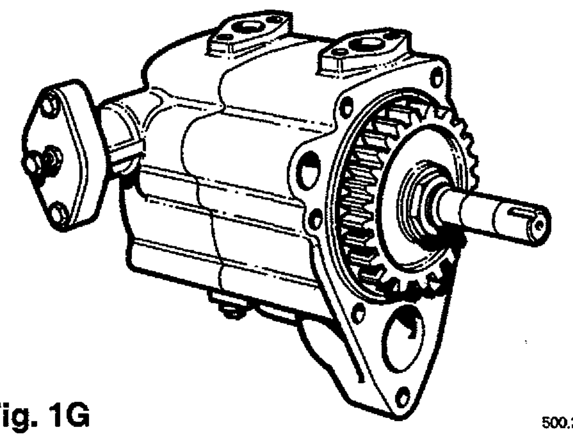


**Fig. 1G** 500.2

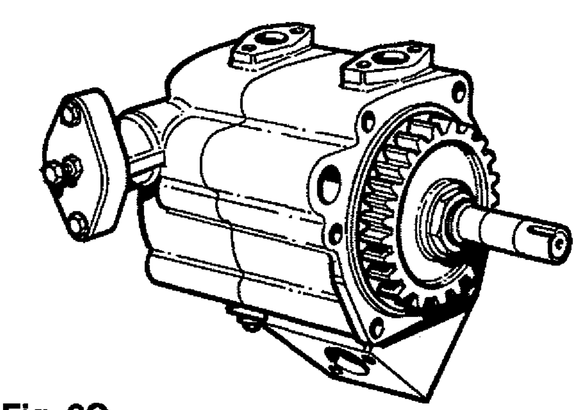


**Fig. 2G** 501.2

As the rotor lobes go deeper into mesh, the oil confined to the upper half of the body and pump cover is pumped out through delivery ports at the top of the body and in the end of the pump cover. Oil from these ports is then delivered via pipes to the oil coolers mounted on each side of the engine. Oil pressure in excess of engine requirements lifts the relief valve plunger and oil is returned to the sump via the timing gear case.

## OIL PUMP REPLACEMENT

In the event of failure or if the engine is undergoing a major overhaul, service exchange oil pumps are normally supplied.

1 Pump body
2 Pump cover
3 Shaft
4 Bearing
5 Inner rotor
6 Outer rotor
7 Pump gear
8 Retaining washer
9 Nut M30 x 2 pitch
10 Parallel key - inner rotor to shaft
11 Woodruff key - gear to shaft
12 Pump drive dog - fuel feed
13 Oil seal carrier
14 Oil seal
15 Joint - pump body to cover
16 Joint - oil pump to suspension plate
17 Pump drive coupling } OLD 4012
18 Spirol pin } OLD 4012
19 Flange
20 Adjusting screw
21 Lock nut
22 Joint
23 Spring retainer and 'O' ring
24 Spring
25 Plunger

**NOTE:** Items 12, 13 and 14 are fitted on the later engines. The 4012TAG/4016TAG engines are fitted with a fuel pump drive coupling as shown in scrap view item 17.

**FRONT ENTRY OIL PUMP ASSEMBLY FIG. 3G**

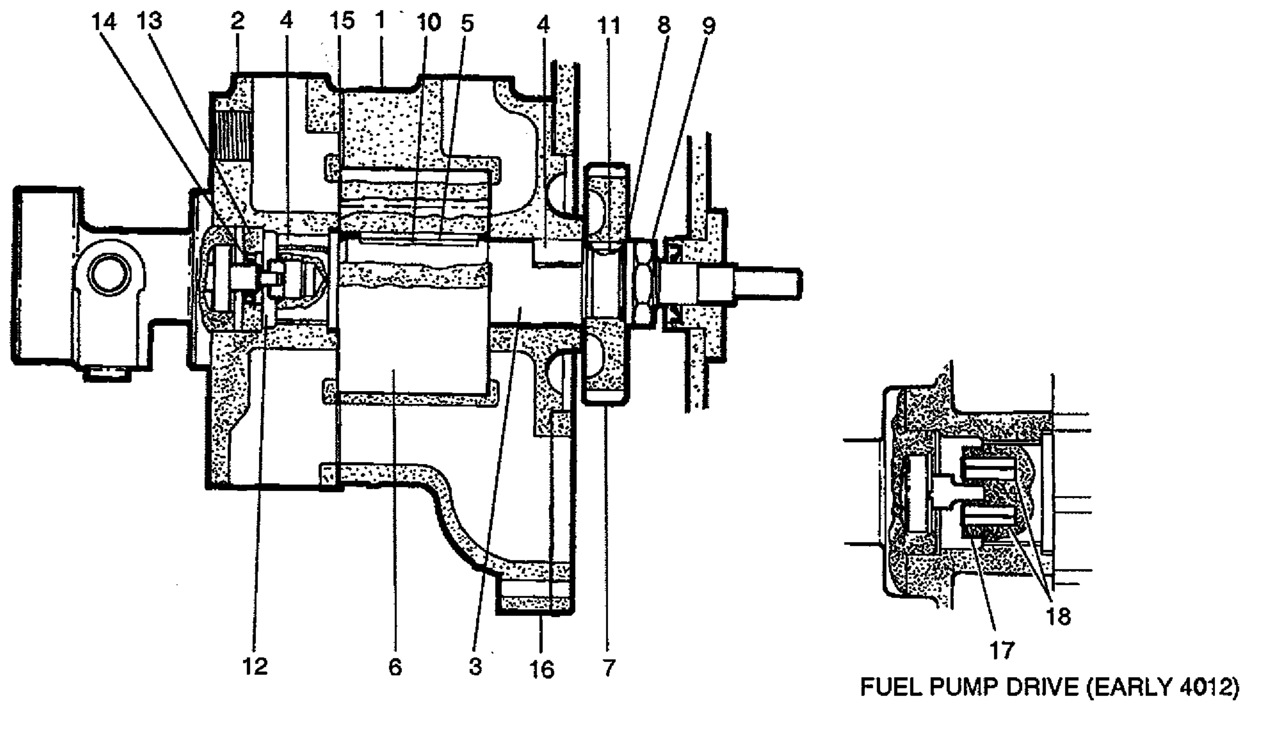



Fig. 3G

## SCRAP VIEW EARLY ENGINES (FIG. 4G)
## OIL PRESSURE RELIEG VALVE (FIG. 5G)
## LATER OIL PUMP ASSEMBLY (FIG. 6G)

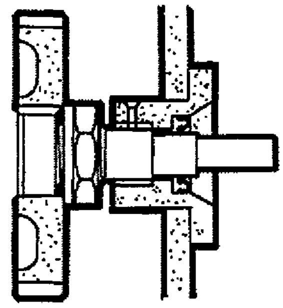


Fig. 4G 504.2

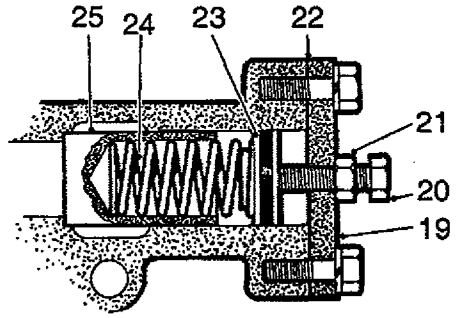



Fig. 5G 62.2

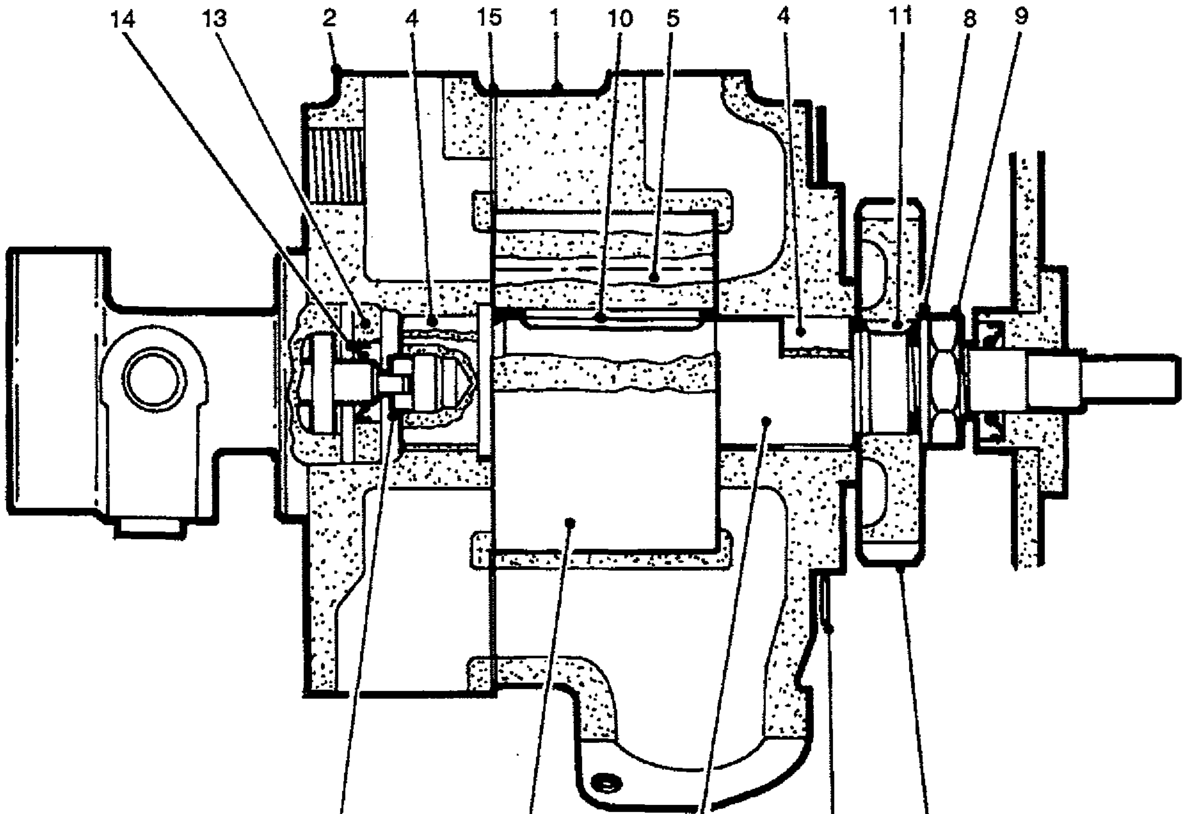



Fig. 6G 739.2

## REMOVING THE OIL PUMP FROM THE ENGINE

> **WARNING** ⚠ DISCONNECT BATTERIES OR ANY OTHER MEANS OF STARTING THE ENGINE.

Turn off the fuel supply to the engine and drain the pipes supplying the fuel lift pump.
Remove the fuel lift pump as described in **Section KK1**.
Remove the alternator and drive as described in **Section B1**.
Using a suitable container to catch the remaining oil, remove the 4 screws and spring washers securing the oil delivery pipe between the oil pump and 'A' bank oil cooler and remove the pipe, together with joints.
Using a suitable container to catch the remaining oil, remove the 4 screws and spring washers securing the oil delivery pipe, between the oil pump and sump cross pipe to 'B' bank oil cooler, and remove the pipe together with joints.
Remove the 6 bolts and spring washers securing the oil pump to the suspension plate and remove the oil pump complete with joint and gear from the engine.
If the pump is being transported or taken away from site for overhaul it is necessary to fit slave bolts and nuts to hold the cover and body together.
Cover the aperture in the suspension plate against the ingress of dirt, etc., while the oil pump is removed.

## TO DISMANTLE

**NOTE:** The working parts of the oil pump are finely machined and work to close limits, therefore only suitably qualified personnel should attempt to overhaul the pumps which should be dismantled as follows:
Remove the slave bolts and nuts. Separate the pump cover (2) together with the joint (15) from the pump body (1) and remove the fuel lift pump drive coupling (17) from the spring dowels (18).
Using a suitable vice with protective grips, grip the gear (7). Using a 46 mm a/f deep socket remove the thin nut (9) securing the gear (7) to the shaft (3). Remove the flat washer (8) and pull the gear (7) off the shaft (3) and Woodruff key (11). Remove the key.
Push the shaft (3) with the inner rotor (5) out of the pump body (1), remove the outer rotor (6) which is free to slide out of the pump body.
Remove the inner rotor (5), which is a push fit, from the shaft (3). Remove the parallel key (10).
Release and remove the 2 screws with spring washers from the relief valve body and remove the relief valve assembly consisting of the flange (19), with adjusting screw (20), locknut (21), joint (22), spring retainer (23), spring (24), and plunger (25).
Remove the screws, spring washers and the lower blank flange, together with its joint.
Do not disturb the bearings (4) unless it is intended to renew them.

## TO INSPECT

All parts should be cleaned and checked against the dimensions quoted in the **Wear and Renewal Limits** (see **pages 41-42**).

Examine the bearing surfaces of the outer rotor for scoring. Blend out any such marks using a fine oil stone.

Examine the lobes of both rotors for ridging, pitting or plucking. Blend out any light score marks. Check the end faces of the rotors for scoring. Blend out any light score marks.

Check the bearings for scoring, these bushes are pre-finished and cannot be reworked; if in doubt as to serviceability renew both bushes.

Examine the pump cover for score marks caused by rotor contact. Blend out light score marks using a flat scraper.

Examine the pump body for score marks caused by rotor contact. Blend out light score marks using fine emery cloth. Heavy score marks in the body due to excessive bearing wear and rotor contact, will require body renewal.

Check that all oilways in the pump body and end cover are clear.

Examine the drive shaft for wear or scoring on the bearing surfaces.

Examine the keys and keyways for wear, renew if worn.

Examine all dowels and dowel holes for fretting and all bolt and screw threads for serviceability.

Renew the oil seal (if fitted).

Examine the fuel lift pump drive coupling and dog for wear. Renew if worn.

Check the clearances between the inner and outer rotors (see **Figs. 7G & 8G**).

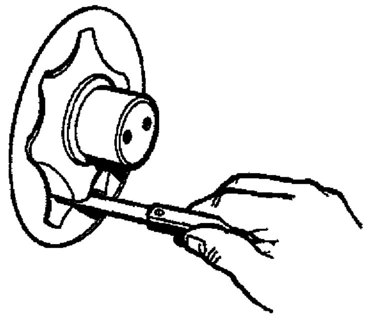


Fig. 7G 578.2

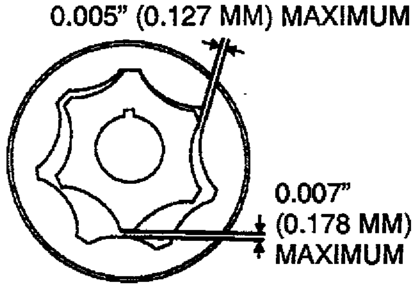



Fig. 8G 64.2

**REPLACING THE FUEL PUMP DRIVE DOG**

It is recommended that a replacement fuel lift pump drive dog is fitted by a Perkins Engines (Stafford) Ltd. agent, since the drive dog must be 'frozen' in liquid nitrogen to reduce its diameter before it is fitted.

**A new fuel pump drive dog must not be fitted to an oil pump assembly; the oil pump must be removed from the engine and the shaft separated from the pump before starting work.**

WARNING ⚠ FAILURE TO FOLLOW THE RECOMMENDED FITTING PRACTICES MAY INVALIDATE THE ENGINE WARRANTY, SINCE IT MAY RESULT IN DAMAGE TO THE OIL PUMP, WITH CONSEQUENT ENGINE DAMAGE.

To remove a fuel pump drive dog (see **Fig. 9G**) the central hole should be carefully tapped M6 and the dog extracted by screwing an M6 setscrew right through the dog until it bottoms, then carry on tightening the setscrew until the dog is pushed up the threads and is free of the shaft.

A new fuel pump drive dog **must** be 'frozen' in liquid nitrogen before being gently tapped into position with a small soft faced hammer (see **Fig. 10G**) until it protrudes by 3mm (see **Fig. 11G**). The use of a 3mm distance piece (e.g. an M20 plain washer) is strongly recommended.

**Key**
**(Fig. 10G)**
1 3 mm distance piece used for location purposes only

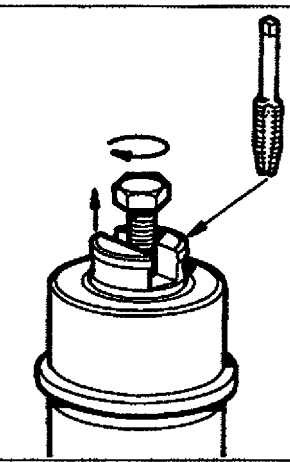


**Fig. 9G** 949.2

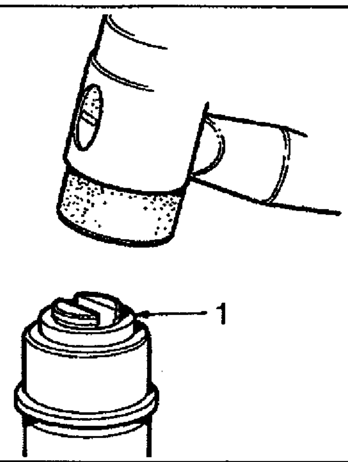



**Fig. 10G** 950.2

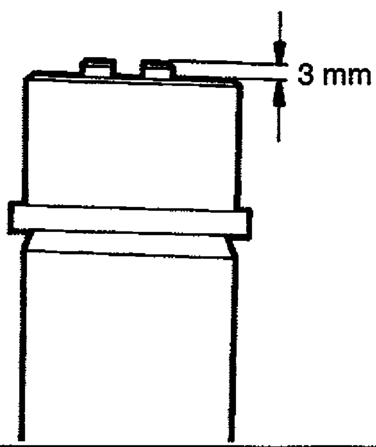



**Fig. 11G** 951.2

## TO ASSEMBLE

The following procedure is based on the assumption that the lubricating oil pump has been completely dismantled. Ensure that all mating faces are clean and free from old jointing, burrs or surface imperfections which may impair sealing or alignment.

If it is found necessary to renew the bearings, press the bush (4) into the pump body (1) ensuring that it is flush with the drive end of the body. The bush is pre-finished and **WILL NOT** require reaming or broaching.

Fit the parallel key (10) to the shaft (3), align the key with the keyway in the inner rotor (5) and slide the rotor onto the shaft until it is against the raised shoulder.

Lightly oil and place the outer rotor (6) with **CHAMFER FIRST** into the pump body (1). Insert the assembled shaft (3) and the inner rotor (5) into the pump body passing the extended end of the drive shaft through the fitted bearing (4), then engage the lobes of the rotors and the shaft in the bush and ease the assembled shaft into the pump body. Force should not be necessary.

**NOTE:** If new rotors are to be fitted, check the following limits with the end faces of the rotors dry and clamped into the pump body:

Using a straight edge across the rotors, check the gap between the rotors and the end face of the pump body with feeler gauges (see **Fig. 12G**).

Check the thickness of the new pump cover joint (15) (see **Fig. 12G** (1))which should be 0.229 mm to 0.254 mm (0.009" to 0.011"). Reject any joints which fall outside this limit. Allow for approximately 0.05 mm to 0.08 mm (0.002" to 0.003") compression of the pump cover joint when the holding bolts are tightened. Calculate the end float of the rotors on the drive shaft to pump body and pump cover see **Fig. 12G** (2), which should be a minimum 0.08 mm (0.003") and a maximum 0.15 mm (0.006") (see **Fig. 12G** (3)).

Remove the outer rotor (6) from the body (1) to avoid dropping and possible damage while fitting and tightening the gear (7).

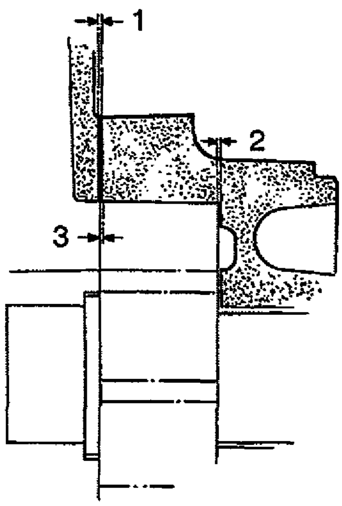



**Fig. 12G** 65.2

Fit the Woodruff key (11) to the shaft (3), align the key with the keyway in the gear (7) and push the gear onto the shaft. Fit the M30 nut (9) and retaining washer (8) with the gear held in a suitable vice (with soft jaws) and using a suitable torque wrench with a 46 mm a/f deep socket tighten the M30 nut to the required torque (See **Torque Settings pages 38-40**).

Lightly oil and refit the outer rotor (6) **CHAMFER FIRST** into the body (1) and engaging the lobes of the inner rotor (5) check that the drive shaft and rotors rotate freely within the body and bush.

Checking for fitted alignment of the oil hole in the bush with the oil hole in the cover, press the bearing (4) into the pump cover (2). This bush is pre-finished and **WILL NOT** require reaming or broaching.

Fit the two spring dowels (18), for the fuel pump drive, to the holes in the end of the drive shaft (3).

Fit the two spring dowels into the pump body (1).

Using a selected pump cover joint (15) and slave bolts and nuts, fit the pump cover (2) to the pump body (1) engaging the dowel holes in the cover with the dowels in the body, and the shaft (3) with the fitted bearing (4). Using a hide mallet, tap the cover gently into place, lightly and evenly tighten the bolts and nuts, checking continually that the pump drive shaft still rotates freely with the required torque applied to the bolts and nuts (see **pages 38-40**).

Using a new joint (22) assemble the relief valve plunger (25), spring (24), retainer (23) and flange (19) to the pump cover. Using screws with spring washers secure the flange (19) to the pump cover.

Screw the adjusting screw (20) with locknut (21) into the flange (19) leaving approximately 12.7 mm (1/2") protruding from the flange to under the head. Adjust and set the final pressure setting on test to 3.8 bar (55 lb/in2) hot.

Using a new joint and screws with spring washers, fit and secure the bottom blank flange.

**FITTING THE OIL PUMP TO THE ENGINE**

Clean the oil pump mating surface on the engine mounting plate making sure no jointing material is left on its surface.

Remove the slave bolts and nuts holding the cover to the pump body.

Using a new joint and bolts, fit the assembled oil pump to the suspension plate, (see **Torque Settings Operators Handbook page 38-40** for bolt torques).

Using a new joint and bolts with spring washers at the pump end, and a new joint, screws with spring washers and a flange with a new 'O' ring at the sump end, fit the oil delivery pipe between the pump cover and the sump cross pipe. Evenly tighten the bolts.

Fit a new oil seal to the seal housing. Using a new joint and screws with spring washers, lubricate the oil seal and shaft, then place the oil seal with housing onto the front-end of the oil pump shaft and engage the spigot of the housing with the bore in the suspension plate.

Check the alignment of the spigot and that the oil seal sits evenly on the shaft, and secure the housing with the screws.

Using two new joints and bolts with spring washers, fit the oil delivery pipe between the oil pump and the oil cooler 'A' bank side.

Fit the fuel lift pump coupling (17) early 4012 engines only, to the drive shaft. Using a new joint, fit the fuel lift pump, and fit the supply and delivery pipes to the fuel lift pump (see **Section KK1**).

**NOTE:** The drive pulley for the alternator is held onto the shaft with a taper lock bush which should be fitted correctly (see **Section B2**).

Refit and tension the alternator drive belt, secure the screws and bolts holding the tensioner and the alternator.

Refit the screws with spring washers and the guards covering the alternator drive.

Prime the lubricating oil system.

Turn on the fuel supply and prime the system (see **Operator's Handbook**).

Re-connect the engine starting system.

## PRIMING THE OIL PUMP AND ADJUSTING OIL PRESSURE

Make sure the sump is filled with the correct grade and quantity of oil. Crank the engine over with the governor control lever in the stop position until a pressure of 0.35 bar/40 kPa (5lb/in²) registers on the oil pressure gauge in the engine's instrument panel. Check the oil pump and its pipes for leaks.

## INITIAL SETTING

Referring to **Fig. 14G**, initially the adjusting screw (20) is set at 17 mm and locked in this position, using locknut (21). The flange (19) is then pulled up to the pump by tightening the fixing screws progressively. Run engine and check that the oil pressure is above 30 lb/in² (2.06 bar) and below 60 lb/in² (4.13 bar).

## FINAL ADJUSTMENT

Run the engine until it is thoroughly warm, (65°C to 75°C water temperature) and check the oil pressure gauge reading at rated speed. It should read 50 lb/in² (3.5 bar). If the figure is above or below this it may be corrected by adjusting the pressure relief valve on the oil pump **Fig. 5G.** Slacken the lock nut on the regulating screw, screw the regulating screw in to increase and out to decrease the pressure.

## SUPPLEMENTARY OIL RELIEF VALVE

An occasional problem with the oil pressure relief valve capacity, due to low ambient temperature operation, has neccesitated the fitting of an additional preset valve screwed into a crankcase inspection cover. This is connected to the oil pipe from the pump to the cooler by a rigid pipe. The valve is entirely automatic in operation see **Fig. 15G.**

**Key**
**(Fig. 13G)**
1 Locknut
2 Adjusting screw
3 Increase oil pressure
4 Decrease oil pressure

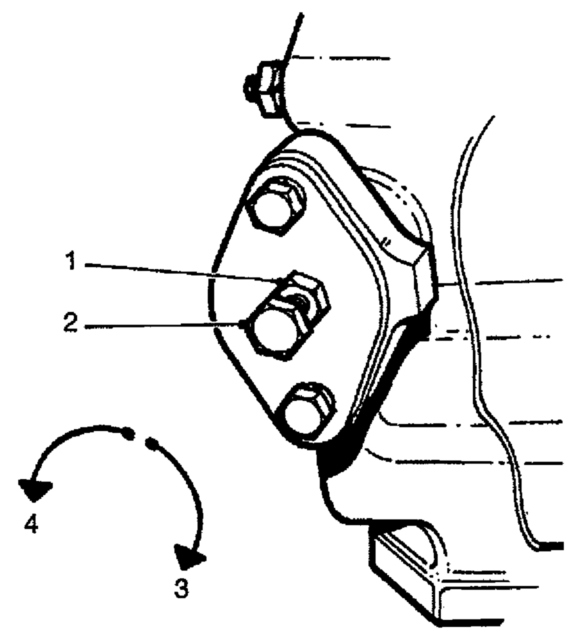



**Fig. 13G** 66.2

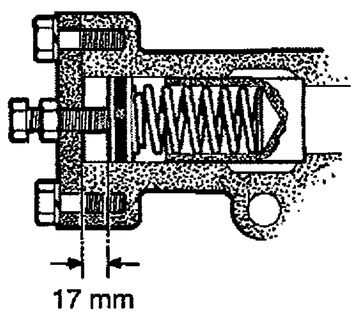



**Fig. 14G** 68.2

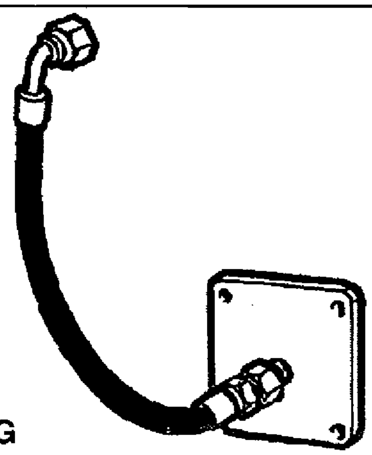


**Fig. 15G** 1072.2

**Caution:** Engine must not be run without thermostats fitted.

**Caution:** Engines intended for use with a remote radiator should be fitted with an external 'Amot' thermostat or similar instead of the standard thermostats described below (see **Installation Manual**).

## DESCRIPTION

To ensure the engine reaches its operating temperature quickly when starting from cold, and that the optimum working temperature is maintained as accurately as possible, the engine is fitted with two thermostat assemblies (1 off per bank) each assembly fitted with two thermostats of the wax element type.

Coolant from the engine enters the thermostat housing from the water rail (9) and whilst the engine is cold is diverted via the bypass pipe (2) back to the water pump.

As the coolant temperature rises, element (3) expands, moving upper disc (4) off its seat and lower disc (5) towards its seat in the housing (6) (see scrap view).

At optimum working temperature, the lower disc (5) is in full contact with its seat, allowing the flow of coolant past the fully open upper disc (4) through the outlet port (7) to the heat exchanger or radiator (see **Fig. 1H**).

A small bleed groove (8) formed in the upper disc (4) equalises the pressure in the circuit, and prevents the formation of air pockets and surge as the upper disc begins to move off its seat.

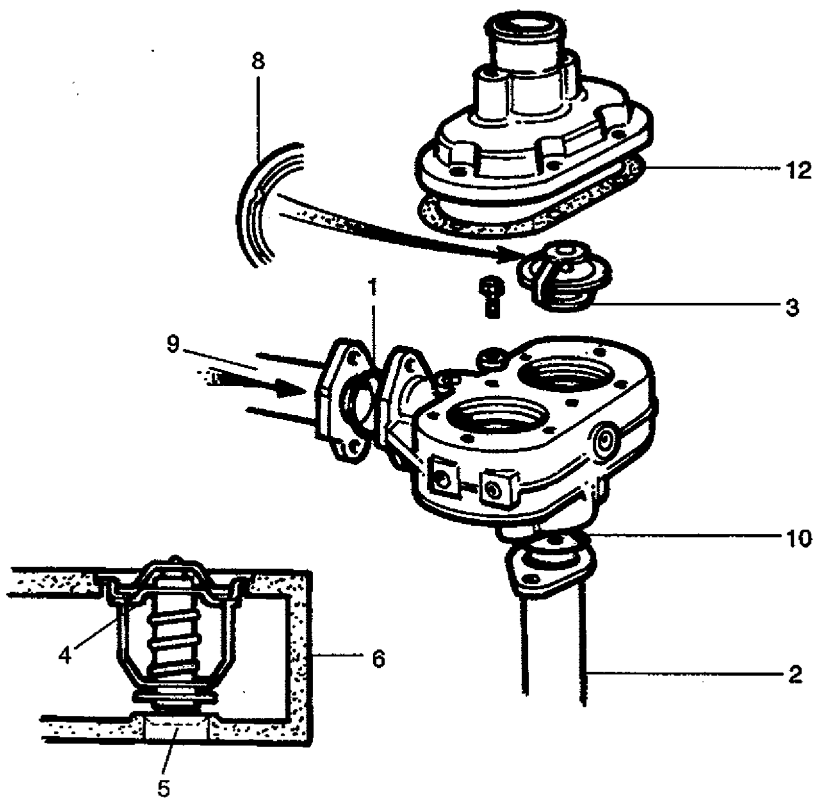



Fig. 1H

**WARNING** ⚠ REMOVING THERMOSTAT ELEMENTS ENSURE COOLING COOLANT IS COLD. HAND PROTECTION MUST BE WORN WHEN DRAINING OR FILLING SYSTEM.

## REMOVING THE THERMOSTAT ELEMENTS

Drain the coolant until the level is below the thermostat housing. Slacken the clips on the hose carrying the water pipe from the thermostat body to the radiator, then carefully remove the water pipe.

Unscrew the six nuts holding the top cover to the thermostat body.

Lift off the cover exposing the two elements in the thermostat body, remove clamping bolts (later models) and carefully prise the thermostat elements from their seats and inspect them for damage.

## CHECKING THERMOSTAT ELEMENT OPERATION

The temperature at which a thermostat element is designed to operate is stamped on its top face. To check its operation heat a quantity of water to the stated temperature allowing sufficient to completely immerse the element.

Having immersed the element it should open almost immediately. Remove the element from the heated water and after a short interval it should close. If an element fails either check, it should be replaced.

## REBUILDING THE THERMOSTAT ASSEMBLY

Clean and check the thermostat housing and cover, then refit the serviceable or new thermostat elements (having checked that the temperature rating is correct), bolts and clamping plates, (later models), new housing with combined top cover and joint (12) and the top, tighten the six nuts diagonally to avoid distorting the housing or covers. Refit the water pipe from the thermostat housing to the radiator and tighten the hose clips.

Slowly refill the cooling system with the approved mix of coolant to the recommended level. Run the engine for a few minutes then stop it and check the coolant level before the engine goes back into full service.

Refer to **page 28** for concentration of anti-freeze, inhibitor, etc.

**NOTE:** Should the complete thermostat assembly have to be removed from the engine to renew the housing (6), when refitting to the water rail (9), a new 'O' ring (1) should be fitted, and a new 'O' ring (10) in the bypass pipe (2).

**WARNING** ⚠ ALWAYS USE CORRECT LIFTING EQUIPMENT WHEN REMOVING A TURBOCHARGER.

## DESCRIPTION

The turbocharger consists of an exhaust gas driven turbine and a radial compressor on a common shaft. The turbine and compressor wheels are mounted at opposite ends of the shaft which is enclosed and supported by a centre housing. The turbine and compressor wheels are enclosed by cast housings attached to the centre housing (see **Fig 0.1J**).
The turbine is made up of a cast turbine wheel (1), wheel shroud (2) and a housing (3) that directs the flow of gas through the turbine. The inlet to the turbine (4) is at the outer diameter of the housing, exhaust gas flowing inward past the blades of the turbine wheel and existing at the centre of the housing.
The centre housing (5) supports the shaft in a pair of fully floating journal bearings (6). Passages drilled in the housing direct oil from the engine lubricating oil system to oil grooves (7) machined in the housing bearing bores. These grooves align with holes in the journal bearings to lubricate and cool the bearing bores and shaft journals. Oil is also directed from the thrust assembly (8) through a passage in the back plate to the thrust bearing. Oil drains from the centre housing by gravity. Seals (9) are installed at each end of the shaft between the journal bearing and the adjacent wheel to prevent lubricating oil entering the compressor and turbine areas.

**Key**
**(Fig. 0.1J)**
**1-9** See **Description**
**10** Compressor outlet
**11** Compressor housing
**12** Compressor wheel
**13** Turbine outlet

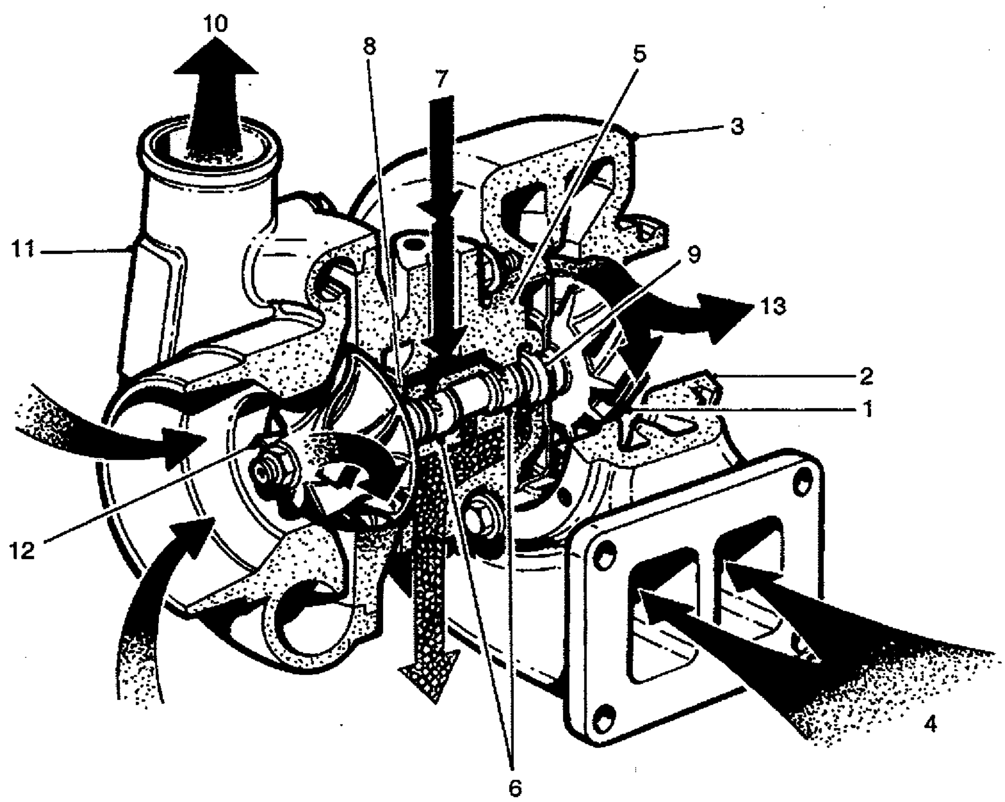


Fig. 0.1J

## PRINCIPLE OF OPERATION

Exhaust gas from the engine passes into the turbine casing where it expands and drives the turbine, which powers the compressor and is then vented to the atmosphere via the exhaust system.

Air for combustion is drawn through the filter, into the compressor which then delivers the mixture to the engine via the charge cooler and or directed to the inlet manifold, maintaining the predetermined boost pressure.

## OPERATION

Turbocharger operation is entirely automatic and no special procedures are required. Do not operate the engine at rated speed/load before normal oil pressure has been established to allow the turbocharger bearings to receive adequate lubrication.

For the initial and normal starting procedures see **Operators Handbook page 28**.

Before engine shut-down, operate the engine at rated speed/no load for **a** few minutes to allow the turbocharger to decelerate and cool down. (See **Operators Handbook pages 33**). Shutting down the engine directly from normal rated speed can cause the turbocharger to continue to rotate after engine oil pressure has dropped to zero, thus damaging the turbocharger bearings.

If the engine has been standing idle for a long period of time, it is essential that the turbocharger is **primed**. (See **Operators Handbook page 23**). Start and run the engine at rated speed/no load for a few minutes to allow the turbocharger bearings to be fully pressurised before increasing to normal rated speed/full load.

In the event of a turbocharger failure or the engine is undergoing a major overhaul it is strongly recommended that service exchange turbochargers is available from Perkins Engines (Stafford) Ltd is fitted.

## REMOVING THE TURBOCHARGERS FITTED ON THE EARLIER 4012TAG, 4012TWG, 4012TEG, 4016TAG, 4016TWG AND 4016TEG ENGINES

Remove the oil feed and return pipes assemblies (1) and (2) from the turbocharger and plug the ends to prevent the ingress of dirt, undo the hose circlips (3) connecting the turbocharger to the air cleaner. Take off the 'V' band clamp (4) holding the turbocharger to the bellows elbow (5), fit a lifting sling on the turbocharger inlet and outlet connections to take the weight of the turbocharger. Remove the 4 bolts, nuts and washers from the turbocharger exhaust elbow (6) and the 2 screws (7) from the tie bracket (8) fixing turbocharger to the air pipe. Remove the 4 straps (11), loosen the clamps (12) and withdraw the air pipe (13) from the engine. Lift the turbocharger off the exhaust elbow (see **Fig. 1J**).

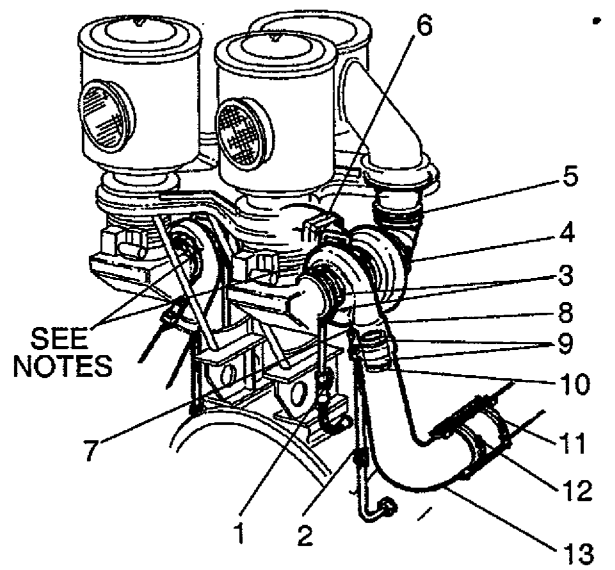



**Fig. 1J**

## REFITTING THE TURBOCHARGERS

Turbochargers operate at very high speeds and are extremely vulnerable to damage by foreign bodies entering the system, or entering the turbocharger from the exhaust manifold. It is therefore essential that great care should be taken to ensure **complete** cleanliness of both the air inlet system and the exhaust manifolds before refitting a turbocharger.

Check that the oil supply and drain are free from blockages. Remove any trace of the old gasket from the turbocharger elbow, then fit a new gasket onto the elbow, making sure that it does not protrude into the gas flow. Lift the turbocharger onto the exhaust elbow, at the same time locating it in the air cleaner hose and exhaust 'V' band clamp. Fit new 'O' rings (9) to the air pipe gland (10).

Schwitzer turbochargers **must** have their 'V' band clamps tightened as follows:-

1. Tighten the 'V' band clamp to 11 Nm (8 lbft) with a torque wrench.
2. Tap the clamp at 3 equi-spaced intervals with a hammer (do not damage the turbocharger housing).
3. Check the tightness with a torque wrench.
4. If the clamp tightens further during step 3, repeat the procedure until no further movement is obtained.

Connect the oil drain pipe and pour one litre of clean engine oil into the oil feed hole. The oil feed pipe should now be connected, but **should be fitted with the special combined joint and strainer (see Illustrated Spares Catalogue) for the first 8 hours of running**, after which it must be replaced with the standard joint.

**NOTE: It is extremely important to fit the special joint / strainer for the first 8 hours of running especially after any work on the engine lubrication system upstream of the turbocharger oil feed.**

## REMOVING THE TURBOCHARGERS FITTED ON THE LATER 4012TAG, 4012TWG/2, 4012TAG1, 4012TAG2 AND 4012TEG/2 ENGINES

Remove the oil feed and drain pipe assemblies (1) and (2) from each turbocharger and plug the ends to prevent the ingress of dirt. Undo the hose clips (3) connecting the turbocharger to the air cleaner. Take off the 'V' band clamp (4) holding the turbocharger to the bellows elbow (5). Fit a lifting sling on the turbocharger inlet and outlet connections to take the weight of the turbocharger. Remove the four bolts, nuts and washers from the turbocharger exhaust elbow (6) and the 2 screws (7) from the tie bracket (8) fixing the turbocharger to the air pipe. Remove the 6 bolts in the air pipe flange. Disconnect the air pipe from the support bracket (11) and withdraw the air pipe (13) from the engine. Lift the turbocharger off the exhaust elbow. Repeat for the second turbocharger. (see **Fig. 2J**).

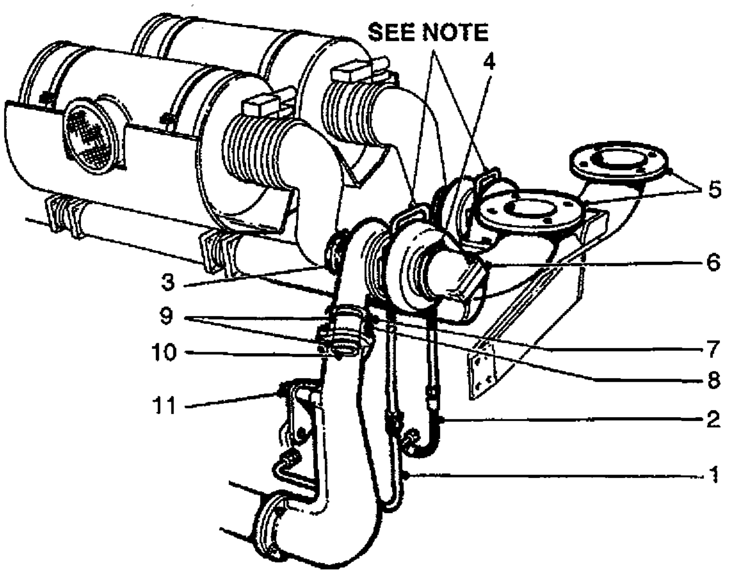



**Fig. 2J**

## REFITTING THE TURBOCHARGERS

Turbochargers operate at very high speeds and are extremely vulnerable to damage by foreign bodies entering the system, or entering the turbocharger from the exhaust manifold. It is therefore essential that great care should be taken to ensure **complete** cleanliness of both the air system and exhaust manifolds before refitting a turbocharger.

Check that the oil supply and drain are free from blockages. Remove any trace of the old gasket from the turbocharger elbow, then fit a new gasket onto the elbow, making sure that it does not protrude into the gas flow. Lift the turbocharger onto the exhaust elbow, at the same time locating it in the air cleaner hose and exhaust 'V' band clamp. Fit new 'O' rings (9) to the air pipe gland (10).

**Schwitzer** turbochargers **must** have their 'V' band clamps tightened as follows:-

1. Tighten the 'V' band clamp to 11 Nm (8 lbft) with a torque wrench.
2. Tap the clamp at 3 equi-spaced intervals with a hammer (do not damage the turbocharger housing).
3. Check the torque with a torque wrench.
4. If the clamp tightens further during step 3, repeat the procedure until no further movement is obtained.

Connect the oil drain pipe and pour one litre of **clean** engine oil into the oil feed hole. The oil feed pipe should now be connected, but **should be fitted with the special combined joint and strainer (see Illustrated Spares Catalogue) for the first 8 hours of running**, after which it must be replaced with the standard joint.

**NOTE: It is extremely important to fit the special joint/strainer for the first 8 hours of running especially after any work has been done on the engine lubrication system upstream of the turbocharger oil feed.**

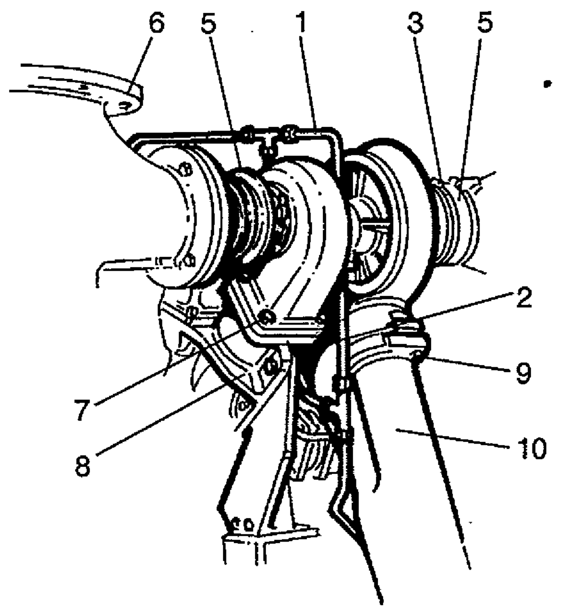



**Fig. 3J** 507.2

## REMOVING THE FOUR TURBOCHARGERS FROM 4016TWG2, 4016TEG2 AND 4016TAG2 ENGINES

Remove the four oil feed pipe assemblies (1) and detach the four oil drain pipes (2) from the turbochargers. Plug all the holes. Remove the eight hose clips (3) and four hoses (4) connecting the turbochargers to the air shut-off valves. Remove the four 'V' band clamps (5) securing the turbochargers to the exhaust elbows (6), and the sixteen nuts and bolts (7) attaching them to the exhaust 'Y' pieces (8). Finally take out the two capscrews (9) securing each turbocharger to the air 'Y' pieces (10) and lift them off one at a time. Cover all holes to prevent anything falling into the inlet or exhaust systems. See **Fig. 3J**.

## REFITTING THE FOUR TURBOCHARGERS

Turbochargers operate at very high speeds and are extremely vulnerable to damage by foreign bodies entering the system, or entering the turbochargers from the exhaust manifold. It is therefore essential that great care should be taken to ensure **complete** cleanliness of both the air system and exhaust manifolds before refitting the turbochargers.

Carefully clean all joint faces, making sure that nothing falls into the pipes. Check that the oil drain systems (2) are not blocked, particularly the flexible sections. Also check that the rectangular exhaust joints do not protrude into the gas flow. Lift each turbocharger in turn, and lower it onto its air 'Y' piece, using two new 'O' rings on the air gland, at the same time inserting a new oil drain joint. Refit the hoses (4) and clips (3) to the air shut-off valves, and the 'V' band clamps (5) onto the exhaust elbows.

**Schwitzer** turbochargers **must** have their 'V' band clamps tightened as follows:-

1 Tighten the 'V' band clamp to 11 Nm (8 lbft) with a torque wrench.
2 Tap the clamp at 3 equi-spaced intervals with a hammer (do not damage the turbocharger housing) see **Fig. 4J**.
3 Check the torque with a torque wrench.
4 If the clamp tightens further during step 3, repeat the procedure until no further movement is obtained.

Fit the capscrews to the air 'Y' pieces, and the nuts and bolts (7) to the exhaust 'Y' pieces (8). Secure the oil drain pipes (2), and pour about one litre of new engine oil into each turbocharger before attaching the oil feed pipes (1), which **should be fitted with the special joint and strainer combined (see Illustrated Spares Catalogue) for the first 8 hours of running**, after which it must be replaced with the standard joint see **Fig. 3J**.

**NOTE: It is extremely important to fit the special joint/strainer for the first 8 hours of running especially after any work on the engine lubrication system upstream of the turbocharger oil feed.**

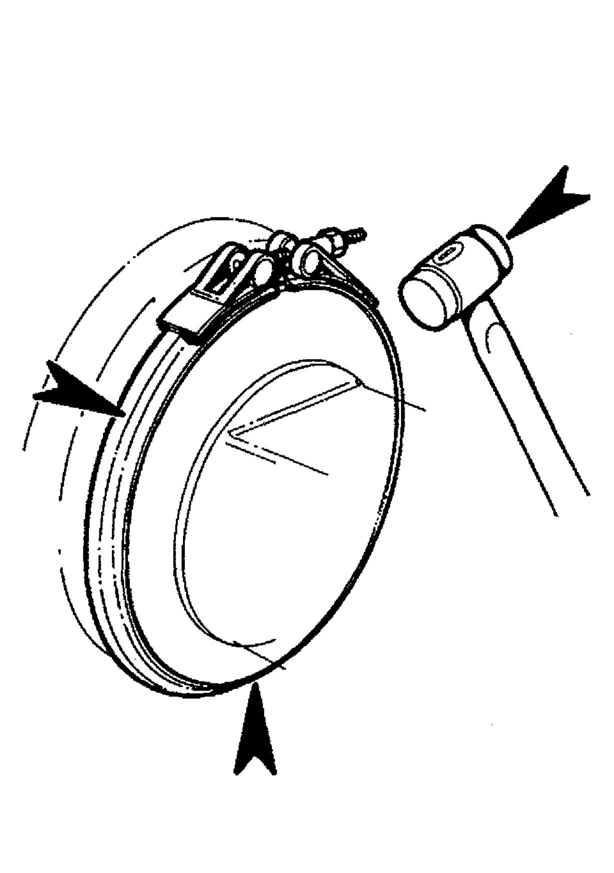


**Fig. 4J** 996.2

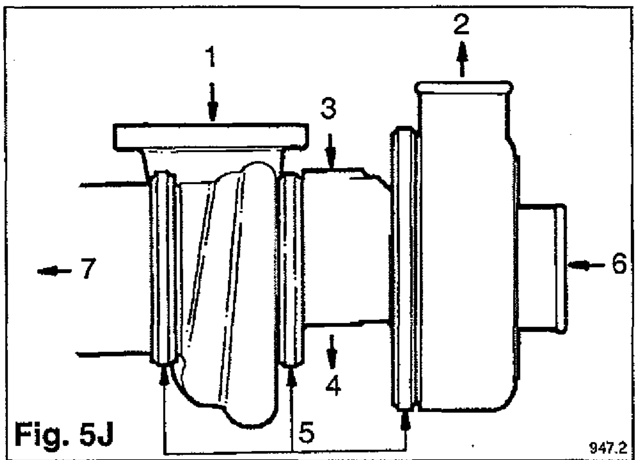



**Fig. 5J** 947.2

**Key**
**(Fig. 5J)**

**1** Exhaust gas in
**2** Air out
**3** Oil feed
**4** Oil drain
**5** 'V' band clamps
**6** Air in
**7** Exhaust gas out

A typical turbocharger arrangement **Fig. 5J**.

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THESE ARE VERY HEAVY UNITS 46.3 kg (102 lb) FOR THE 4012TEG AND 60 kg (132 lb) FOR THE 4016TEG ENGINES. A LIFTING SLING WILL BE REQUIRED FOR THIS OPERATION.

## CHARGE AIR COOLERS AS FITTED ON THE 4012TWG/2, 4012TEG/2, 4016TWG/2, AND 4016TEG/2 ENGINES

### GENERAL DESCRIPTION

Charge air from each turbocharger enters the cooler via an air pipe, where it flows over a tubular matrix, and is cooled by water passing through the tubes, before entering the engine via the inlet manifold. In the case of the 4012TEG/2 and 4016TEG/2 engines, the cooling water is delivered from an engine driven raw water pump and passes from the inlet port through the tubes to the end cover and back via a two pass system to the outlet port and thence to the main heat exchanger. On the 4012TWG/2 and 4016TWG/2 engines, the cooling water is delivered from the engine driven fresh water pumps via the oil coolers and passes from the inlet ports through the tubes to the end covers and back via the two pass system to the outlet ports and thence to the engine water jackets.

**NOTE:** The charge air cooler is a service exchange item. It need only be removed for cleaning and inspection at a major overhaul or if it has developed a water leak. (A leaking charge air cooler must be replaced as its construction makes it difficult to effect a satisfactory repair).

## REMOVING A CHARGE AIR COOLER AS FITTED ON THE 4012TEG AND 4016TEG ENGINES

Drain off the coolant from the charge air cooler system. Remove the water feed (1) and return (2) pipes and joints from the flywheel end of the charge air cooler (5).
Take off the tie bar (9) and slacken off the hose clips (10).

> **WARNING** ⚠ THE NEXT OPERATION MUST BE CARRIED OUT BY TWO SERVICE ENGINEERS.

Take out the four bolts (3) in the air pipe (4) flange and whilst each service engineer supports the combined weight of the charge cooler (5) and bottom air pipe (6), remove the air pipe (4) and joint.

Still taking a firm grip on the unit, remove the capscrews (7) from the charge cooler mating flange to the air manifold (8). Then carefully remove the combined unit of the charge cooler and bottom air pipe. (See **Fig. 1K**). Repeat for the other charge air cooler.

**Key**
**(Fig. 1K)**
**A** View looking in direction of arrow

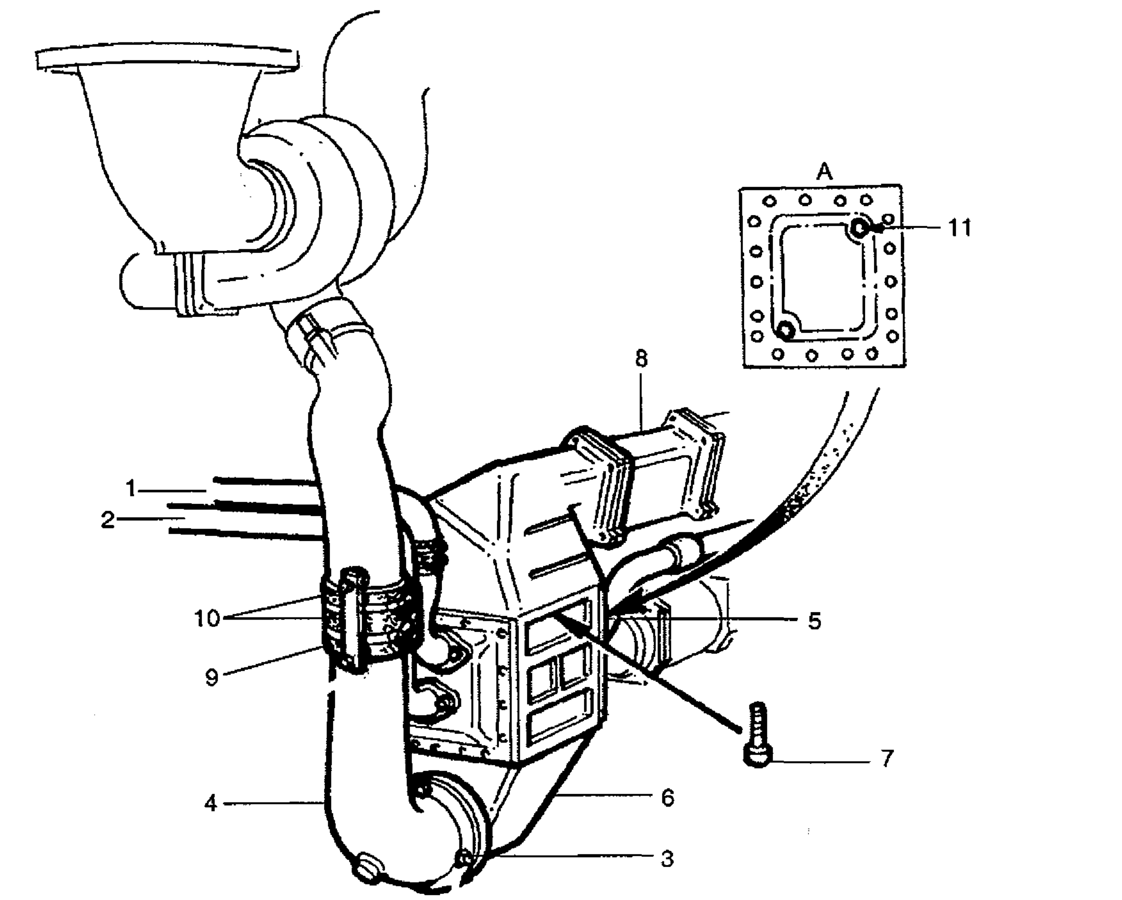



Fig. 1K

**CHARGE AIR COOLERS AS FITTED ON 4012/16TEG2**

Generally carry out the same procedures as for the 4012/16TEG engines mentioned above.

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THESE ARE VERY HEAVY UNITS 46.3 kg (102 lb) FOR THE 4012TEG AND 60 kg (132 lb) FOR THE 4016TEG ENGINES. A LIFTING SLING WILL BE REQUIRED FOR THIS OPERATION.

**REMOVING A CHARGE AIR COOLER AS FITTED ON THE 4012TWG AND 4016TWG ENGINES**

Drain off the coolant from the charge air cooler system, Remove the water feed (1) and return (2) pipes and joints from the front end of the charge air cooler (5).

Take off the tie bar (9) and slacken off the hose clips (10).

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THESE ARE VERY HEAVY UNITS 46.3 kg (102 lb) FOR THE 4012TEG AND 60 kg (132 lb) FOR THE 4016TEG ENGINES. A LIFTING SLING WILL BE REQUIRED FOR THIS OPERATION.

Take out the four bolts (3) in the air pipe (4) flange and whilst each service engineer supports the combined weight of the charge cooler (5) and bottom air pipe (6), remove the air pipe (4) and joint.

Still taking a firm grip of the unit remove the capscrews (7) from the charge cooler mating flange to the air manifold (8), then carefully remove the combined unit of the charge cooler and bottom air pipe. (See **Fig. 2K**). Repeat for the other charge air cooler.

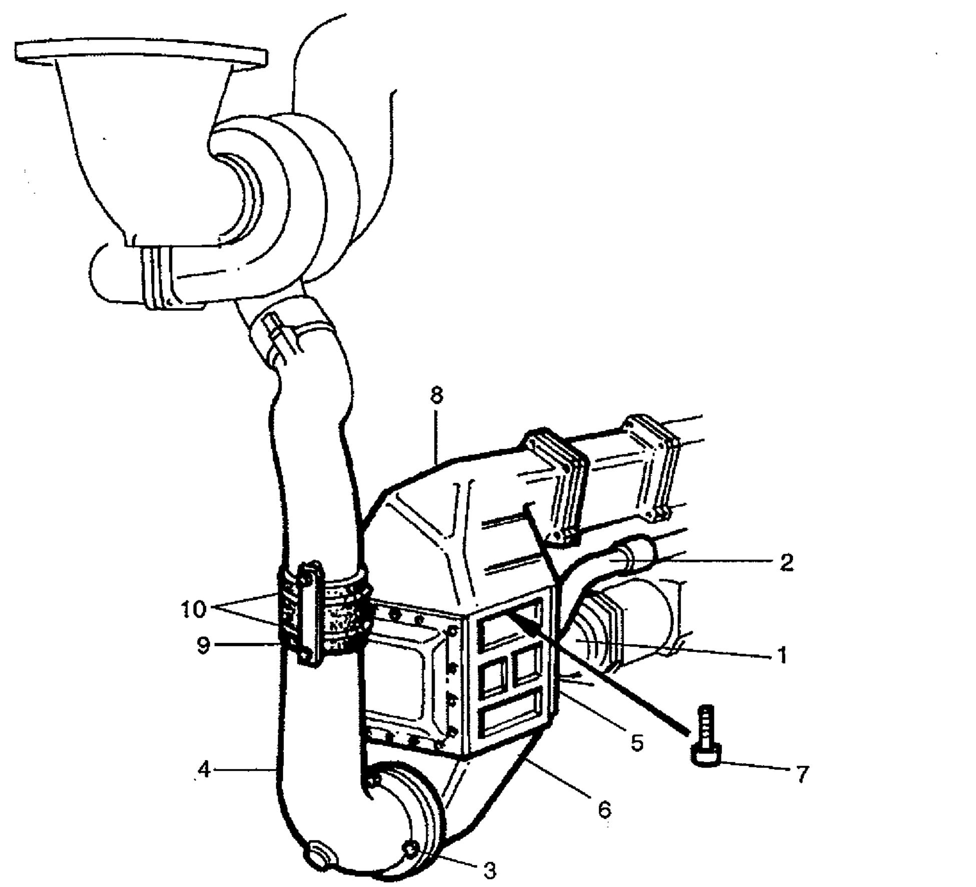



**Fig. 2K**

## DISMANTLING AND CLEANING A CHARGE AIR COOLER

Take out the capscrews holding the bottom air pipe to the charge air cooler. Clean off (using a cleaning agent) any jointing material left on the mating surfaces, but do not remove the end covers of the cooler. If the inhibitor content of the charge air cooling system has been maintained, there should be no appreciable limescale build up in the water tubes. If there is a limescale build, up it must be removed using a proprietary chemical de-scaling solution which will not attack the aluminium body of the charge air cooler. (**see page 35**).

Check the fins on the water tubes for carbon build up, and if any is present wash the fins with kerosene (paraffin) and dry using an air line.

If there is any doubt about water leaks, limescale or carbon build up, replace the charge air cooler, as the refitting of a faulty unit will lead to a drop in engine output, or engine damage in the case of water leaks. Repeat for the other charge air cooler.

## REFITTING THE CHARGE AIR COOLERS

Using new joints for the top and bottom charge air cooler flanges, tighten the retaining capscrews in a sequence that will pull the flanges squarely to each other without distortion. Fit the cooler air pipe assemblies to the engine using new joints and again tightening the retaining bolts in a sequence that will pull the mounting flanges squarely together.

Fit the water feed and return pipes to the charge air coolers using new joints. Refill the charge air cooler radiator with the appropriate mixture of inhibitor/anti-freeze and water. (**see page 28**).

Run the engine on light load for a few minutes, check for water leaks and stop the engine. After filling the charge air cooler water system always bleed any trapped air from the coolers by slackening the small plugs near the top of each charge air cooler (see **item 11, Fig.1K** and **Fig. 2K**) and top up the radiator if necessary. The engine is now ready to resume its duty.

## CHARGE AIR COOLERS AS FITTED ON THE 4012TWG2 AND 4016TWG2

Generally the same procedure as previously mentioned for the 4012TWG and 4016TWG engines will apply, but see the important note on **page 28** regarding antifreeze content for tropical conditions.

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT
AS THIS IS A VERY HEAVY UNIT 30 kg (66 lb). A LIFTING SLING WILL BE REQUIRED FOR THIS OPERATION.

## THE OIL COOLERS AS FITTED TO EARLY ENGINES

### GENERAL DESCRIPTION

The oil cooler need only be removed for cleaning and inspection at major overhaul, or if it has become blocked or has developed a leak.

Service exchange coolers are available from Perkins Engines (Stafford) Limited.

An oil cooler is fitted to each bank of the engine and is attached to and supported by a transfer water pipe which in turn is bolted to the coolant inlet ports on the side of the crankcase.

The oil cooler comprises a tube stack enclosed within a cast aluminium body and sealed by ported end covers with 'O' rings. The covers are dowelled and bolted (see **Fig. 1L**) to the body.

## OIL COOLERS AS FITTED TO SOME EARLIER ENGINES

Lubricating oil is drawn from the engine sump by a lobe rotor pump mounted on the suspension plate on the 'A' bank side of the engine and driven from the gear train. An adjustable relief valve built into the pump controls the system pressure.

On leaving the pump, the oil flow is split to supply each bank, that for the 'A' bank being supplied direct (1), whilst the supply to 'B' bank is taken via a pipe (16) connecting to an internal pipe through the sump walls.

Oil delivered from the pump for 'A' bank flows through the pipe (1) and passes to the inlet port (2) into the front end of the coolant/oil transfer pipe (7). From the coolant/oil transfer pipe the oil enters the cooler body through port (3) circulating the outside of tubes (4) and exits from port (5) to the rear end of the coolant/oil transfer pipe. The oil enters the cover (6) through port (14) and exits from port (8) to the oil filter header (9) and the piston jet filter and gallery connection (10).

Coolant delivered from the water pump, passes from the front end of the coolant/oil transfer pipe to ports (11) in the cover (12), and passing through the tubes (13) to the cover (6) exits from ports into the rear end of the coolant/oil transfer pipe, and thence via the inlet pipes (15) into the water jackets.

The arrangement of the oil cooler, filters and header for 'B' bank is the same as for 'A' bank (see **Fig. 1L**).

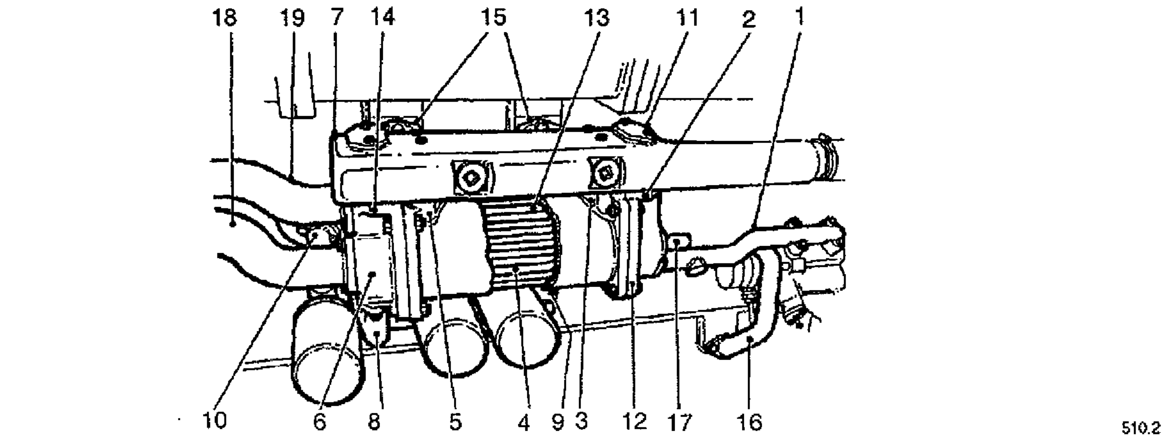


Fig. 1L

## OIL COOLER AS FITTED TO SOME EARLIER 4012TWG AND 4016TWG ENGINES

In the case of the 4012TWG and 4016TWG engines the coolant is divided in cover (6) between the engine and the charge air cooler. Cooling water from the cover (6) passes through the charge air cooler via inlet pipe (18) and outlet pipe (19) into the water transfer pipe and thence into the water jackets.

## REMOVING THE OIL COOLER AND WATER PIPE ASSEMBLY

**WARNING** ⚠ BATTERIES OR ANY OTHER MEANS OF STARTING THE ENGINE.

Unplug the instrument panel from the engine wiring harness, then remove the instrument panel and its brackets.
Drain the cooling system via the drain tap (17). Take off the oil feed pipe from the oil pump to the oil cooler (place a container beneath the cooler to catch the oil spillage).
Take off the pipe between the oil filter header and the oil cooler.
Slacken both pipe clips on the water hose feed pipe to the oil cooler. Take out the bottom two screws from each of the transfer water pipe connections to the crankcase mounting flanges.

**WARNING** ⚠ THE NEXT OPERATION MUST BE CARRIED OUT BY TWO SERVICE ENGINEERS, AS THE COOLER WEIGHS 30 kg OR 66 lb.

Remove the two screws in the top of each mounting flange while each service engineer pushes against the oil cooler to ensure that the water pipe/oil cooler unit stays suspended on its locating dowels whilst taking a firm grip of the unit to fit a lifting sling around it. Carefully pull the unit away from its locating dowels and lift it away from the engine.

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT
AS THIS IS A VERY HEAVY UNIT 30 kg (66 lb). A LIFTING SLING WILL BE REQUIRED FOR THIS OPERATION.

## THE OIL COOLERS AS FITTED TO EARLY ENGINES

## GENERAL DESCRIPTION

The oil cooler need only be removed for cleaning and inspection at major overhaul, or if it has become blocked or has developed a leak.

Service exchange coolers are available from Perkins Engines (Stafford) Limited.

An oil cooler is fitted to each bank of the engine and is attached to and supported by a transfer water pipe which in turn is bolted to the coolant inlet ports on the side of the crankcase.

The oil cooler comprises a tube stack enclosed within a cast aluminium body and sealed by ported end covers with 'O' rings. The covers are dowelled and bolted (see **Fig. 1L**) to the body.

## OIL COOLERS AS FITTED TO SOME EARLIER ENGINES

Lubricating oil is drawn from the engine sump by a lobe rotor pump mounted on the suspension plate on the 'A' bank side of the engine and driven from the gear train. An adjustable relief valve built into the pump controls the system pressure.

On leaving the pump, the oil flow is split to supply each bank, that for the 'A' bank being supplied direct (1), whilst the supply to 'B' bank is taken via a pipe (16) connecting to an internal pipe through the sump walls.

Oil delivered from the pump for 'A' bank flows through the pipe (1) and passes to the inlet port (2) into the front end of the coolant/oil transfer pipe (7). From the coolant/oil transfer pipe the oil enters the cooler body through port (3) circulating the outside of tubes (4) and exits from port (5) to the rear end of the coolant/oil transfer pipe. The oil enters the cover (6) through port (14) and exits from port (8) to the oil filter header (9) and the piston jet filter and gallery connection (10).

Coolant delivered from the water pump, passes from the front end of the coolant/oil transfer pipe to ports (11) in the cover (12), and passing through the tubes (13) to the cover (6) exits from ports into the rear end of the coolant/oil transfer pipe, and thence via the inlet pipes (15) into the water jackets. The arrangement of the oil cooler, filters and header for 'B' bank is the same as for 'A' bank (see **Fig. 1L**).

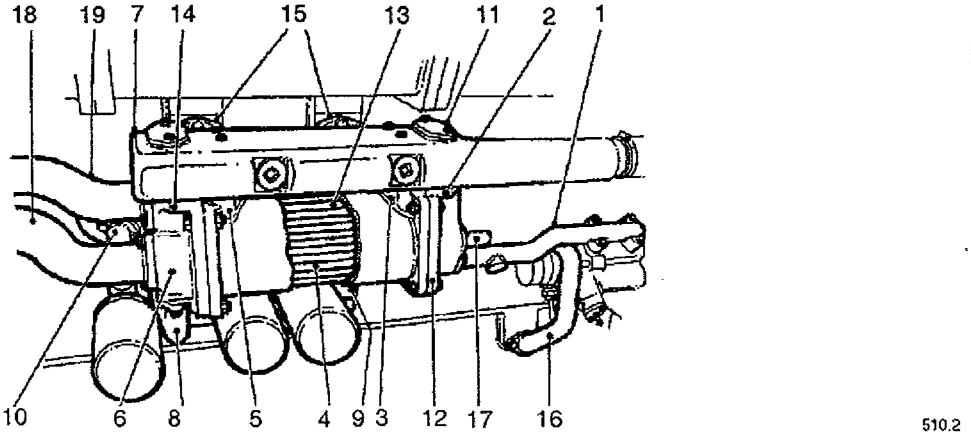



Fig. 1L

## DISMANTLING AND CLEANING

Remove the eight bolts holding the transfer water pipe to the oil cooler. The water pipe will then separate from the cooler, two of the retaining bolts also pass through a blanking plate which will also separate.
Clean all mating surfaces removing any jointing material left on the surface and discard the two 'O' rings. Check the water pipe for corrosion and general damage. Clean out any limescale build up by using a suitable proprietary descaling chemical solution. See **page 35. (NOTE: One which does not attack aluminium).** Remove the four bolts and nuts retaining each end cover on the oil cooler body. A few light blows may be needed with a soft mallet to free the end covers from the dowels locating them in the oil cooler body.
Remove and discard the 'O' rings from both ends of the tube stack. The tube stack is a push fit in the oil cooler body. If the inhibitor content of the cooling system has been maintained it should be an easy job to push it out.
Place the oil cooler body vertically with its mounting flanges supported on blocks of wood (a notch will have to be cut in each block to clear the end cover locating dowels in the mounting flanges).
Place a block of wood on the end of the tube stack, ensuring that the block covers the entire face of the tube stack, as it has to spread the load evenly.
Using another long piece of wood as a drift, very carefully drive the tube stack out of the body, making sure that it does not foul the wooden blocks supporting the oil cooler body.
Initially wash all components in diesel fuel or kerosene removing any build up of dirt and jointing material from the mating surfaces and allow to dry. Make sure that the oil cooler body is clear of oil sludge. Clean the limescale from the inside of the tubes by either using a de-scaling agent **(NOTE: One which does not attack brass)** or if necessary a soft rod.
If the limescale build up is heavy and cannot be satisfactorily removed, the tube stack should be discarded as its heat transferring properties will be adversely affected. This may lead to major engine failure if refitted due to the lubricating oil overheating.

## RE-ASSEMBLING THE OIL COOLER

Refit the tube stack to the oil cooler body and equalise the amount the tube stack flanges protrude. Fit new 'O' rings to each flange and fit the end covers, carefully locating them on their dowels. Fit the retaining nuts and bolts tightening them evenly so the covers are pulled evenly to the oil cooler body.
Refit the transfer water pipe to the oil cooler body using new joints and 'O' rings. Be sure that the 'O' rings are correctly seated before tightening the retaining bolts. Again, tighten the bolts evenly to ensure that the water pipe is pulled squarely to the oil cooler body.

## REFITTING AND OIL COOLER

Fit new joints to the water mounting flanges on the crankcase, locating them on the dowels set in the flanges. A smear of sealing compound may be used to keep them in position.

Two service engineers can now lift (using a lifting sling) the water pipe/oil cooler as a unit onto the crankcase, first fitting the water pipe into the hose on the water pump outlet, then locating the mounting flanges on the dowels set in the crankcase. While both service engineers push against the oil cooler body, fit the retaining screws in the top of the mounting flanges. Do not tighten them down fully. Fit the bottom retaining screws. Now tighten the retaining screws in a sequence that will pull the water pipe/oil cooler unit squarely up to the crankcase.

Fit the oil feed pipe from the oil pump to the oil cooler using new 'O' rings, leaving the retaining screws finger tight until all four are fitted, then tighten the screws evenly to ensure that the pipe fits squarely with the oil pump and cooler.

Refit the oil pipe between the oil filter header and the oil cooler. Use new joints and assemble initially with all bolts finger tight, then tighten them down in a sequence that will pull the pipes squarely to the oil filter header, the oil cooler, and the crankcase.

Tighten the pipe clips on the hose connecting the water pipe to the water pump.

Refit the instrument panel, plugging it into the wiring harness and reconnect the batteries. Tighten the drain tap (17) on both sides of the engine.

Refill the cooling system with the appropriate mixture of water and inhibitor/anti-freeze. (**See page 28**) Check that there is sufficient oil of the correct grade (**See page 26**) in the sump. Set the fuel control lever in the 'stop' position and crank the engine on the starter until oil pressure registers on the gauge, stop cranking and check for water and oil leaks. Top up the sump with oil, start and run the engine on light load for a few minutes, checking again for oil or water leaks, stop the engine and check oil and water levels, topping up accordingly. The engine is now ready to resume its duty.

## OIL COOLER ASSEMBLY AS FITTED ON INTERMEDIATE AND LATER ENGINES (SEE FIG. 2L)

**WARNING** ⚠ USE LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT 27 kg (59.5 lb). A LIFTING SLING WILL BE REQUIRED FOR THIS OPERATION.

The oil cooler is fitted on one side of the engine and is attached to and supported by brackets (14) which in turn are bolted on the side of the crankcase.

The oil cooler comprises a tubestack enclosed within a cast body and sealed by 'O' ring and joints to the ported end covers. The covers are secured by bolts and setscrews and spring washers to the body.

Oil delivered from the engine driven lubricating oil pump enters via a flexible pipe into the inlet port (A) and the cooler body (2) circulating the outside of tubes (3) and exits from the outlet port (B) to the oil pipe and relief valve into the lubricating oil filters and the engine main oil gallery.

Coolant delivered from the engine driven water pump passes from the outlet pipe into the inlet port (C) and the end cover (8) and exits from the outlet port (D) to the water transfer pipe and into the engine water jacket.

**Key (Fig. 2L)**

**1** Oil cooler assembly
**2** Body
**3** Tube stack
**4** 'O' Ring
**5** End cover
**6** Joint
**7** Joint
**8** End cover
**9** Double turn spring washer
**10** Setscrew
**11** Bolt
**12** Bolt
**13** Setscrew
**14** Bracket LH
**15** Bracket RH
**16** Setscrew
**17** Spring washer
**18** Spirol pin dowel
**19** 'O' Ring

**OIL COOLERS AS FITTED TO INTERMEDIATE ENGINES (SEE FIG. 3L)**
Lubricating oil is drawn from the engine sump by a lobe rotor pump mounted on the suspension plate on the 'A' bank side of the engine and driven from the gear train. An adjustable relief valve built into the pump controls the system pressure. On leaving the pump the oil flow is split to supply each bank, that for the 'A' bank being supplied direct, whilst the supply to the 'B' bank is taken via a pipe (18) and an internal pipe through the sump walls.
Oil delivered from the pump enters the inlet pipe (1) and passes through the block (2) into the cooler body, circulating over the outside of the tubes (3) and exits from pipe (4) to the tee connection (5) where the oil flow is divided between oil filter header (6) and the piston jet gallery connection (7).
Coolant delivered from the water pump passes via the water pipe (8) into the inlet port (9) and the front end cover (10) passing through the tubes (11) to the rear end cover (12) and back via the two pass system to the front cover (10) and exits from the outlet port (13) to the water transfer pipe (14) and thence to the inlet ports (15) into the water jackets.
The arrangement of the oil cooler, filters and header block for 'B' bank is the same as the 'A' bank (see **Fig. 3L**).

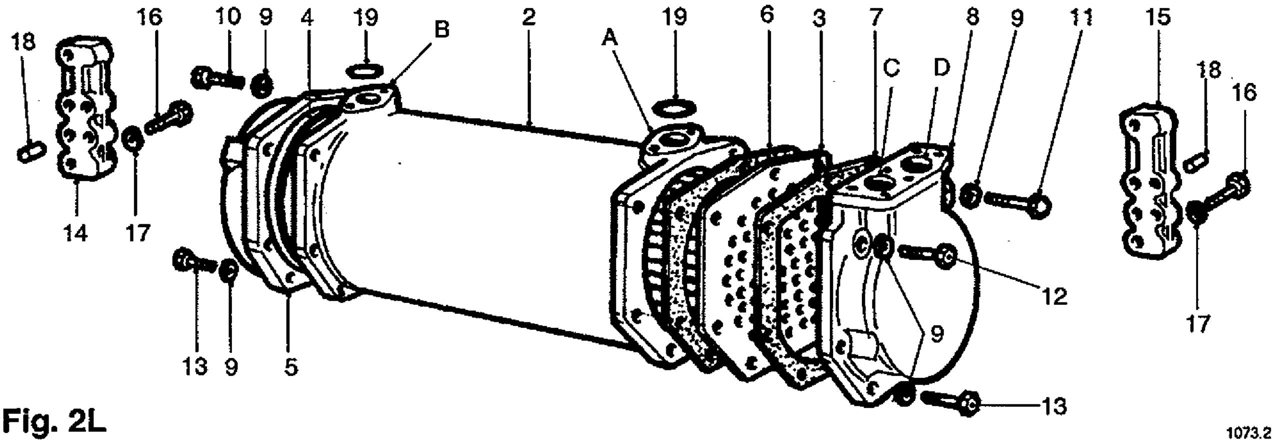


**Fig. 2L**

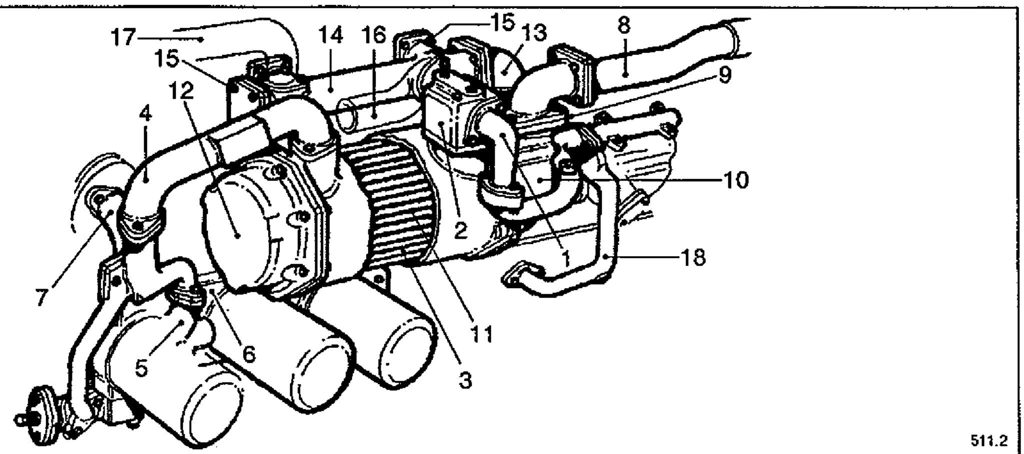


**Fig. 3L**

## OIL COOLERS AS FITTED TO 'A' BANK (LATER ENGINES ONLY)

Lubricating oil is drawn from the engine sump by a lobe rotor pump mounted on the suspension plate on the 'A' bank side of the engine and driven from the gear train. An adjustable relief valve built into the pump, together with a supplementary pre-set relief valve mounted on one of the crankcase doors, control the oil system pressure. On leaving the pump the oil flow is split to supply each bank, that for the 'A' bank being supplied direct, whilst the supply to the 'B' bank is taken via a cross pipe through the sump. **See Fig. 4L.**

Oil delivered from the pump through the main flexible pipe (1) passes through the inlet body (2) which has a smaller flexible pipe (16) running to a pre-set relief valve (17) mounted on a crankcase door, relieving into the sump. The bearing oil supply passes into the cooler body, circulating the outside of the tubes (3) and exits through the pipe (4) to the tee connection (5) where the oil flow is divided between oil filter header (6) and the piston jet gallery (7).

Coolant delivered from the water pump passes through the water pipe (8) and the elbow (9) into the front end cover (10) passing through the tubes (3) to the rear end cover (12) and back via a two pass system to the front end cover (10) and exits from the outlet elbow(13) to the water transfer pipe (14) and thence to the inlet ports (15) into the water jacket of the cylinder block.

The arrangement of the oil cooler, filters and headers for 'B' bank is similar to that shown for 'A' bank in **Fig. 4L.**

## OIL COOLERS FITTED ON THE 4012TWG2 AND 4016TWG2 ENGINES (SEE FIG. 3L & 4L)

In the case of the 4012TWG2 engine the coolant after the oil cooler is diverted via outlet port (13) and water pipe (16) to the charge air cooler. The cooling water passes through the charge air cooler and outlet pipe (17) and thence into the inlet ports (15) and the water jackets.

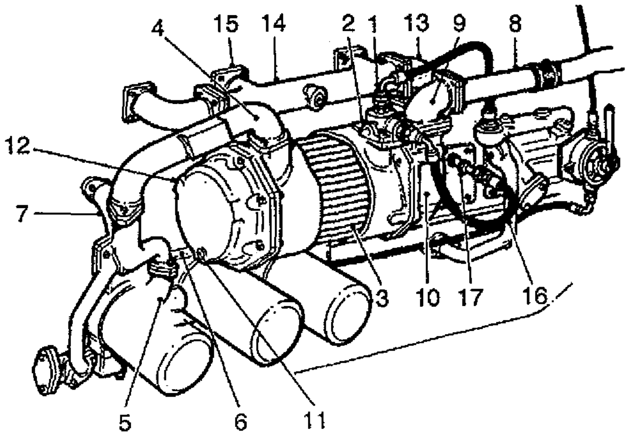



**Fig. 4L**

## REMOVING THE OIL COOLER, WATER AND OIL PIPES

**WARNING** ⚠ BATTERIES OR ANY OTHER MEANS OF STARTING THE ENGINE.

Unplug the instrument panel from the engine wiring harness, then remove the instrument panel and its brackets.
**Drain the cooling system, via the drain plugs (11) in the ends of the oil coolers (see Fig. 4L).**

**Removing the oil pipes (intermediate engines)**
Take out the two screws in the flange of the middle section of the oil feed pipe fitted at the oil cooler end (place a container beneath the oil cooler to catch any oil spillage), and the two bolts in the pipe flange fitted at the oil pump end and remove the pipe. Take out the two screws from the oil cooler outlet flange and the two bolts in the flange of the oil filter header and remove the oil pipe.
Slacken both pipe clips on the water hose, and take out the four screws in the flange of the water pipe from the water pump to the oil cooler and remove the water pipe. Take out the eight screws in the flanges of the water pipe from the oil cooler to the crankcase and remove the water pipe.
Slacken the four setscrews fixing the oil cooler support brackets to the crankcase.

**Removing the oil pipes (later engines) (see Fig. 4L)**
Remove the flexible pipe (1) between oil pump and oil cooler and the second flexible pipe (16) between the oil cooler and the relief valve (17) mounted on the crankcase door. Take out the two capscrews and remove the inlet body (2). Remove the stub pipe and relief valve (17) from the crankcase door.

**WARNING** ⚠ THE NEXT OPERATION MUST BE CARRIED OUT BY TWO SERVICE ENGINEERS AS THE OIL COOLER WEIGHS 27 kg OR 60 lb.

The service engineers should take a firm grip of the oil cooler unit and fit a lifting sling around it. Both men should push against the unit whilst removing the four screws from the support brackets and then together carefully pull it away from its locating dowels to lift it away from the engine.

## DISMANTLING AND CLEANING

Clean all surfaces, removing any old jointing material, and discard the two 'O' rings. Check the water pipes for corrosion and general damage. Clean out any limescale build up by using a suitable proprietary descaling solution. **See page 35. (NOTE: One which does not attack aluminium).**

Remove the seven bolts retaining each end cover to the oil cooler body. A few light blows may be needed with a hide mallet to free the end covers from the oil cooler body. Remove and discard the 'O' ring and joints from the ends of the tube stack. The tube stack is a push fit in the oil cooler body.

Place the oil cooler body vertically with the flange of the tube stack mounted downward. Support the oil cooler body underneath the upper mating flange on blocks of wood, allowing sufficient clearance below the oil cooler body for the removal of the tube stack. Place a block of wood on the end of the tube stack. The block should cover the entire face of the tube stack, as it has to spread the load evenly. Using another long piece of wood as a drift, very carefully push the tube stack out of the body making sure it does not foul the wooden blocks supporting the oil cooler body.

Wash all components, removing any jointing material. Make sure that the oil cooler body is clear of oil sludge. Clean the limescale from the inside of the tubes by either using a de-scaling agent, **(NOTE: One which does not attack brass)** or if necessary a soft rod.

**Caution:** If the limescale build up is heavy and cannot be satisfactorily removed, the tube stack should be discarded, if refitted this may lead to the lubricating oil overheating and major engine failure.

## RE-ASSEMBLING THE OIL COOLER

Refit the tube stack to the oil cooler body, having fitted a new joint between the flange of the tube stack and oil cooler body. Fit a new 'O' ring to the rear end cover (12) and a new joint between the front end cover (10) and the flange of the tube stack. Fit the retaining bolts and spring washers, tightening them evenly so that the covers are pulled squarely up to the oil cooler body.

**REFITTING THE OIL COOLER**

Using a lifting sling, two service engineers can now lift the oil cooler unit complete with support bracket up to the crankcase, locating the brackets on the dowels set in the crankcase. While both service engineers push against the oil cooler body, fit the four retaining screws and tighten them down fully.

Refit the middle section of the oil feed pipe from the oil pump to the oil cooler inlet flange, using new joints between the flanges.

**Refitting the oil pipes (earlier engines) (See Fig. 1L)**

Refit the oil pipe (8) from the cooler outlet flange to the filter header (9) using new joints between the flanges on the cooler body and the filter header, on both 'A' and 'B' banks.

**Refitting the oil pipes ('A' bank, later engines) (See Fig. 4L)**

Apply a thin layer of grease to a new 'O' ring and fit it into the counterbore in the inlet body (2). Carefully replace the inlet body (2), tightening the two capscrews alternately with an Allen key. Apply Loctite 542 Hydraulic Seal to the threads of the relief valve (17) and fit it to the crankcase door. Fit the stub pipe to the relief valve and then the flexible pipe (16) between the stub pipe and the inlet body (2). The flexible main oil feed pipe (1) should then be fitted between the oil pump and the inlet body.

**Refitting the water pipes (See Fig. 4L)**

Using a new joint refit the water pipe (8) and elbow (9) from the water pump to the oil cooler inlet flange. Tighten the pipe clips on the hose connecting the water pipe (8) to the water pump. Refit the elbow (13) and the water pipe (14) from the oil cooler outlet flange to the crankcase, using new joints.

Reconnect the batteries, refit the instrument panel, plugging it into the wiring harness. Refit the drain plugs (11) in the ends of the oil coolers.

Refill the cooling system with the appropriate mixture of water and inhibitor/anti-freeze **(See pages 41-42)**. Check that there is sufficient oil of the correct grade **(See page 26)** in the sump. Set the fuel control lever in the 'stop' position and crank the engine on the starter until oil pressure registers on the gauge. Stop cranking and check for water and oil leaks. Top up the sump with oil and run the engine on light load for a few minutes, checking again for oil and water leaks. Stop the engine and check oil and water levels, topping up accordingly.

The engine is now ready to resume its duty.

**WARNING** ⚠ NEVER CHANGE STANDARD LUBRICATING OIL FILTERS WITH THE ENGINE RUNNING. ALWAYS WEAR PROTECTIVE GLOVES.

## GENERAL DESCRIPTION

The six lubricating oil filters fitted on these engines are of the disposable canister type, fitted with by-pass valves and screwed onto a header mounted on each side of the crankcase (i.e. two filters for the bearing supply and one filter for the piston cooling spray oil).

All the filters are of the full-flow type, meaning that all the oil in the system passes through them.

There is a by pass valve which opens if the filter is allowed to become blocked.

The oil enters the filter header after passing through the cooler at the inlet flange connection (1) into a common inlet gallery (2). From the inlet gallery the oil flows via outlet slots (3) and holes in the top of each canister, to the outside of each element, through the paper filter medium, into the centre of each unit, and out through the central connection to a common outlet gallery (4). From this outlet gallery of the main header the oil flows via the inlet connection (5) into the crankcase side gallery, and via a pipe (6) to the cylinder head valve gear. Also oil flows from the single filter header (7) to the piston cooling jet oil gallery (see **Fig. 1M**).

From the crankcase side gallery on each side of the engine, the oil is transferred via angled cross drillings to the central oil gallery. Vertical drillings convey oil from this central gallery to the main and camshaft bearings. Further drillings in the crankshaft and connecting rods convey the oil to the large end and small end bearings. Oil from the piston spray gallery, running the length of the engine, supplies the piston cooling jets. Each jet directs a stream of oil upwards to a drilling in the piston, feeding a gallery cast in the piston. After circulating this cooling gallery, the oil drains back to the sump via a second drilling.

The vertical oilway supplying No.1 main bearing also supplies oil to a jet lubricating the teeth of the timing gear train. The bearings for the two idler gears in the train are pressure lubricated from the side galleries via grooves in the crankcase end face. The cylinder head valve gear is lubricated by a supply piped from the side galleries. Oil is piped to each rocker box and is conveyed to the rocker shaft via a recess around the fulcrum shaft securing stud, radial drillings in the shaft supplying oil to the rocker lever bearings. The cam follower assemblies are lubricated by oil piped from the side galleries to jets in each cam follower housing. At the front end the pipe supplies oil to the governor drive housing, the oil filling the bottom of the housing to form an oil bath for the governor drive gears.

The turbochargers are supplied with oil piped from the rear end of the main central gallery and it then drains by gravity back to the crankcase.

## OIL FILTERS AND HEADERS

As the dirt particles are deposited on the paper element, the resistance to flow increases. Once this resistance creates a certain pressure (1.6 to 2.5 bar), the filter by-pass valve opens and allows unfiltered oil to pass to the bearings. if the service intervals are neglected then all the filters will eventually become blocked and the oil supply to the lubricating oil gallery will be unfiltered oil, resulting in an increase in the rate of wear and engine damage.

## CHANGING THE OIL AND FILTERS (SEE PAGE 50 IN THE OPERATORS HANDBOOK)

## THE OIL FILTER HEADERS

The oil filter headers need only be removed at a major overhaul to facilitate the cleaning of the crankcase oil galleries.

**Key**
**(Fig. 1M)**

- **A** To rocker box
- **B** Fuel
- **C** Oil

## REMOVING AN OIL FILTER HEADER

Remove all three oil filters and the two bolts holding the oil cooler feed pipe to the header. Then take out the setscrews holding the filter header to the crankcase. (If the oil cooler is still fitted oil in the tube stack will drain from the cooler feed pipe when the header is removed. Catch this oil in a suitable container).

**WARNING** ⚠ ALWAYS WEAR EYE PROTECTION WHEN USING COMPRESSED AIR.

## CLEANING AND REFITTING THE OIL FILTER HEADER

Remove any jointing material from the oil filter header and the crankcase, wash the header, and blow out the oil galleries with compressed air. Refit the oil filter header to the crankcase using a new joint. Tighten the retaining setscrews in a sequence that will pull the header squarely up to the crankcase.

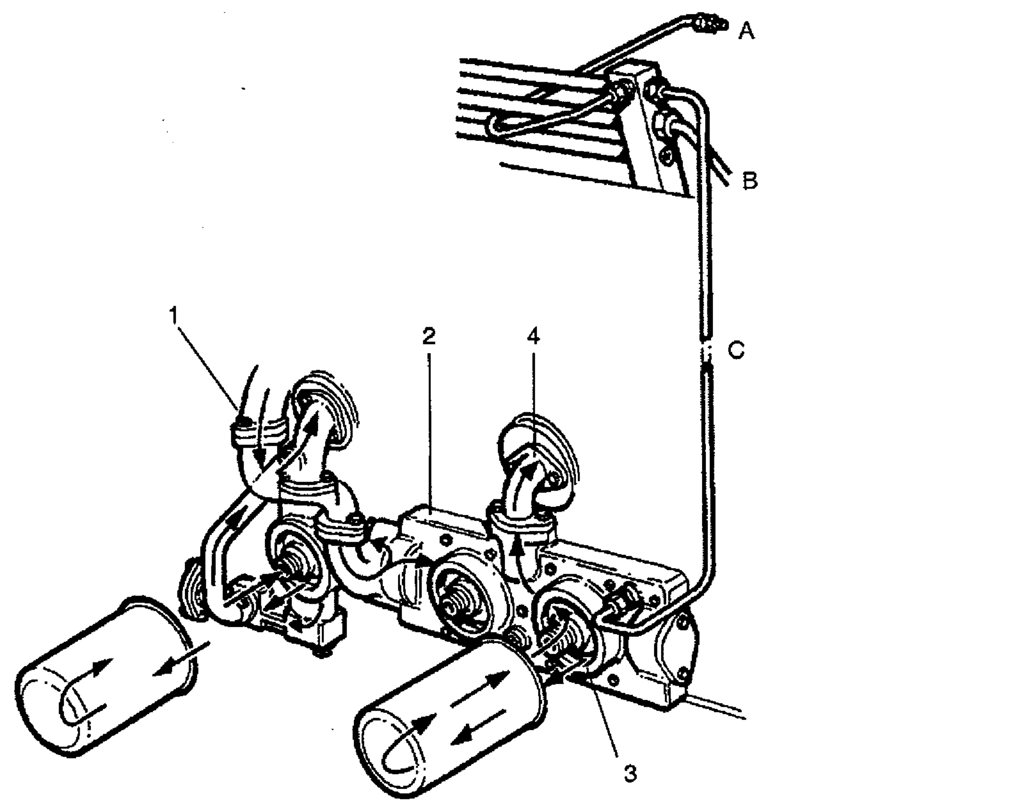



**Fig. 1M**

**WARNING** ⚠ REDUCE ENGINE SPEED TO IDLING IF CHANGING THE FILTERS WHILST THE ENGINE IS RUNNING.

**DESCRIPTION**
These special duplex filters are intended for use on long running engines, when it may be impractical to stop the engine. For this reason they are fitted with a three way change-over valve in the head, which enables the elements to be changed one at a time, whilst the engine continues to run. **(This does not apply to the piston cooling jet filters).**
**Caution:** If the flexible connections to the filter are removed for any reason, it is essential that they are reconnected correctly. See **Fig. 3M & 4M.**

**Key (Fig. 2M)**
1 Change right filter
2 Normal running position
3 Change left filter
4 Both filters in circuit

**WARNING** ⚠ DISCONNECT BATTERIES OR ANY OTHER MEANS OF STARTING. ALWAYS WEAR PROTECTIVE GLOVES.

**CHANGING THE FILTER ELEMENTS WHEN THE ENGINE IS STOPPED (INCLUDING PISTON JET FILTERS).**
All that is necessary is to unscrew the canisters with a strap wrench, as shown in **Fig. 2M**, without moving the change-over valve as there is no pressure in the system when the engine is stationary. The underside of the header is then wiped clean and a smear of clean oil applied to the sealing rings on the the new canisters, before screwing them up by hand and tightening them by no more than three quarters of a turn after the seals contact the header. Check the filters for leaks after the engine is restarted.

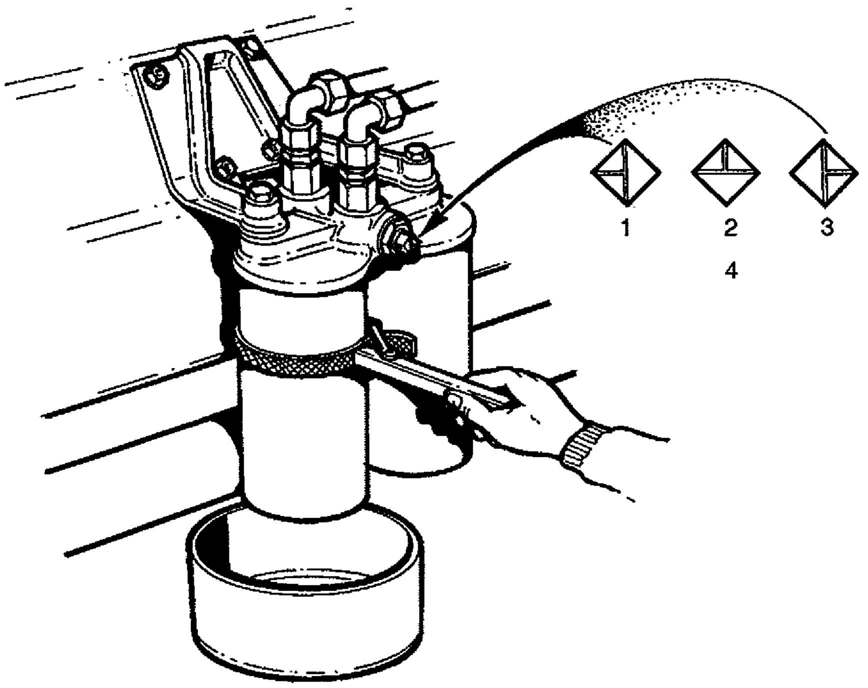


Fig. 2M

**CHANGING THE MAIN FILTER ELEMENTS WITHOUT STOPPING THE ENGINE (Reduce to Idling)**
**NOT THE PISTON JET FILTERS WHICH CAN ONLY BE CHANGED WITH THE ENGINE STOPPED**
The normal position of the change-over valve is with the leg of the **T**, marked on the square end of the valve spindle, pointing upwards (see **Fig. 2M**) when both filter elements are in circuit. Turning the valve with the spanner provided, so that the leg of the T points to the left, puts the right hand filter out of service so that it may be exchanged for a new one. Turning the valve so that the leg points to the right puts the left hand filter out of service, so that this one can now be exchanged for a new filter canister. The valve is then returned to its original position, so that both elements of the filter are back in service. Check for oil leaks.

**NOTE:** Prepare for a small spillage of oil from the filter as each canister is removed, by placing a container of about 5 litres or 1 gallon capacity under the filter. Also fill the new oil filters with new oil before screwing each one into position, to reduce the amount of air introduced into the lubrication system.

**REMOVING AND REFITTING THE OIL MANIFOLD (EARLY ENGINES)**
The oil manifold need only be removed at a major overhaul to facilitate the cleaning of the crankcase oil galleries.
**Mark the flexible pipes in order to make sure that they are reconnected to the correct positions.** Disconnect the flexible pipes from the cooler and the manifold inlet connections (if the cooler is still fitted, oil left in the tube stack will drain from the outlet when the flexible pipe is removed. A suitable container should be placed underneath to catch the oil). Unscrew the four screws from the oil manifold flange connections into the crankcase, and remove it.

**REMOVING AND REFITTING THE OIL FILTER HEADER (LATER ENGINES)**
The oil filter header need only be removed at major overhaul to facilitate cleaning internal oil galleries in the crankcase. **Mark the flexible pipes before disconnecting them in order to make sure that they are reconnected to the correct position.**
Remove the flexible pipes and the two bolts holding the oil cooler feed pipe to the oil filter header, then take out the 11 setscrews holding the filter header to the crankcase. (If the oil cooler is still fitted residual oil left in the tubestack will drain from the oil cooler feed pipe when the filter header is removed, catch this oil in a suitable container).

**WARNING** ⚠ FAILURE TO CONNECT THE FLEXIBLE OIL PIPES IN THE CORRECT POSITION MAY RESULT IN ENGINE DAMAGE AND WILL INVALIDATE THE ENGINE WARRANTY. ALWAYS WEAR EYE PROTECTION WHEN USING COMPRESSED AIR.

Remove any jointing material from the oil manifold and the crankcase, wash it in clean kerosene and blow out the galleries with compressed air. Refit the manifold to the crankcase using a new joint and tighten the 4 retaining screws to pull it squarely up to the crankcase.

**Key**
**(Fig. 3M)**
1 Change right filter
2 Normal running position
3 Change left filter
4 Oil cooler
5 Oil manifold
6 Support bracket

**(Fig. 4M)**
1 Change right filter
2 Normal running position
3 Change left filter
4 Dirty oil into filter
5 Clean oil into engine

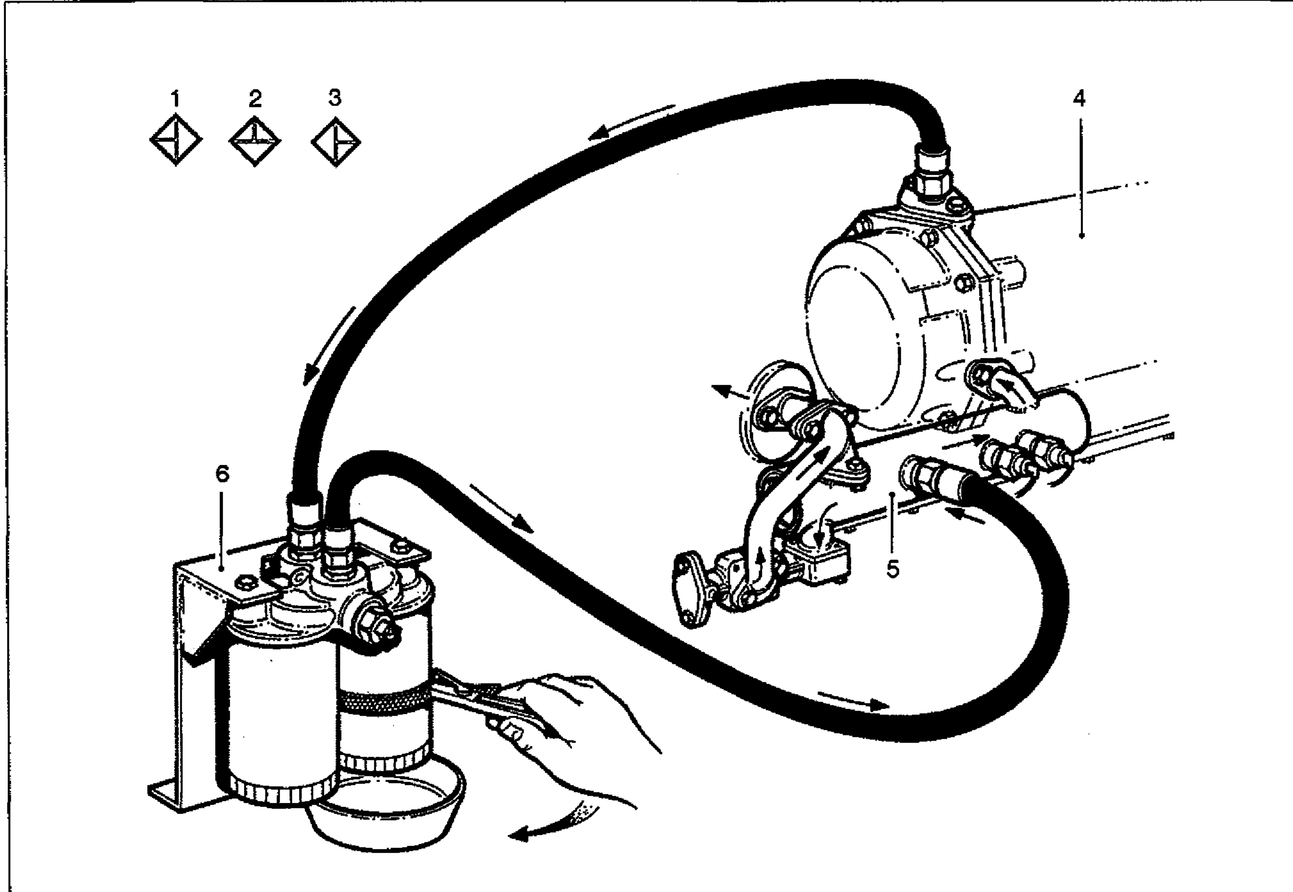



Fig. 3M

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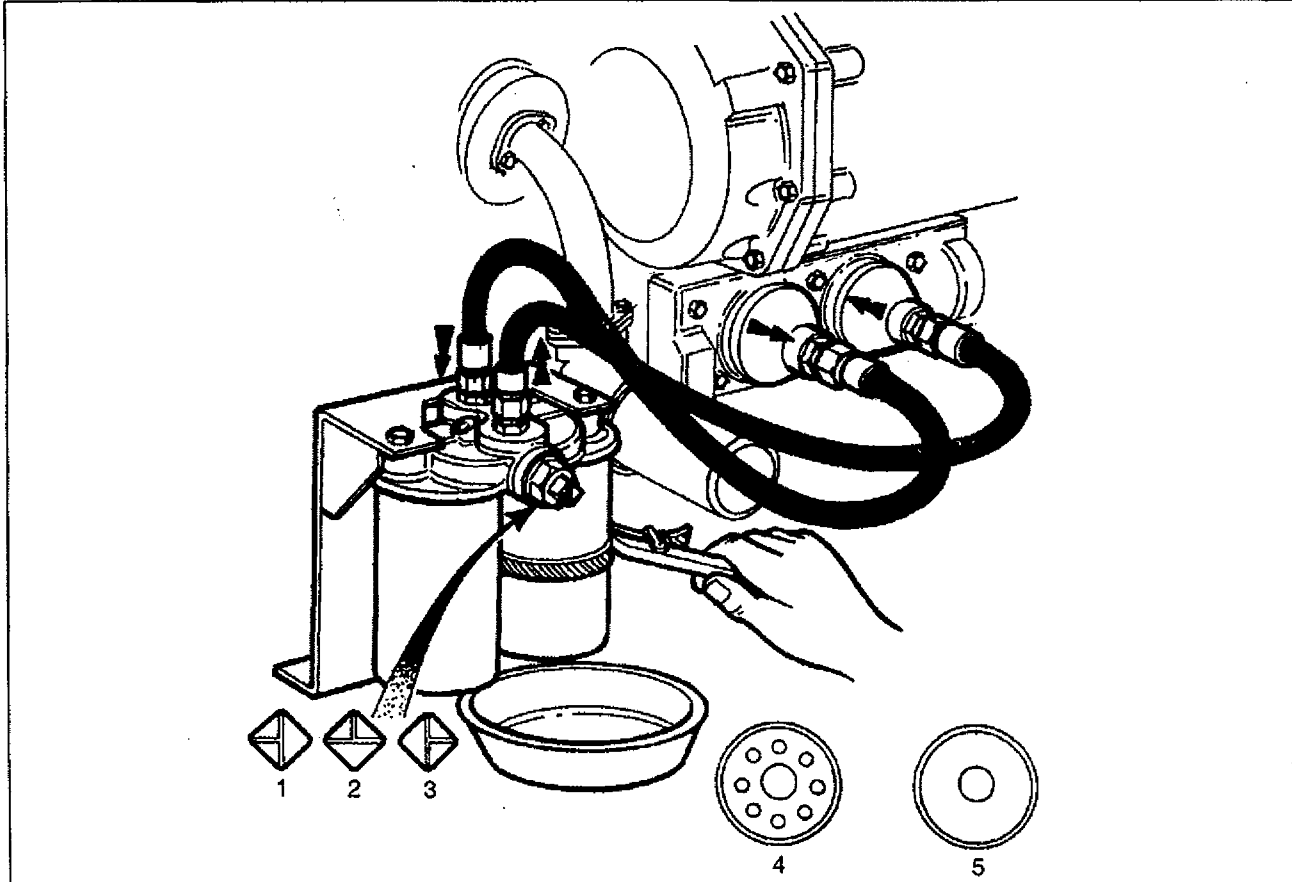



Fig. 4M

1004.2

## CLEANING CENTRIFUGAL OIL FILTER (SEE FIG. 6M)

**WARNING** ⚠ DISCONNECT BATTERIES AND ALL OTHER MEANS OF STARTING. ALWAYS WEAR PROTECTIVE GLOVES.

**Stop the engine, and allow time for the oil to drain back to the sump.**

1 Slacken safety clamp (1) unscrew cover nut and lift off cover.

2 Lift off rotor assembly (2) having allowed oil to drain from nozzles. The rotor should be removed and replaced on the spindle with extreme care in order to ensure that bearings are not damaged.

3 Secure rotor in dismantling tool **T6253/292**. Unscrew rotor cover nut (3) and separate rotor cover from body.

4 Remove standtube (4) using extraction tool **T6253/293** and clean.

5 Remove sludge from inside the rotor by means of a spatula and wipe clean. Ensure that all rotor components are thoroughly cleaned and free from deposits of dirt before reassembling the rotor. Failure to do so could cause an out-of-balance condition which will accelerate bearing spindle wear.

6 Clean nozzle with brass wire. Examine 'O' ring (5) and renew if damaged.

7 Reassemble rotor complete and tighten top nut.
**IMPORTANT:** Ensure that rotor cover and rotor body are always matched by balance reference number and pin location.
**DO NOT INTERCHANGE ROTOR COVERS.**

8 Examine spindle journals, if damaged or worn replace with body assembly complete.

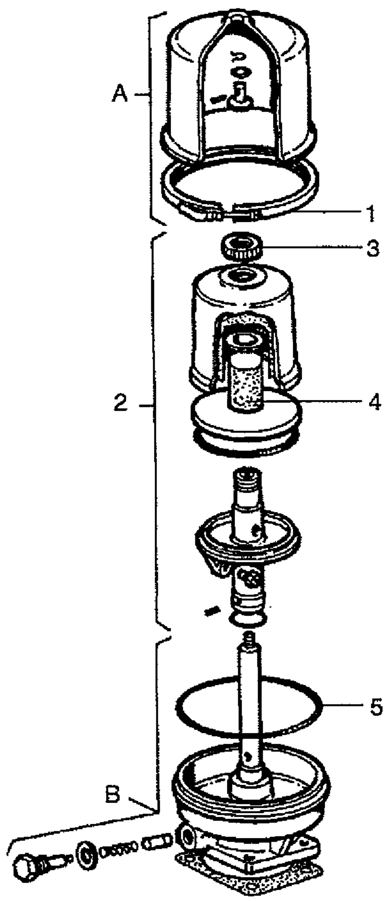


Fig. 6M

9 Reassemble filter complete checking that rotor revolves freely then replace filter body cover. Tighten cover nut and secure safety clamp. The clamp ring should be securely fitted at all times and the filter should not be run without the clamp ring fitted.

10 With the engine running check all joints for leakage. Check for excessive vibration.

**NOTE:** A special oil priming pump is used when this centrifugal filter is fitted.

**Key**
**(Fig. 6M)**
**A** Cover assembly
**B** Body assembly

**WARNING** ⚠ NEVER CHANGE STANDARD FUEL FILTERS WITH THE ENGINE RUNNING. ALWAYS WEAR PROTECTIVE GLOVES.

## DESCRIPTION

### FUEL FILTER AS FITTED ON ALL EARLY ENGINES (AND LATER 4016 ENGINES ONLY)

The fuel filters on the early engines are screwed into a filter head mounted on each side of the crankcase.

The filters are of the full-flow type, meaning that all the fuel in the system passes through them.

As the dirt particles are filtered out and deposited on the paper element, the resistance to flow will increase, until the element becomes blocked which will stop the engine. This should not happen if the service periods are not exceeded.

When the maintenance point has been reached the dirty filter canisters are simply unscrewed and replaced by new filter canisters, oiling the sealing rings (see **page 53 in the Operators Handbook**).

The fuel enters each filter head at the inlet connection and flows via holes in the top of the canister casing, through the paper element into the centre of the filter and head, leaving via the outlet connection at the side (see **Fig. 1N**).

**Key**
**(Fig. 1N)**
**1** Outlet connection
**2** Feed pipe to injectors
**3** Inlet connection
**4** Inlet pipe

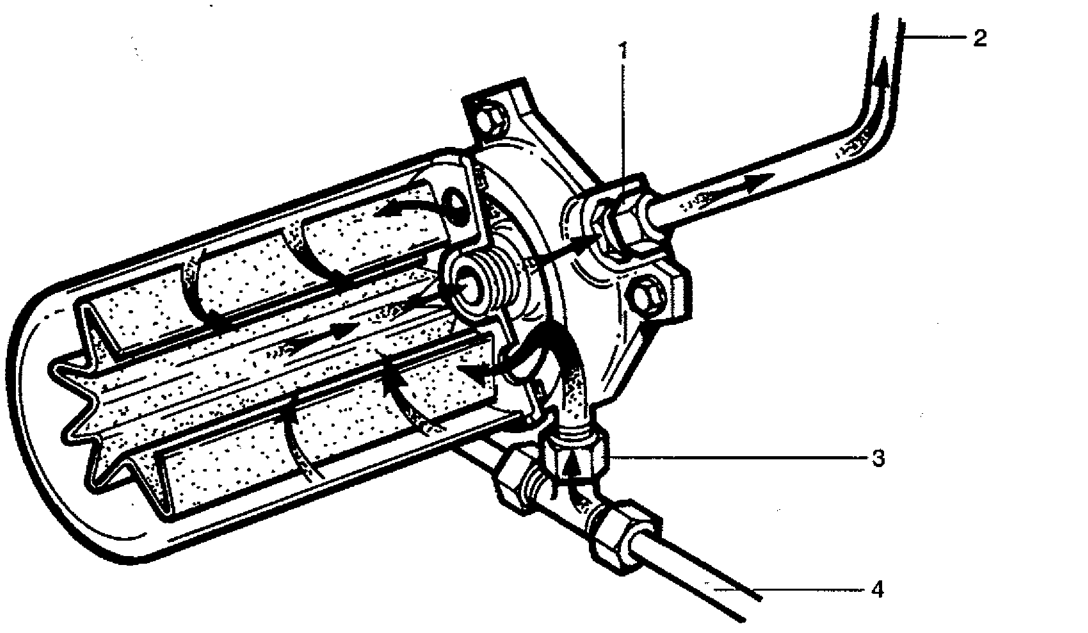



**Fig. 1N**

## FUEL SUPPLY CIRCUIT

The fuel from each filter flows via feed pipes to fuel rails mounted on each side of the engine. The rail system comprises a fuel block bolted to each cylinder head and connected by short lengths of pipe sealed by 'O'-rings to convey the fuel to and from the pump injectors.

Fuel flows from the lower rail through a pipe to the rocker box where drillings in the box and cylinder head convey it to each pump injector unit. The quantity of fuel passing through the pump injector is in excess of the power requirement and the surplus acts as a coolant.

Unused fuel and injector leakage is returned by more drillings in the cylinder head and piped back to the block and the upper rail.

A pressure relief valve mounted at the drive end of the upper rail controls the pressure of the fuel in the system, and also acts as a non-return valve.

The fuel supply to the engine is via the suction pipe (1) and strainer (2) to the inlet connection on the lift pump (3). From the lift pump outlet connection (4) via the delivery pipes (5) and (6) to the fuel filter inlet connections (7) and (8).

After flowing through the fuel filter (see above) the fuel flows via the filter outlet connections (9) and (10) and the feed pipes (11) and (12) to the fuel rails (see **Fig. 2N / 3N**).

**Key (Fig. 2N)**

**1** Fuel inlet
**2** Strainer
**3** Lift pump inlet
**4** Lift pump outlet
**5** Feed to 'A' bank filter
**6** Feed to 'B' bank filter
**7/8** Filter inlet
**9/10** Filter outlet
**11/12** Feed to fuel feed rails
**13** Vent plug
**14** Fuel relief valve
**15** Fuel supply to rocker box
**16** Fuel return from injectors

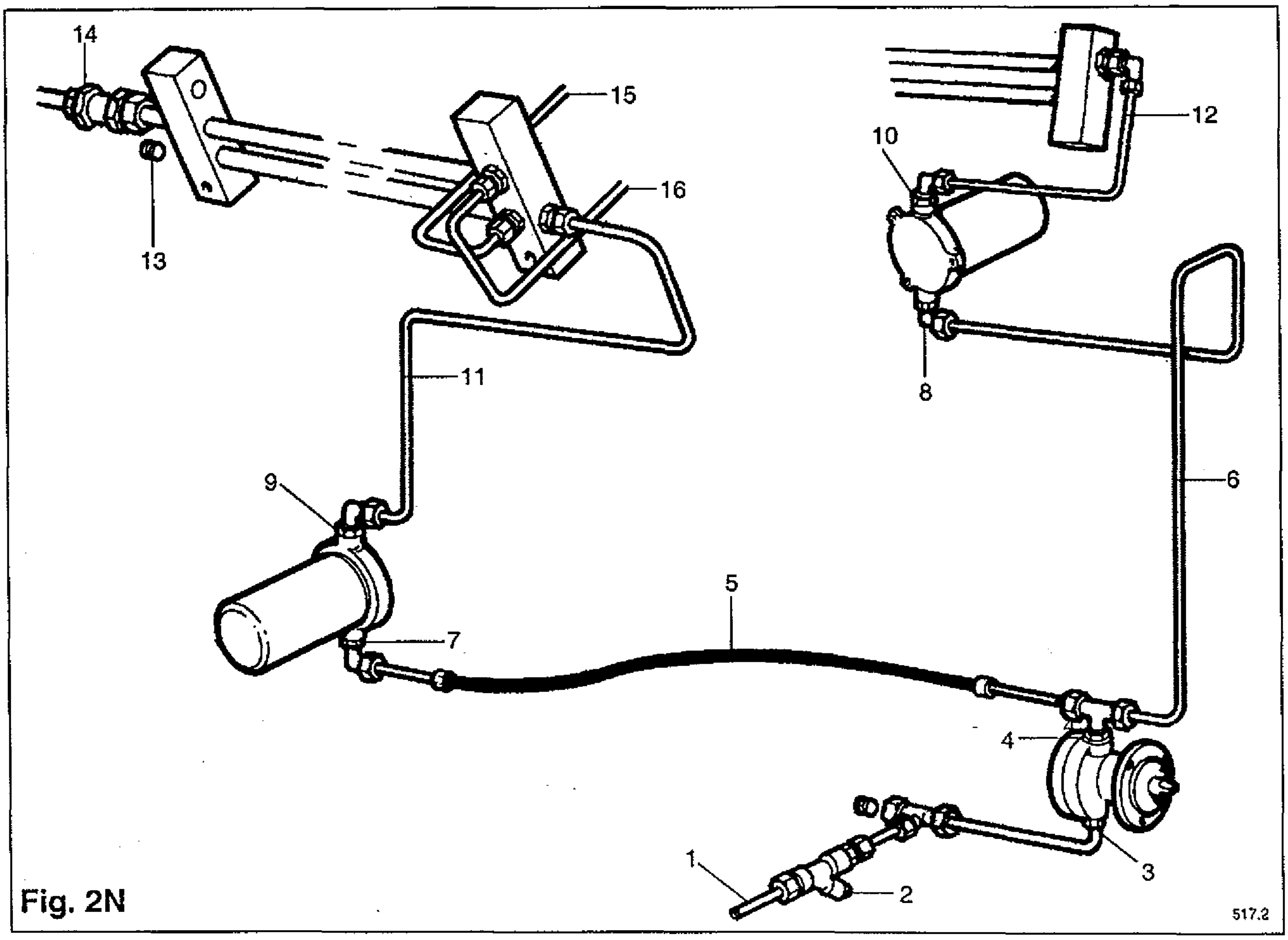



**Fig. 2N**

## HAND PRIMING CIRCUIT - OPTIONAL PRIMING CIRCUIT

Incorporated in the fuel supply circuit is a priming circuit for bleeding air from the system for the initial start up, or after the engine has been stopped for a considerable time (see **Operators Handbook**).

When the lift pump is in operation the priming pump is by-passed, and the fuel supply circuit is as described above. With the engine stopped the fuel is sucked through the pipe (1) via the strainer (2) by operating the priming pump (13). From the priming pump outlet connection (14) via the non-return valve (15) the fuel is supplied to the fuel filter inlet connections (7) and (8) via the flexible pipe (5), (6) and thence to the fuel rails.

## MAINTENANCE

### FUEL LIFT PUMP

For information on the lift pump see **Section KK1**.

### HAND PRIMING PUMP

The pump requires no maintenance but should it fail to operate a replacement unit is normally supplied.

### STRAINER (4016 ENGINES ONLY)

The screen inside the strainer body should be removed for cleaning (using diesel fuel or kerosene) at the same time that the filter elements are replaced. To remove the screen, unscrew the cap nut underneath and withdraw it.

**Key (Fig. 3N)**

**1** Fuel inlet
**2** Strainer
**3** Lift pump inlet
**4** Lift pump outlet
**5** Feed to 'A' bank filter
**6** Feed to 'B' bank filter
**7/8** Filter inlet
**9/10** Filter outlet
**11/12** Feed to fuel rail
**13** Vent plug
**14** Fuel relief valve
**15** Fuel supply to rocker box
**16** Fuel return from injectors

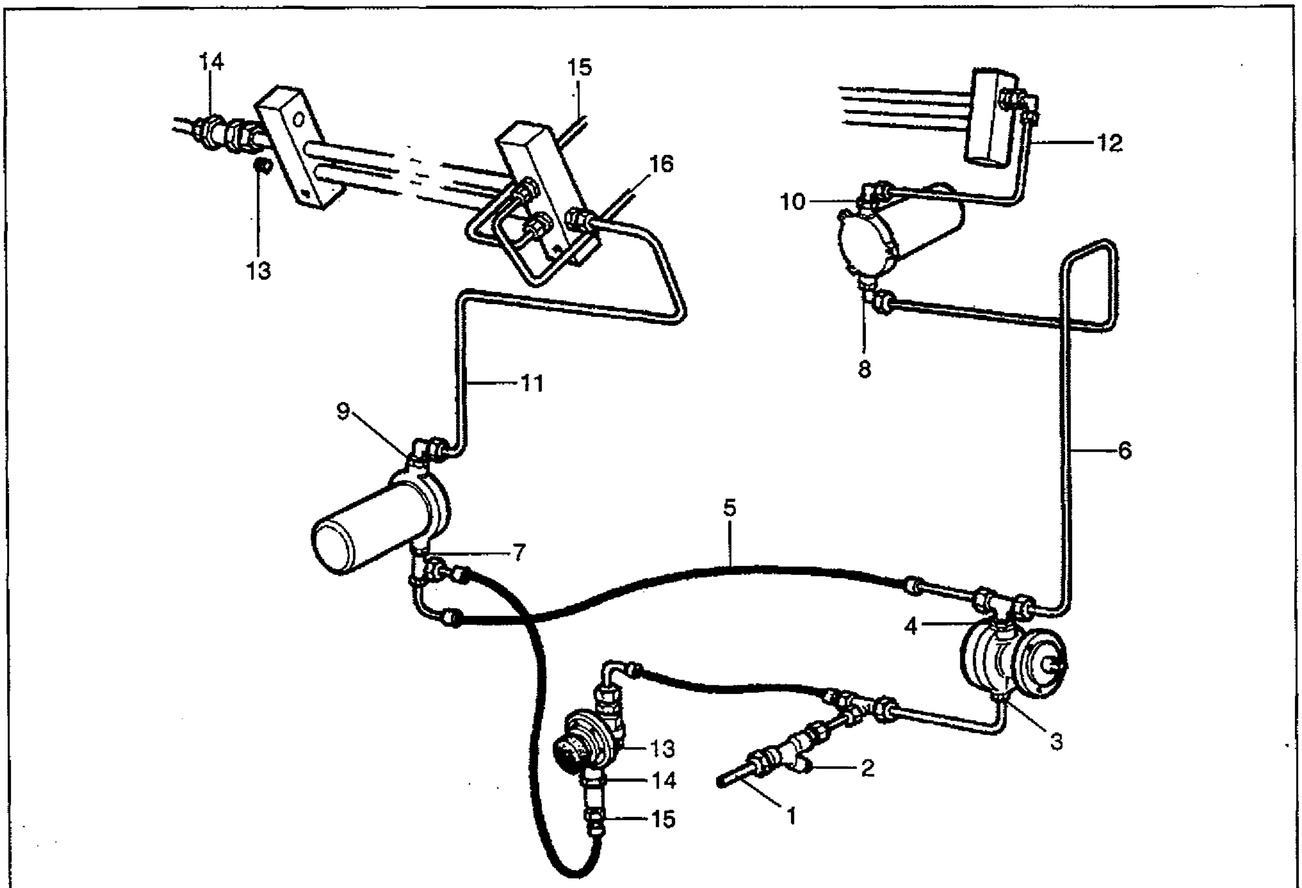



Fig. 3N

**WARNING** ⚠ NEVER CHANGE STANDARD FUEL FILTERS WITH THE ENGINE RUNNING. ALWAYS WEAR PROTECTIVE GLOVES.

## DESCRIPTION

### FUEL FILTER AND WATER SEPARATOR AS FITTED ON LATER 4012 ENGINES

The fuel filter and water separator is of the disposable spin on canister type, fitted with a self-venting valve.

The filter is of the full-flow type, meaning that all the fuel used by the engine passes through it.

As the dirt particles are filtered out and deposited on the paper element the resistance to flow increases, until the element becomes blocked, stopping the engine. This should not happen if the maintenance periods are not exceeded.

The water collected in the bottom of the canister should be drained off weekly.

To remove the water and sediment just turn the self-venting valve until water free fuel appears, then close the valve.

When the maintenance period has elapsed the dirty filter/water element canister is simply unscrewed from the head casting, and replaced by a new canister (see **page 53 in the Operators Handbook**).

Fuel enters the unit, passes over the top end plate of the element, through the holes and down between the casing and the element.

The fuel then flows through the element and as the water separates from the fuel, globules of water are formed which drop into the bottom of the casing, where it is held until it can be drained through the manually operated self-venting valve. The fuel continues to flow through the element where solid contaminants are removed, then up the centre into the head casting, and out through the outlet connection (see **Fig. 4N**).

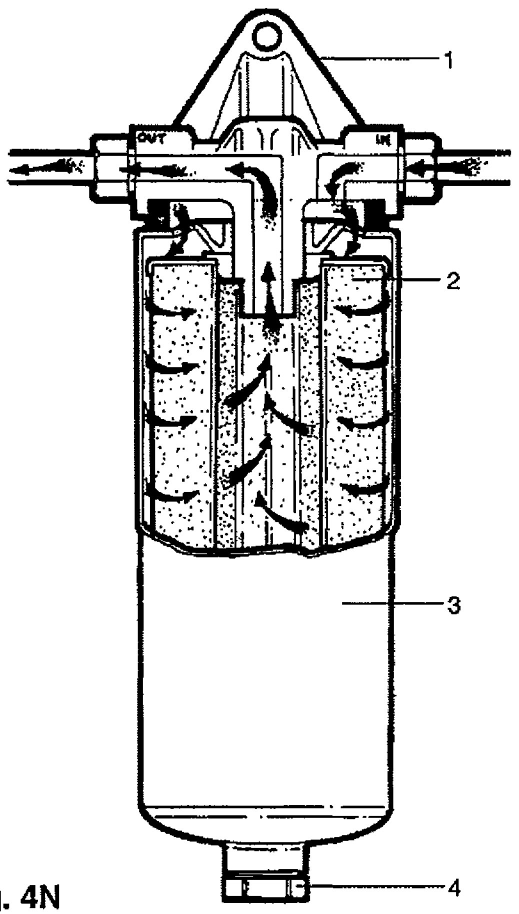



**Fig. 4N**

**Key**
**(Fig. 4N)**
**1** Head casting
**2** Element
**3** Canister
**4** Water drain valve

## FUEL SUPPLY CIRCUIT

The fuel from the fuel filter flows via feed pipes to a fuel rail mounted on each side of the engine. The rail system comprises a block bolted to each cylinder head and connected by short lengths of pipe sealed by 'O' rings to form a three pipe rail.

Fuel is supplied from the lower rail via take-off points on each block to the rocker box where drillings in the box and cylinder head convey the fuel to each pump injector unit. The system is full flow and the quantity of fuel passing through the pump unit is in excess of injection requirements, the surplus acting as a cooling medium.

Unused fuel and injector leakage is returned by drillings in the cylinder head and piped back to the block and the middle rail.

A pressure relief valve mounted at the drive end of the middle rail controls the pressure of the fuel in the system.

The fuel supply to the engine is via the suction pipe (1) to the fuel filter/water separator inlet connection (2).

After flowing through the fuel filter (see above), the fuel flows to the inlet connection of the lift pump (3), and from the lift pump outlet connection (4) via the delivery pipes (5), (6), (7) and (8) to the fuel rails (see **Fig. 5N / 6N**).

The upper rail carries the oil supply to lubricate the rocker gear.

**Key**
**(Fig. 5N)**

**1** Fuel inlet
**2** Fuel filter
**3** Lift pump inlet
**4** Lift pump outlet
**5/6** Feed to tee
**7** Feed to 'A' bank
**8** Feed to 'B' bank
**9** Fuel supply to rocker box
**10** Fuel return from cylinder head
**11** Fuel return valve

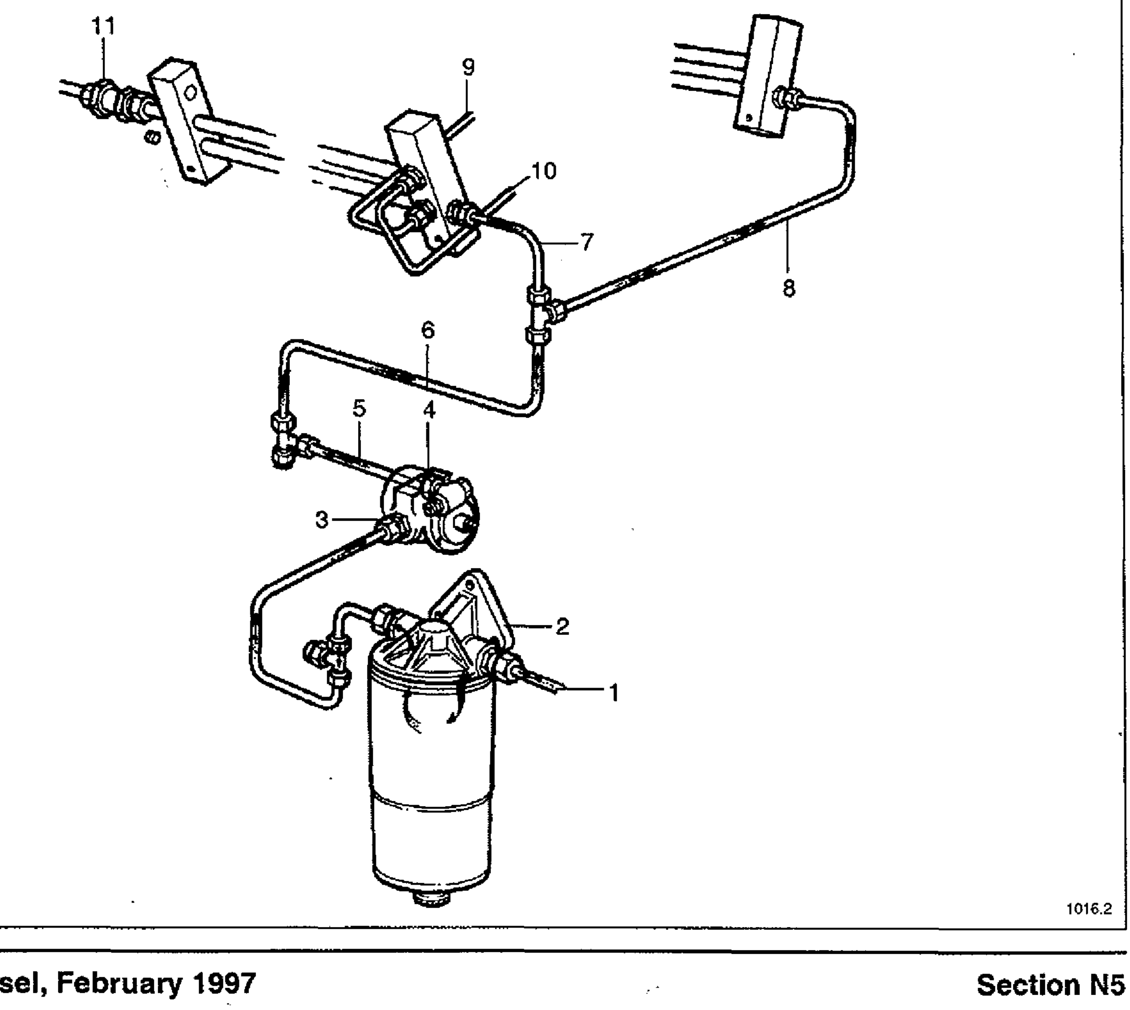



**Fig.5N**

## HAND PRIMING CIRCUIT - OPTIONAL

Incorporated in the fuel supply can be a priming circuit for bleeding air from the system for the initial start up, or after the engine has been stopped for a considerable time (see **page 26 in the Operators Handbook**).

When the lift pump is in operation the priming pump is by-passed, and the fuel supply circuit is as depicted above. With the engine stopped the fuel is sucked through the pipe (1) through the fuel filter/water separator by operating the priming pump (9). From the priming pump outlet connection (10) and the non-return valve (11) the fuel flows via the supply pipe (12) to the delivery pipes (6), (7) and (8) and thence to the fuel rails.

**Key**
**(Fig. 6N)**

1 Fuel inlet
2 Fuel filter
3 Lift pump inlet
4 Lift pump
5 Lift pump outlet
6 Feed to tee
7 Feed to 'A' bank
8 Feed to 'B' bank
9 Priming pump
10 Connection
11 Non return valve
12 Supply pipe
13 Plug
14 Fuel supply
15 Fuel return
16 Fuel supply to rocker box
17 Fuel return from cylinder head
18 Fuel relief valve

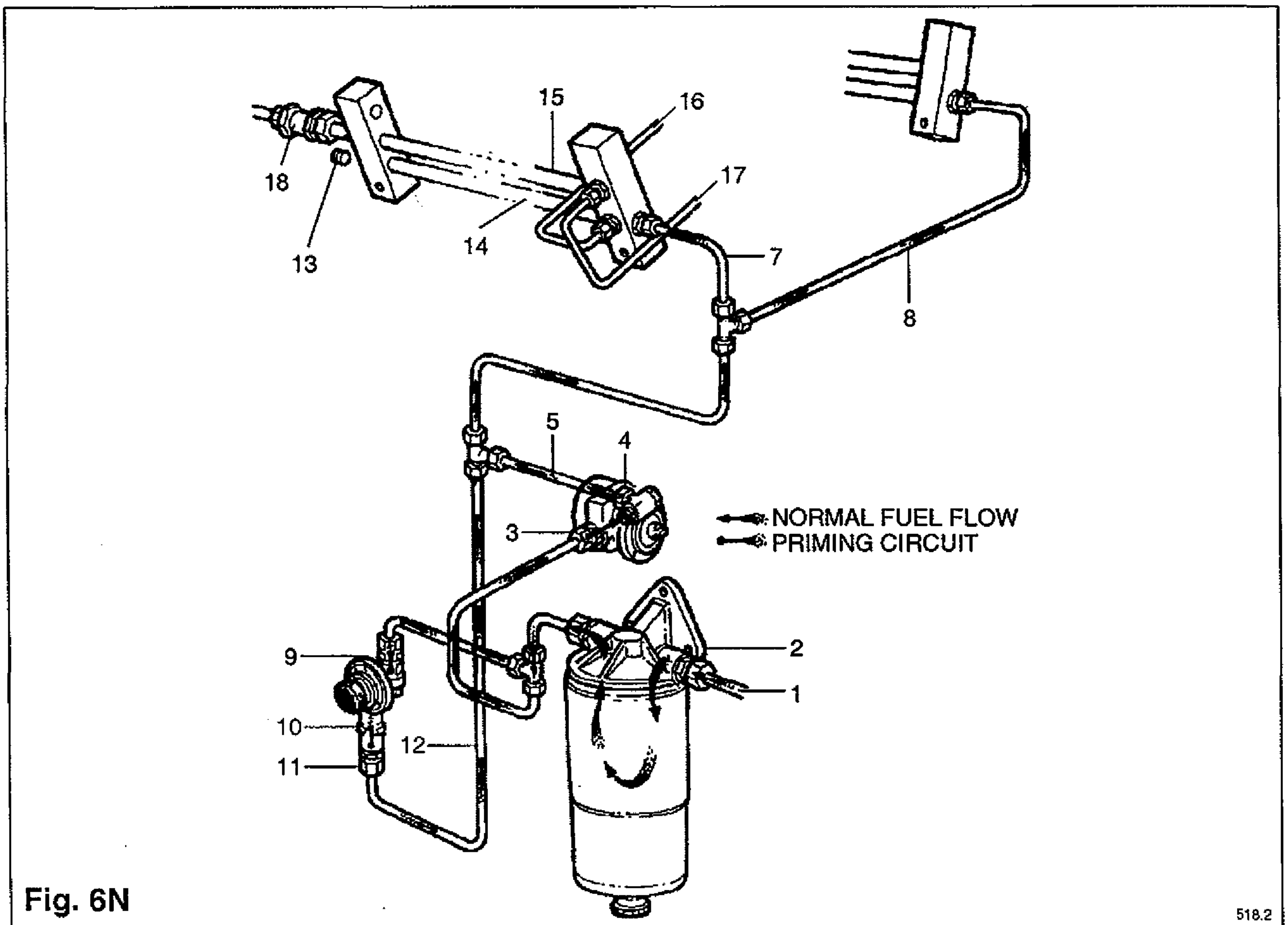



Fig. 6N

**WARNING** ⚠ ALWAYS WEAR PROTECTIVE GLOVES WHEN CHANGING FILTER ELEMENTS.

## DESCRIPTION

These special duplex fuel filters are normally intended for use on long running engines, or where a servicing requirement may occur when it is impracticable to stop the engine to change the filter elements. For this reason they are fitted with a 3 way change-over valve in the head, which enables the elements to be changed, one at a time, whilst the engine continues to run at idling speed, **Fig. 7N.**

**NOTE:** There is no by-pass in these filters, so if servicing is neglected and both elements become blocked, then the engine will stop for lack of fuel.

## CHANGING THE FUEL FILTER ELEMENTS WHEN THE ENGINE IS STOPPED

All that is necessary is to unscrew the canisters with a strap wrench (see **Operators Handbook Fig. 54**), leaving the change-over lever in the vertical position, as there is no pressure in the fuel system with the engine stationary. The replacement canisters are then screwed on, after applying a smear of clean engine oil to the rubber seals, and tightened by hand only. Check for leaks when the engine is restarted.

**Key**
**(Fig. 7N)**
1 Disposable canister
2 Air bleed screws
3 Position of lever
4 Change right filter

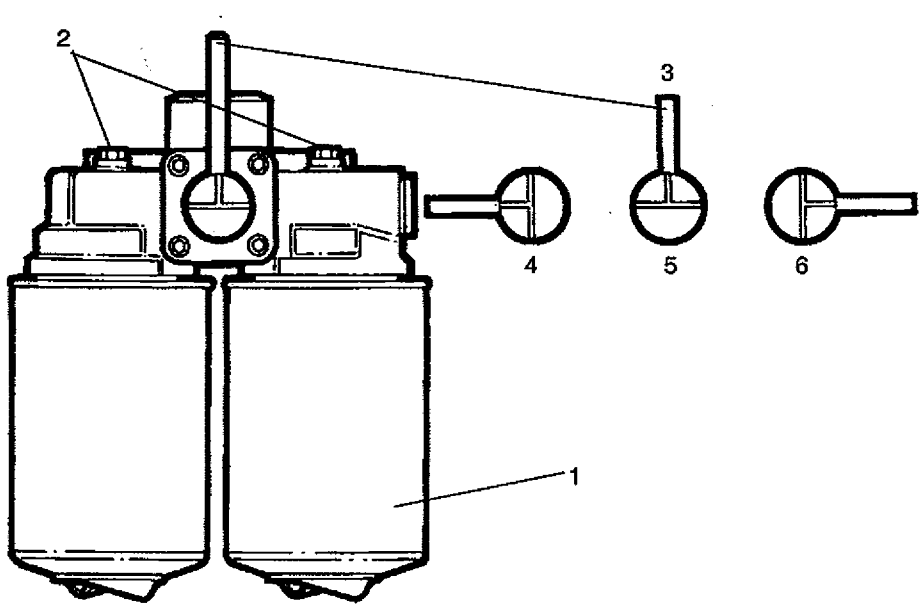



**Fig. 7N**

## CHANGING THE FUEL FILTER ELEMENTS WHEN THE ENGINE IS RUNNING

The normal position of the change-over valve lever is vertically upward, when both filters are in circuit. Turning the lever to the left puts the right hand filter out of service, so that the right hand canister may be exchanged for a new one. Open the bleed screw above the new element and return the lever to the vertical position, closing the bleed screw when all air has been ejected. Turning the lever so that it points to the right, puts the left hand filter out of service so that it can be exchanged for a new one. Again open the bleed screw above the new element and return the lever to the vertical position to eject all air before closing the bleed screw. Finally with both elements now back in circuit, check for leaks. (See **Fig. 8N**).

**NOTE:** Prepare for some spillage of fuel, by placing a bowl of about 5 litres or 1 gallon capacity under the filter, when changing the canisters.

The change-over filters are engine mounted and replace the standard filters (see **Section N1** or **N3**).

**Key**
**(Fig. 8N)**

**A** Change right hand filter
**B** Normal position of lever
**C** Change left hand filter

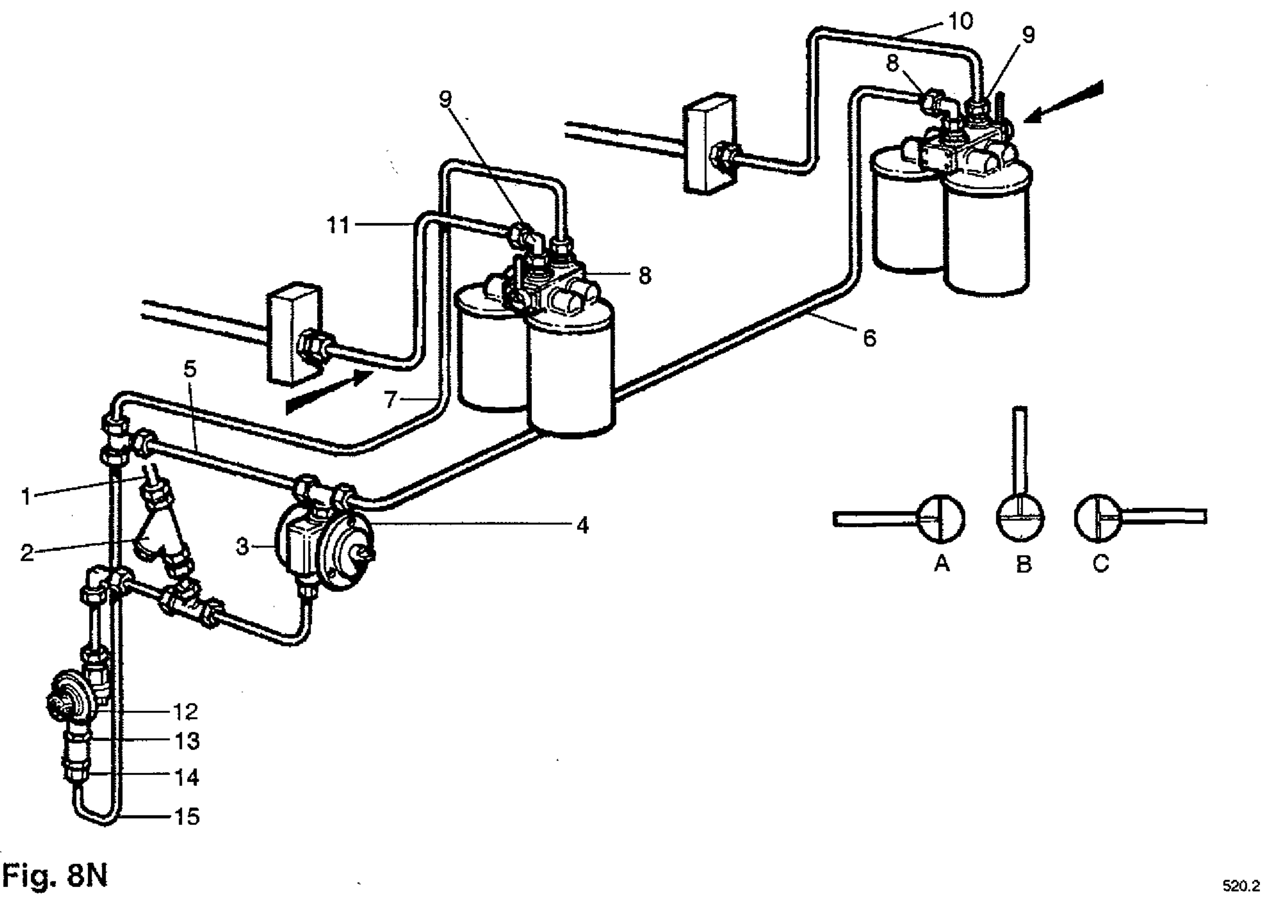



Fig. 8N

## FUEL SUPPLY CIRCUIT

The fuel from each filter flows via feed pipes to a rail mounted on each side of the engine. The rail comprises a block bolted to each cylinder head and connected by short lengths of pipe sealed by 'O' rings to form a two pipe (bottom and middle) fuel rail for each bank.

Fuel is supplied from the bottom rail via take-off points on each block to the rocker box where drillings in the box and cylinder head convey the fuel to each pump injector unit. The system is 'full flow' and the quantity of fuel passing through the pump unit is in excess of injection requirements, the surplus acting as a coolant.

Unused fuel and injector leakage is returned by drillings in the cylinder head and piped back to each block and the middle rail.

The top rail on current industrial engines carries the oil supply to the valve gear.

A pressure relief valve mounted at the rear end of the middle rail maintains the correct fuel pressure in the system, and also operates as a non return valve.

The fuel supply to the engine is via the suction pipe (1) and strainer (2) to the inlet connection on the lift pump (3). From the lift pump outlet connection (4) via the delivery pipes (5), (6) and (7) to the fuel filter inlet connections (8). After passing through the fuel filters (see **Fig. 7N**) the fuel flows via the filter outlet connections (9) and the feed pipes (10) and (11) to the fuel rails (see **Fig. 8N**).

## PRIMING CIRCUIT

**NOTE:** Strainer (2) is still fitted on 16 cylinder engines but 12 cylinder engines now use the water trap/sedimenter shown in **Fig. 5N**.

Incorporated in the fuel supply circuit is a priming circuit for bleeding the system for initial start up or after the engine has been stopped for a considerable time (see **page 26 in the Operators Handbook**).

When the lift pump is in operation, the priming pump is by-passed and the fuel supply circuit is as described above. When the engine is stopped the fuel is sucked through the pipe (1) via the strainer (2) by operating the priming pump (12). From the priming pump outlet connection (13) via the non-return valve (14) the fuel is supplied to the fuel filter inlet connections (8) via the delivery pipes (5), (6), (7) and (15) and thence to the fuel rails.

## DESCRIPTION AND OPERATION

The function of the fuel 'PUMP INJECTOR' is to:

(a) raise the pressure of the fuel sufficiently for it to open the integral injector nozzle valve and spray a predetermined amount of atomised fuel into the combustion chamber,

(b) deliver an equal amount of fuel to each cylinder,

(c) inject the fuel at precisely the correct moment for the most efficient combustion, and

(d) vary the amount of fuel injected in accordance with the requirement of the engine at all conditions of load and speed.

The pump injectors are individual units mounted in the centre of each cylinder head and secured in position by a forked clamp. Each unit performs the function of pump and injector. The pump control plunger helix is operated from the engine governor, mounted at the front of the engine, via transverse and longitudinal linkages.

Each pump injector is cam and rocker lever operated giving a constant stroke, with facility for setting the point at which the spring plunger assembly starts the pumping stroke (which determines the point of injection), using the timing pin fitted to the element housing.

**NOTE:** The plungers and element housings are manufactured to extremely fine limits and the working surfaces are lapped together. For this reason plungers and element housings are not interchangeable. This also applies to injector nozzles and needles.

The element housing is lubricated internally with fuel.

The pump injector enclosed within the cylinder head is arranged for a through flow of fuel, thus keeping the operating temperatures down and allowing for a more consistent supply of fuel over a wide range of engine loads and speeds.

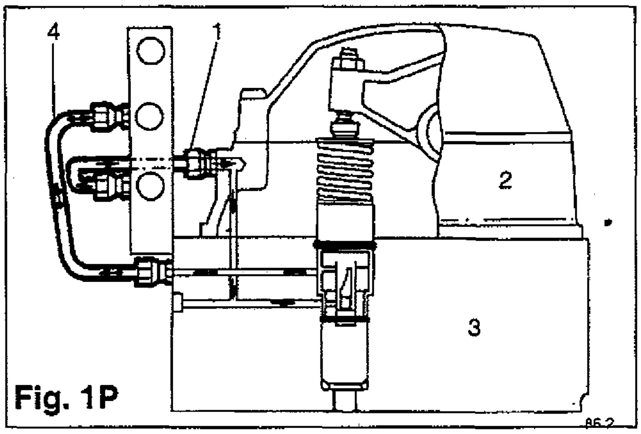



**Fig. 1P**

**Key**
**(Fig. 1P)**

**1** Fuel supply
**2** Rocker box
**3** Cylinder head
**4** Fuel return

Adjustment of the injector pressure setting is varied by fitting shims of the correct thickness at the top of the injector spring, all enclosed within the lower housing. Shims are supplied in various thickness from 0.011" to 0.080" (0.28 to 2.03 mm).

The injector is fitted with a nozzle with eight 0.30 mm (0.0118") diameter holes.

Fuel from the rail enters the rocker box via a drilling which lines up with another drilling in the cylinder head and into the fuel pump chamber. From the pump chamber, fuel enters the bore of the pump via a drilling in the unit injector body.

The fuel flow to each cylinder is regulated by the control arm and the helix on the pump plunger. The excess fuel is returned out of the body back into the pump chamber via a hole in the body. Fuel is then returned to the rail via a drilling in the cylinder head (see **Fig. 1P**).

**WARNING** ⚠ BATTERIES OR ANY OTHER MEANS OF STARTING THE ENGINE WHEN WORKING ON THE FUEL INJECTION SYSTEM.

## REMOVING THE INJECTOR

Remove the rocker box cover by taking out the 4 slot head screws **Fig. 2P**. Rotate the engine, watching the injector rocker, stopping the engine rotating when the injector rocker is on minimum lift i.e. injector at its uppermost travel.

Remove the nut and capscrew from the rocker shaft then lift off the rocker assembly taking care not to drop the hardened cup between the injector rocker arm and the injector **Fig. 3P**. Take out all three push rods, plus the inlet and exhaust rocker bridges, marking them for reassembly in the same order.

Loosen the fuel feed and return union nuts thereby allowing fuel to drain from the fuel rail **Fig. 4P**.

Disconnect the governor mechanism from the control arm **Fig. 5P**. Take care not to drop the capscrew or collar between the ball joint and control arm.

**Key**
**(Fig. 3P)**
**1** Capscrew
**2** Hardened cup

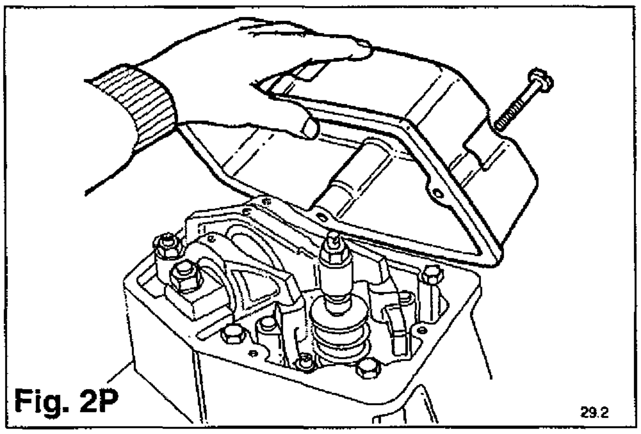



**Fig. 2P**

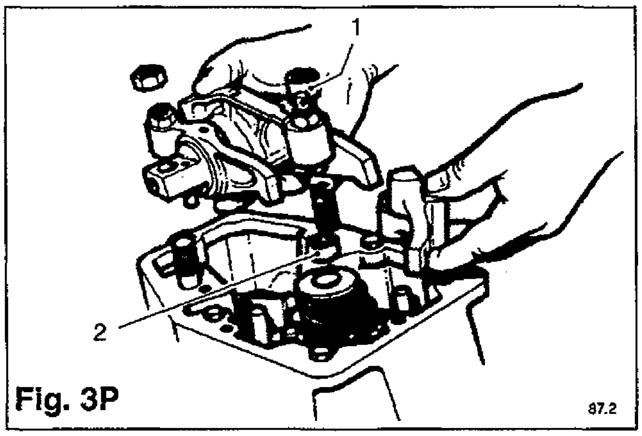



**Fig. 3P**

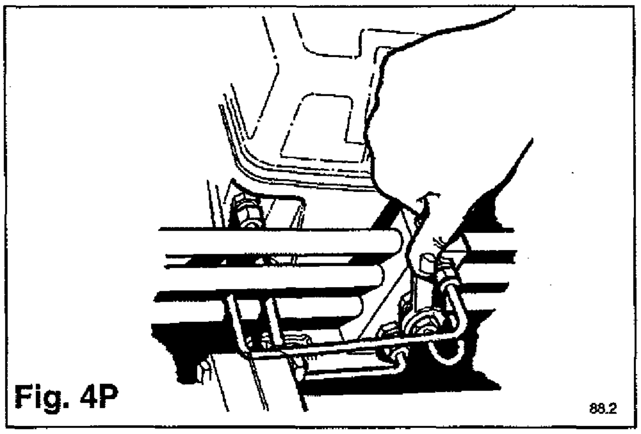



**Fig. 4P**

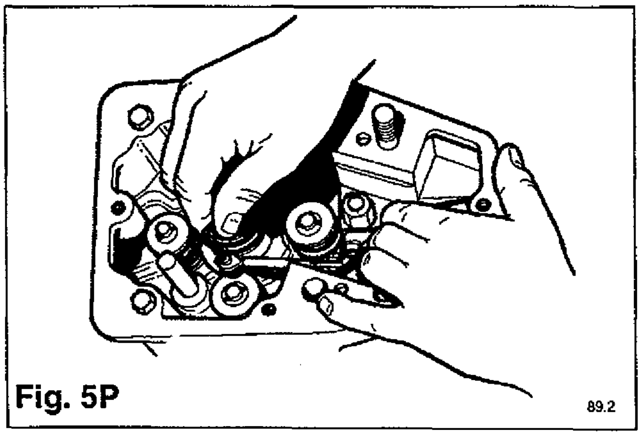



**Fig. 5P**

Finally, remove the capscrew from the injector clamp. Then, using clawfoot tool Part No. **T6253/145**, under the clamp, gently lever the injector out. **Fig. 6P**.

**NOTE:** The injector should not be pulled upwards by the spring mechanism, as this will only lift the plunger from the barrel.

When the injector is out of the cylinder head discard the copper washer. **Fig. 7P**. Remove copper washer from bottom of injector tube, if it does not come out with injector.

**NOTE:** On removal of injector, fuel left in the gallery of the cylinder head will unavoidably run down into the cylinder bore. To avoid serious damage caused by 'hydraulic-ing' it is essential to remove as much of this unwanted fuel as possible. Rotate the engine to top dead centre on the cylinder in question and using a length of plastic tube siphon off the excess fuel which has accumulated in the piston bowl. Later, when the engine is being prepared for start-up, rotate the engine on its starter for 10 seconds with the governor lever in the stop position as an added precaution.

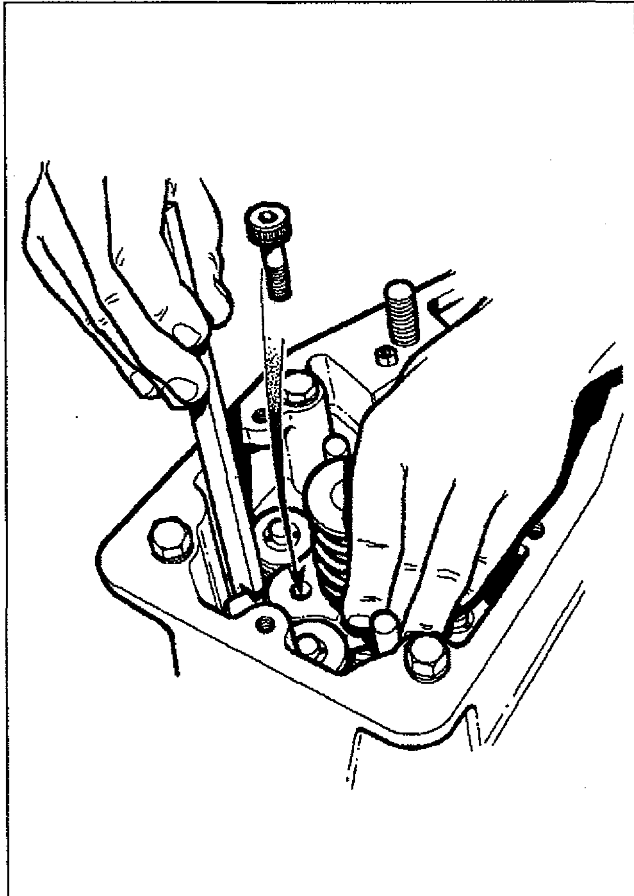


**Fig. 6P** 90.2

**WARNING** ⚠ DO NOT ROTATE ON STARTER WITHOUT THE ROCKER ASSEMBLY FITTED AS DAMAGE TO THE CAM AND PUSH ROD MAY OCCUR.

## STRIPPING AND CHECKING A PUMP INJECTOR

**IMPORTANT** Pump injector dismantling, servicing and testing should only be carried out where suitable test equipment is available. Pump injector dismantling and assembly must be carried out under dust free conditions on a bench used specifically for this purpose. The bench should be covered with zinc or linoleum and be provided with a suitable vice equipped with copper or zinc grips.

**NOTE:** FOR THE PURPOSE OF THIS TEXT, WHETHER THE PLUNGER ASSEMBLY IS SEPARATED FROM THE ELEMENT HOUSING AND NOZZLE OR NOT, THE UNIT IS REFERRED TO AS THE INJECTOR.

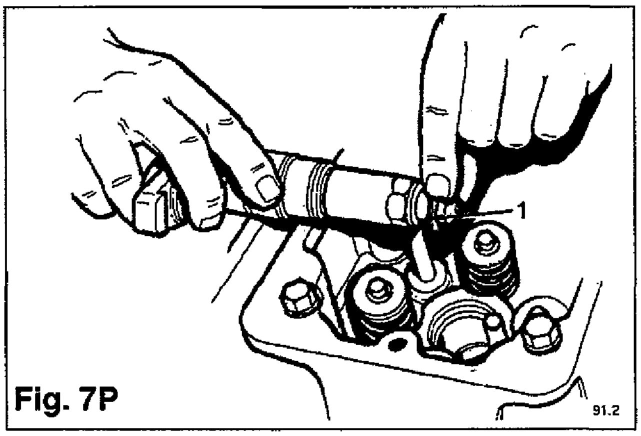



**Fig. 7P** 91.2

**Key**
**(Fig. 7P)**

**1** Copper sealing washer

**NOTE:** It is advisable to work on one injector at a time so as to eliminate the possibility of the plungers being assembled into the wrong element housing.

**TO DISMANTLE**

**NOTE:** Before dismantling pump injectors which are in a very dirty condition seal off the fuel spill ports and wash in clean fuel.
Brush the nozzle externally with a brass wire brush to remove all the carbon deposits.
Remove the plunger spring assembly from the injector using a small screwdriver to prise up the spring plate locating collar over the spring dowel and withdraw the plunger spring assembly from the element housing **Fig. 8P**.

**NOTE:** THE PLUNGER SPRING ASSEMBLY AND ELEMENT HOUSING ARE A MATCHED PAIR AND COMPONENTS CANNOT BE INTERCHANGED. THE PLUNGER SPRING ASSEMBLY AND ELEMENT HOUSING ARE NON-SERVICEABLE ITEMS. IF EXCESSIVELY WORN OR DAMAGED, SERVICE EXCHANGE UNITS ARE AVAILABLE i.e. VISUALLY INSPECT FOR SCORES, SCRATCHES, RUST, CHIPS, BROKEN SPRINGS (INNER AND OUTER).

Place in a bath of CLEAN fuel or calibration fluid.
Remove the timing pin **Fig. 9P**.
With the injector clamp Part No. **T6253/146** only held in a strong vice, slot the injector into the clamp (**Fig. 10P**). Using a suitable torque wrench and a long 27 mm socket, unscrew the nozzle nut (8) (**Fig. 13P**) from the nozzle (7).

**Key**
**(Fig. 10P)**
1 Fuel feed adaptor
2 Injector clamp

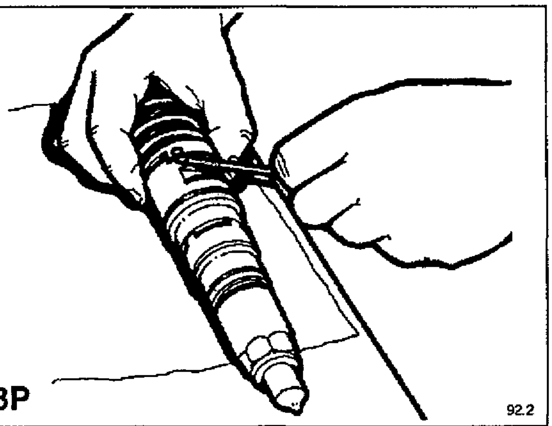


**Fig. 8P** 92.2

**Fig. 9P** 93.2

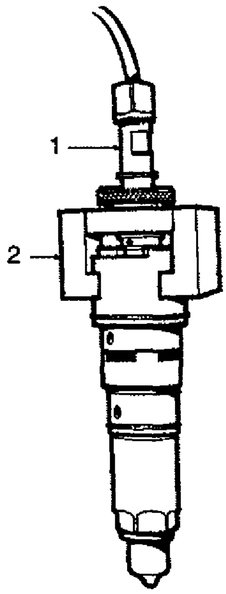



**Fig. 10P** 94.2

**NOTE:**

(1) If the injectors have been in service for some time carbon deposits around the nozzle and nut may make these components stick together. It is therefore advisable to soak the unit in fuel or calibration fluid to soften the carbon and avoid possible damage to the dowels in the transfer block as the nozzle nut is unscrewed. **See Fig. 13P.**

(2) If time will not permit soaking the unit, spray the nozzle nut with 'Plus Gas' or similar releasing fluid to break down the carbon more quickly. **DO NOT** allow releasing fluid to come into contact with 'O' rings as this may cause rapid deterioration.

It will now be possible to lift off the nozzle and needle (6 and 7), transfer block (location adaptor) (5), and thrust cap (spring locator) (**3**) and place in a bath of clean fuel oil or calibration fluid. Release the injector clamp from the vice and suspending the remaining part of the assembly over the bath, invert the body to allow the spring (2) and shims (1) to be removed and placed in the bath with the other parts. Check that all shims (1) are removed from the element housing.

## TO CLEAN AND CHECK

The special tool kit (Part No. **T6253/202 Fig. 11P**) designed to enable quick and safe servicing of the nozzle assembly **MUST** always be used. On no account should tools other than those described here be used or serious damage to the nozzle body and needle valve may result.

Abrasives and metal polish **must not** be used on the nozzle body and needle valve.

Before commencing cleaning operations it is essential to see that the bench is perfectly clean and that ample supplies of **clean** fuel are available.

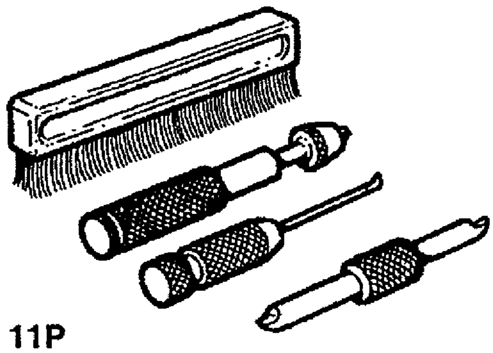


Fig. 11P

95.2

**NOTE:** The nozzle body and needle valve are matched pairs and components **cannot** be interchanged. For this reason it is recommended that only one nozzle assembly is dealt with at a time.

Wash and clean all parts of the element housing assembly with clean fuel paying particular attention to the nozzle clamping shoulder. Remove any carbon deposit with a scraper. Care must be taken not to scratch the shoulder.

Examine the mating faces of the nozzle body, element housing and transfer block. These must be perfectly clean, flat and smooth. If any signs of staining or fretting are apparent, the faces must be lightly lapped on a lapping plate, or if the performance of the injector is suspect, the injector should be tested as described in **Sections P9** to **P11**.

Allow the needle valve and nozzle body to soak in clean fuel oil for a short period. Withdraw the needle from the nozzle body and examine the guide surface. This should be bright and free from high spots, scratches and dull areas. Lightly brush the valve seating with a brass wire brush until bright metal is visible over the whole area.

If the needle valve is discoloured or high spots, scratching or dull areas are visible, the complete pump injector should be returned to an approved agent for examination and reconditioning.

The needle lift in the nozzle body, measured with needle gauge (Part No. **T6253/203**), should be from 0.4 mm to 0.6 mm for new assemblies. If the lift is greater than 0.75 mm a new nozzle assembly should be fitted.

Examine the nozzle body joint face. This should be perfectly clean, flat and smooth.

Examine the needle valve bore in the nozzle body. This should be bright and free from high spots, scratches and dull areas. Check the needle valve slides smoothly in the bore.

**Key**
**(Fig. 12P)**
**1** Plunger spring assembly
**2** Spring dowel
**3** Spring plate locating collar
**4** Element housing
**5** Timing pin

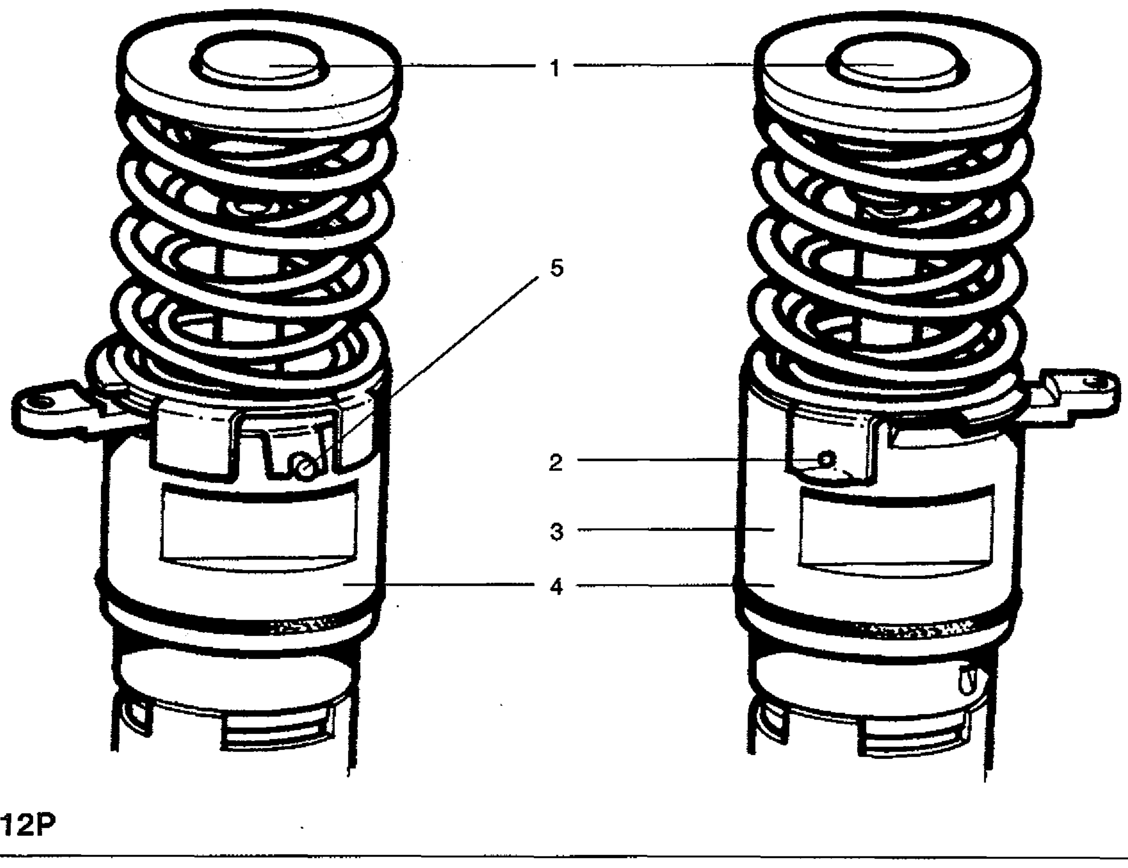



**Fig. 12P**

Clean out the fuel passages in the nozzle body with brass wire of suitable diameter.

Insert the fuel chamber scraper (4) (**Fig. 11P**) into the nozzle body until the nose locates in the fuel gallery. Press against the side of the gallery and rotate to clear any carbon or other deposits.

Insert the seat scraper (2) (**Fig. 11P**) and clean all carbon from the valve seat by rotating and pressing the tool into the seating.

Prick out the holes in the end of the nozzle body with a short piece of wire 0.3 mm (0.0118") diameter, holding it by means of wire holder (3) (**Fig. 11P**). Extreme care must be taken to avoid the danger of the wire breaking in the hole as such particles are almost impossible to remove. If difficulty is experienced cleaning out the holes due to the hardness of the carbon, it is recommended that the complete pump injector is returned to an approved agent for attention.

When using the wire holder, the cleaning wire should be fitted to the tool chuck so that it only protrudes for about 1.5 mm to 2 mm ($^1/_{16}$" to $^5/_{64}$"), thus giving maximum resistance to bending. Insert the wire into the spray hole pushing and rotating gently until the hole is cleared.

**WARNING** ⚠ WHEN TESTING INJECTORS, CARE MUST BE TAKEN TO PREVENT SKIN CONTACT WITH THE SPRAY, SINCE THE WORKING PRESSURE WILL CAUSE THE FLUID TO PENETRATE THE SKIN, NECESSITATING IMMEDIATE HOSPITAL TREATMENT. THE SPRAY IS ALSO HIGHLY FLAMMABLE.

## NOZZLE MULTICLEAN EQUIPMENT

Thoroughly wash away all carbon from the interior of the nozzle body using nozzle '**Multiclean**' equipment (**Fig. 14P**) Part No. **T6253/204** then blow clean. Wash the body backwards through the spray holes with clean fuel oil under pressure from the test pump. Examine the seat closely under a strong light to ensure that all traces of foreign matter have been removed.

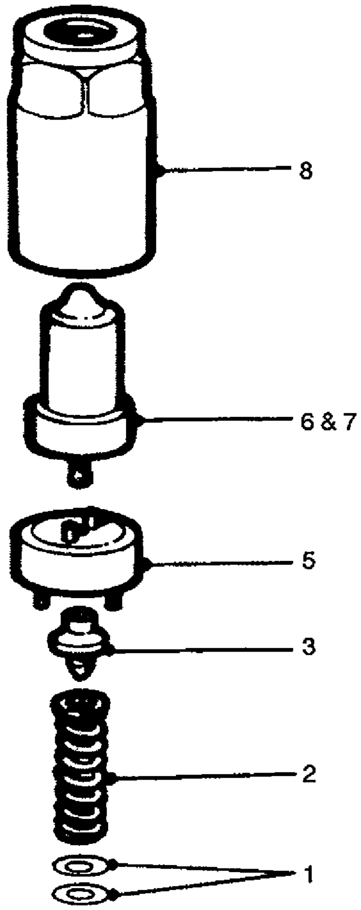



**Fig. 13P**

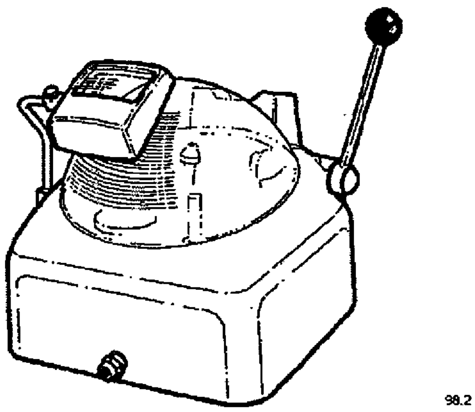



**Fig. 14P**

**Key**
**(Fig. 13P)**

1 Shims
2 Spring
3 Spring locator
4 -
5 Location adaptor
6 Needle
7 Nozzle body
8 Nozzle nut

## TO REASSEMBLE

Thoroughly wash all parts in clean fuel and bring together without wiping. Carefully reassemble the injector (**Fig. 13P**), taking extreme care to ensure the dowels in the transfer block (location adaptor) enter the nozzle and element housing correctly and the fuel feed and return holes are not obstructed.

With the injector clamp Part No. **T6253/146** held in a vice, slot the injector into the clamp. Apply a light coating of grease to the nozzle body clamping shoulder. This will lubricate the clamping shoulder of the transfer block (location adaptor) and nozzle body whilst tightening the nozzle nut. Tighten the nozzle nut by hand as far as possible, then using a suitable torque wrench and a long 27 mm socket, tighten the nozzle nut to the required torque and test as described in **Sections P9 to P11**. (See **Torque Settings pages 38-40**).

If the spray from the nozzle is defective check under '**Injector Troubles**' **Section P9** and replace if necessary.

If the nozzle opening pressure is not within the range specified, shims may be added or taken away from above the injector spring to increase or decrease the pressure.

Shims are supplied in various thicknesses from 0.011" to 0.80" (0.2794 mm to 2.0320 mm), so by careful selection small adjustments in loading can be achieved e.g. 0.002" (0.0508 mm) increase in shim thickness will give approximate pressure increase of 5.2 bar (5.1035 atm) (75 lbf/in$^2$) 5.273 kgf/cm$^2$).

After testing as described in **Section P10** to **P11** remove the injector from the fuel feed adaptor and injector clamp (**Fig. 10P**), and assemble the spring plunger assembly (**Fig. 12P**) to the element housing, ensuring that the spring dowel (2) and timing pin (5) engage with the spring plate locating collar (3) as shown.

## INJECTOR TROUBLES

| SYMPTOMS | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Operating pressure too high or too low | Wrongly set | Readjust shims to obtain correct operating pressure |
| | Damaged or worn injector needle or nozzle | Renew |
| | Incorrect needle or nozzle seating angles, giving incorrect seating line or no angular difference | Renew |
| | Restricted needle lift | Renew nozzle assembly and/or thrust spindle and upper spring |
| | Nozzle holes clogged with carbon | Clean nozzle or renew |
| Form of spray distorted | Nozzle dirty and coated with carbon | Clean |
| | Damaged or eccentric seats | Renew nozzle assembly |
| | Out of true joint faces between transfer block, nozzle and element housing caused by foreign matter between joint faces or by fretting | Dismantle injector, clean and check joint faces. Lap faces to obtain good even contact or renew components |
| | Needle valve slack due to wear | Renew nozzle assembly |
| | Spray holes eroded | Renew nozzle assembly |
| | Needle valve damaged | Renew nozzle assembly |
| Nozzle drips | Carbon on valve seat | Clean or replace with spare unit |
| | Damaged or eccentric seats | Renew nozzle assembly |
| Nozzle blueing | Faulty fitting, tightening or cooling | Renew nozzle assembly. Check cylinder head coolant passages for scale deposits |
| Excessive leak-off (Pressure drop time less than 8 seconds) | Needle valve slack | Renew nozzle assembly |
| | 'O' ring on fuel feed adaptor worn | Check and renew 'O' ring |
| | Foreign matter between face of nozzle body and transfer block or element housing | Clean |
| Insufficient leak-off (Pressure drop time greater than 60 seconds) | Needle valve lacquered | Clean nozzle assembly |
| | Needle valve damaged | Renew nozzle assembly |
| Fuel system gassing-loss of injection to cylinder | Faulty copper sealing washer allowing combustion gases to blow into fuel system | Renew copper sealing washer |
| | Built up carbon not properly cleaned from bottom of injector sleeve preventing copper sealing washer seating | Clean injector sleeve renew copper sealing washer and injector 'O' rings. |
| | Nozzle needle sticking | Clean thoroughly after inspection and retest. |

**NOTE: Always test the injector immediately after cleaning the assembly.**

## TO TEST AND SET THE INJECTOR

**WARNING** ⚠ WHEN TESTING INJECTORS, CARE MUST BE TAKEN TO PREVENT SKIN CONTACT WITH THE SPRAY, SINCE THE WORKING PRESSURE WILL CAUSE THE FLUID TO PENETRATE THE SKIN, NECESSITATING IMMEDIATE HOSPITAL TREATMENT. THE SPRAY IS ALSO HIGHLY FLAMMABLE.

**TEST OILS:** The recommended test oils are Shell Calibration fluid 'C' or 'B' or equivalent fluids (Viscosity 38 Redwood No. 1 at 100°F/ 37.8°C). **DO NOT** use diesel fuel.

To enable the operator to test the injector a special tool assembly Part No. **T6253/146** is used. This consists of an injector clamp and fuel feed adaptor (**Fig. 10P**) which is used in conjunction with the recommended nozzle '**Testmaster**' (**Fig. 15P**) Part No. **T6253/208**.

### SETTING UP INJECTOR FOR TESTING

Ensure the reservoir of the nozzle '**Testmaster**' is filled with calibration fluid to the correct level, which is half way up the sight tube.

**Key**
**(Fig. 15P)**

1 Illuminated spray chamber
2 Light switch
3 High pressure pipe
4 Clock
5 Pressure gauge
6 Fuel control valve
7 Gauge isolator
8 Switch for extractor fan on/off
9 Filler cap
10 Fuel outlet
11 Hand lever
12 Sight tube
13 Tank drain
14 Inclined support
15 Quick action clamp

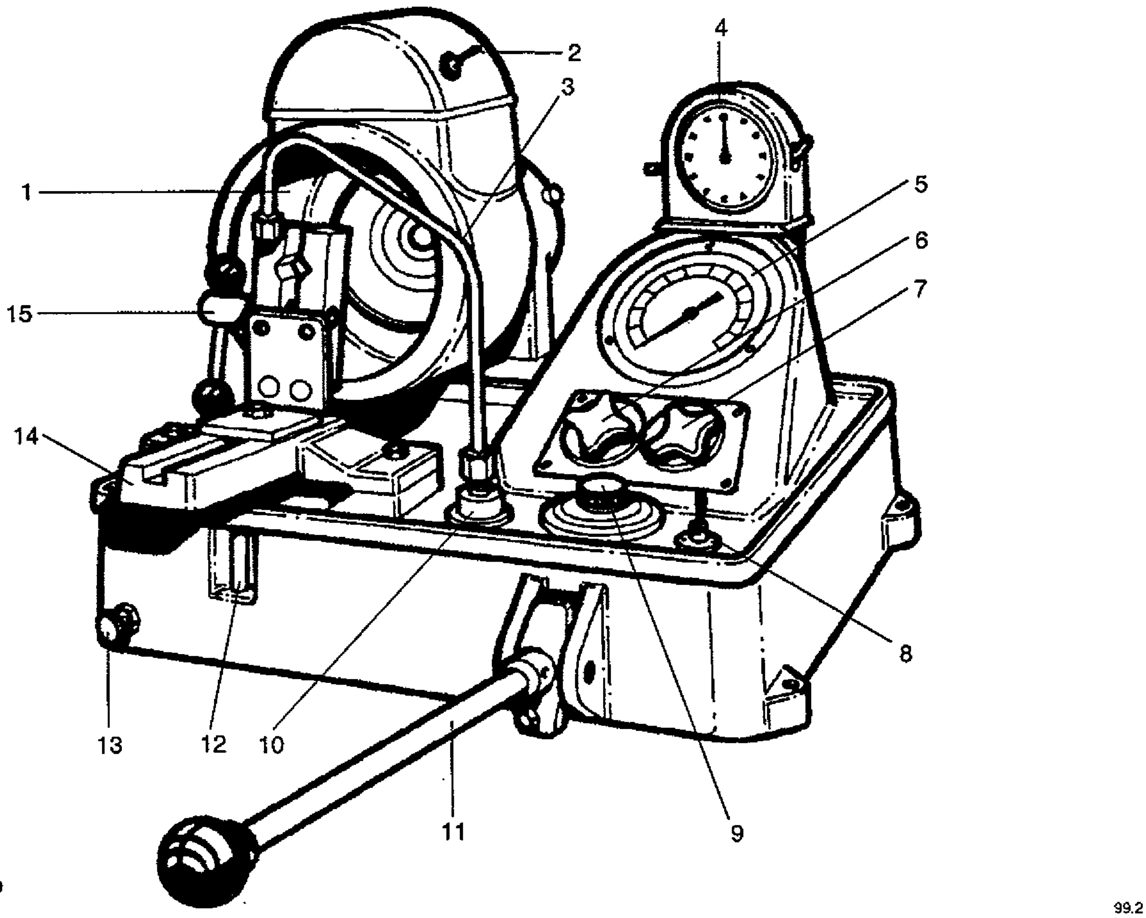



**Fig. 15P**

Slot the injector into the injector clamp Part No. **T6253/146A** with dowel fitting uppermost. Grease the oil seal Part No. **T6253/146B** on the fuel feed adaptor and fit the adaptor with a rotating pushing motion to avoid damaging the oil seal, through the clamp into the element housing and lock in position with the knurled nut (see **Fig. 10P**).
**NOTE:** Oil seal Part No. **T6253/146B** usually requires changing after 10/15 injector tests.

Place the injector for testing loosely in the jaws of the quick action clamp (15) (**Fig. 15P**) and connect the high pressure pipe (3) to the fuel feed adaptor (**Fig. 10P**). Adjust the clamp on the inclined support (14) (**Fig. 15P**) to position the injector nozzle tip inside the spray chamber (1). Tighten the clamp and ail pipe connections.

**NOTES:**

(1) The fuel control valve when closed completely isolates the injector from the hand pump. The degree of opening restricts the amount of test oil which can be delivered to the injector.

(2) The gauge isolator, when closed, isolates the pressure gauge from the high pressure circuit, which eliminates the damping effect of the gauge and will prevent damage to it when testing for atomisation and chatter. If pressure should become trapped in the gauge, release the gauge isolator a very small amount to let the pressure fall slowly. Only fingertip pressure is required to operate both this control and the fuel control valve.

**PRESSURE SETTING (REFER TO FIG. 15P)**
**NOTE:** A tolerance of $\pm$ 5 bar is permissible when adjusting the injector pressure setting with shims (Refer to **Section P8** for shim data).

(a) Close the gauge isolator.

(b) Open the fuel control valve one full turn.

(c) Switch on the extractor fan.

(d) Operate the hand lever smartly until all air is expelled from the injector.

(e) Close the fuel control valve and set the gauge pointer to 'ZERO', then open the valve the minimum amount that will allow the injector to operate when pressing down hard on the hand lever. Note reading on the scale.

(f) Open the gauge isolator. Depress the hand lever and note the highest pressure on the gauge before the nozzle 'pops', indicating needle valve opening. Adjust as necessary to 234 bar (231 atm) (3400 lbf/in$^2$) (23400 kPa), by adjustment of the shim thickness as described in **Section P7**.

(g) With the gauge isolator open, raise the pressure to approximately 220 bar (218 atm) (3200 lbf/in$^2$). Release the hand lever and allow the pressure to fall naturally, **timing** the drop of the gauge needle from 207 bar (204 atm) (3000 lbf/in$^2$) (20700 kPa) to 138 bar (136 atm) (2000 lb/in$^2$) (13800 kPa). For a nozzle in good condition, this time should be between 8 and 60 seconds with the test oil at a temperature of 68°C - 70°C (20°C - 21°C).

**NOTES:**

(1) When carrying out this test, observe that no leakage occurs at the lapped pressure faces of the element housing, transfer block and nozzle body.

(2) Leakage may be external, when it is visible at the nozzle nut screw thread, or internal, in which case it cannot be readily distinguished from excessive leakage past the lapped portion of the needle valve. If leakage at the pressure faces is suspected, do not overtighten the nozzle nut in an effort to cure such a leakage. Remove the nozzle assembly and re-examine the pressure faces for signs of dirt or surface imperfections. Clean thoroughly, and if everything appears to be in order replace the components and retest. If the pressure drop time is still low, this indicates excessive leakage past the lapped portion of the needle valve.

(3) Restricted back leakage, i.e. the pressure drop takes longer than 60 seconds, is indicative of insufficient clearance between the nozzle bore and needle valve, possibly brought about by lacquering, which may cause seizure of the needle valve in its bore.

(4) These back leakage figures apply to the nozzle 'Testmaster' only.

**SEAT TIGHTNESS TEST**

This test comprises holding a pressure 7 bar (6.8 atm) (100 lbf/in$^2$) (700 kPa), below the injector release pressure (d) and observing the nozzle tip for leaks.

(a) Switch off the extractor fan.

(b) Open the fuel control valve.

(c) Open the gauge isolator.

(d) Depress the hand lever and check the injector nozzle release pressure is set at 234 bar (231 atm) (3400 lbf/in$^2$) (23400 kPa).

(e) Wipe the nozzle tip dry.

(f) Depress the hand lever and raise the pressure to approximately 7 bar (6.8 atm) (100 lb/in$^2$) (700 kPa) below the release pressure as shown in (d) and maintain for 10 seconds.

(g) Allow pressure to drop to 207 bar (204 atm) (3000 lb/in$^2$) (20700 kPa) and check for seat leakage. The nozzle tip should be dry and there should be no tendency for blobs of fuel to collect or drip. A slight dampness may be ignored.

**DO NOT** allow fuel to run down the injector from the leak-off drilling and give a false impression during the test.

**SPRAY FORMATION AND CHATTER TEST**

The nozzle must atomise the fuel completely to produce a regular spray pattern entirely without dribble or hosing. The spray from each nozzle hole should be the same shape.

(a) **CLOSE THE GAUGE ISOLATOR VALVE**, if the valve is open the nozzle will not function properly and the **PRESSURE GAUGE MAY BE DAMAGED.**
(b) Switch on the extractor fan.
(c) Set the fuel control valve to minimum flow rate.

**Chatter Test** - With the gauge isolator closed operate the pump lever at the slowest possible rate at which the nozzle can be made to discharge. Under these conditions the nozzle must discharge with a sharp and crisp chattering action. It must be impossible to make the nozzle squirt or dribble by working the test pump at any speed.

**Spray Form** - With the gauge isolator valve closed, operate the hand lever at a speed of 90 - 100 strokes per minute and check that the spray from each hole is well atomised, of regular form and free from ragged edges. All sprays must be equal and correctly spaced.

**Release Pressure** - Open the gauge isolator valve, check that injector is opening at the pressure of 225-235 atmospheres. Close the gauge isolator valve, operate the pump a few times to ensure that all components have settled and finally re-check the pressure.

**Pressure Gauge** - Before removing the injector from the test pump, close the gauge isolator valve to prevent damage to the pressure gauge which may result from a sudden drop in pressure.

If the injector is not being fitted immediately, blank off the inlet and leak-off drillings with masking tape and fit a protective cap over the nozzle assembly.

## TO PREPARE THE ENGINE AND FIT THE INJECTORS

### FLUSHING PROCEDURE (FIG. 16P)

**NOTE:** In order to eliminate the risk of introducing swarf, dirt or any other contaminants into the pump injector after cylinder heads and fuel pipes have been removed and refitted, a dummy fuel injector (1) **T6253/138 must be fitted to each cylinder head injector sleeve**, and the complete low pressure fuel system beyond the filter (6) flushed through using a slave pump (8) and filter (6) to ensure that the fuel system is perfectly clean, before the injectors are fitted to the individual cylinder heads.

Assuming the cylinder heads and fuel pipes are fitted carry out the flushing procedure as follows:

### STARTING WITH 'A' BANK

**NOTE:** Cylinders designated 'A' bank are on the left side of the engine when viewed from the front i.e. opposite end to the flywheel.

Check to ensure that the injector sleeve in each cylinder head is clean and free from carbon.

Take the dummy fuel injectors (1) **T6253/138** with copper sealing washer (**Fig. 7P**) and clamp one into each cylinder head injector sleeve.

Using a suitable slave pump (8) with a suction pipe (9) from a reservoir (10), and where possible, a spare fuel filter at (6), couple a ½" BSP adaptor for a flexible pipe (7) to the inlet side of the fuel filter (5) as shown, and a ½" BSP adaptor for a flexible return pipe (11) from the fuel rail non return valve (13), with the other end of the pipe draining into the reservoir (10).

Fill the reservoir (10) with Shell calibration fluid type 'C' or 'B'. Start and run the slave pump (8) for at least ten minutes.

Repeat the above procedure for 'B' bank.

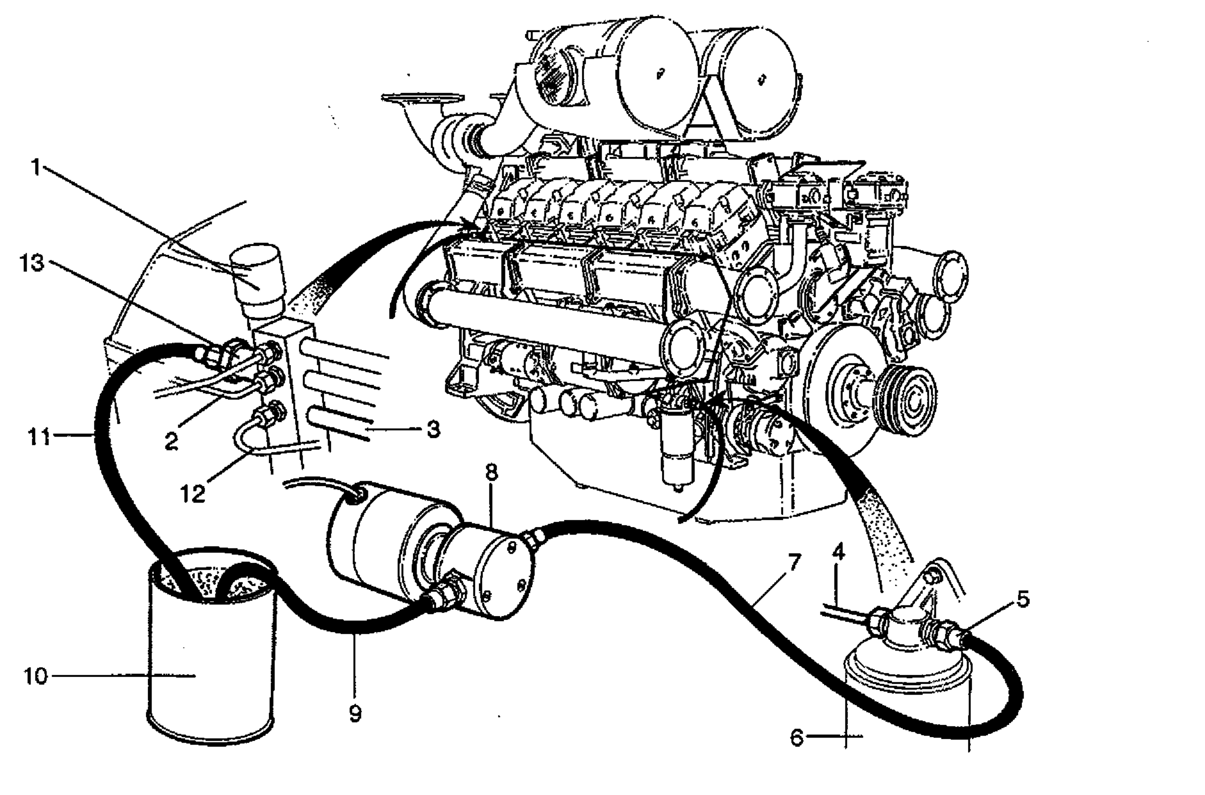



Fig. 16P

**NOTE:** Cylinders designated 'B' bank are on the right side of the engine when viewed from the front of the engine I.e. opposite end to flywheel.
When flushing is completed drain the fuel system.
Using a suitable M16 bolt, remove the dummy injector from each cylinder head. Cover the cylinder heads if the pump injectors are not fitted immediately.
Remove the flushing pipework and refit the pipes from the engine driven fuel pump.
Renew the fuel filters.

**Key**
**(Fig. 16P)**

1 Dummy injector
2 Pipe - fuel return from cylinder head
3 Fuel feed rail
4 Fuel feed pipe - outlet from filter to feed to rail
5 Inlet connection to filter
6 Fuel filter
7 Flexible pipe -with ½" BSP adaptors slave pump to filter
8 Slave pump - pressure setting 40 lb/in²
9 Flexible pipe - slave pump suction
10 Reservoir - for calibration fluid
11 Flexible pipe - with ½" BSP adaptors return rail to reservoir
12 Pipe - fuel feed to cylinder head
13 Check valve - return rail

## TO FIT THE INJECTOR

**WARNING** ⚠ TO ELIMINATE THE RISK OF COMBUSTION GASES ENTERING THE FUEL SYSTEM, ENSURE THAT THE CYLINDER HEAD INJECTOR SLEEVE IS FREE OF CARBON DEPOSITS, ETC.

## REPLACING THE INJECTORS

Fit new 'O' rings and a new soft copper sealing washer. **Fig. 17P**. Lightly grease the 'O' rings to assist fitting. A dab of grease on sealing washer will hold it in place when fitting the injector.
**NOTE:** The injector washer thickness is 2 mm ± 0.1 and must be softened by annealing. Thickness other then this will cause leakage and binding of the governing mechanism due to incorrect height of the injector in the head.

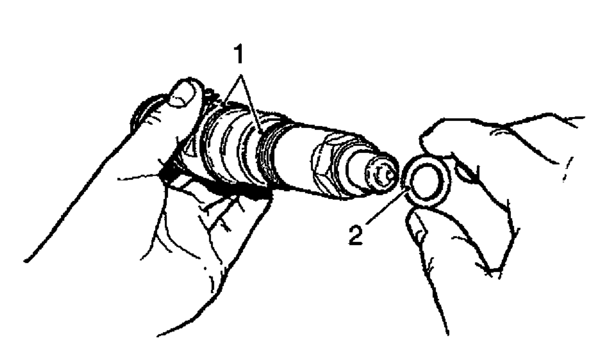


**Fig. 17P**

Before fitting the injector, check that no dirt or cleaning rag has found its way into the cylinder head and that the old copper washer has been removed. If not extract it with suitable wire hook.
Check that the chamber in the cylinder head is free from burrs and smooth it if necessary with a small scraper, taking care not to let debris fall into the engine.
Place the injector clamp in the slots of the pump body and insert the injector into the head. Fit the clamp capscrew 2-3 threads. Finally seat the injector by pushing it down with an anti-clockwise motion until it is finally down. This will ensure that any slack between the injector body and the clamp, and the clamp and the bolt, is taken up in the same direction for all injectors.
Tighten the clamp capscrew to the required torque (see **Torque Settings pages 38-40**).
Repeat this procedure for all injectors that need to be replaced.

**Key**
**(Fig. 17P)**

1 'O' rings
2 Copper sealing washer

## CALIBRATION AND TIMING

To ensure that all aspects of calibration and timing are covered, including early and later rockers and injectors, the following text has been divided into four parts. Parts 'A' and 'C' deal with calibration and parts 'B' and 'D' are for timing purposes. See table in **Section P14** for the appropriate part.

Identification of the various injectors and rockers can be made by removing the rocker covers and using the diagrams below.

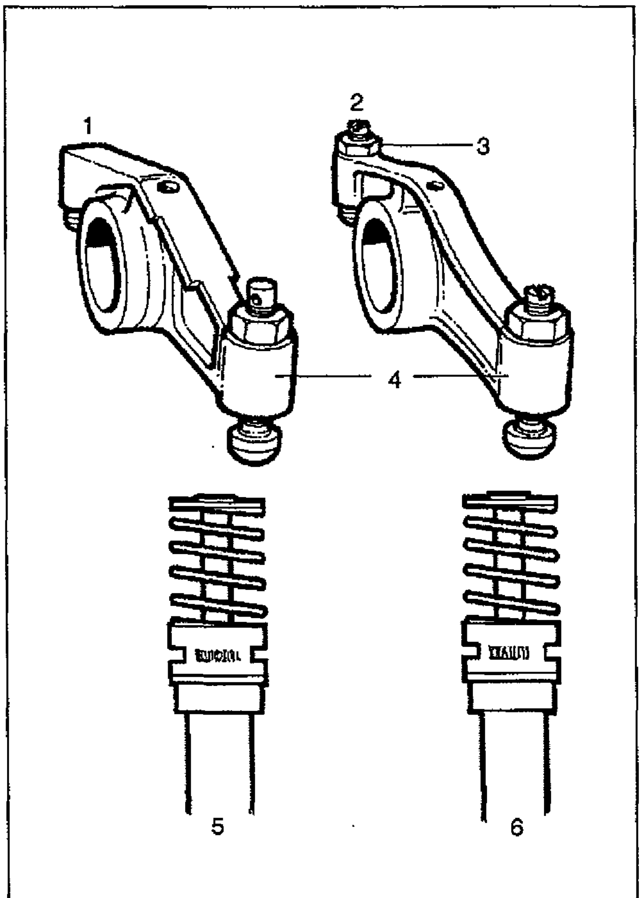



**Fig. 18P**

**Key**
**(Fig. 18P)**
**1** Later type
**2** Earlier type
**3** Push rod end adjustment
**4** Injector end adjustment
**5** Later type
**6** Earlier type

**TABLE**

| INJECTORS AND ROCKERS FITTED | ENGINE | SUB-SECTION TO USE | |
|---|---|---|---|
| ON 4012 ENGINE 12232/1287/001 AND AFTER | 4012 | ~~CALIBRATION~~ | ~~TIMING~~ |
| LATER INJECTORS (3 OR MORE) | 4012 (UPRATE) | 'A' P14 | |
| LATER INJECTORS (1 OR 2) | 4016 | 'A' P19 | |
| LATER ROCKERS (1 OR 2 INJECTORS) | 4016 (UPRATE) | | 'B' P20 |
| LATER ROCKERS (3 OR MORE INJECTORS) | | | 'B' P24 |
| ON 4012 ENGINE 12232/1287/001 | 4012 | | |
| EARLIER INJECTORS (3 OR MORE) | | 'C' P26 | |
| EARLIER INJECTORS (1 OR 2) | | 'C' P31 | |
| EARLIER ROCKERS (1 OR 2 INJECTORS) | | | 'D' P34 |
| (3 OR MORE INJECTORS) | | | 'D' P36 |

**NOTE:** Earlier injectors can be replaced by the later injectors providing they are replaced in full sets, the later calibration tool (No. **T6253/177**) is used and appropriate instructions are followed for setting up purposes as detailed in this manual. However, it is not possible to fit earlier injectors instead of the later injectors.

**WARNING** ⚠ DO NOT FIX A MIXTURE OF LATE AND EARLY INJECTORS WITHIN THE SAME ENGINE.

**CALIBRATION (SUB-SECTION 'A' LATER INJECTORS 3 OR MORE)**
**3 OR MORE INJECTORS**

If **3** or more injectors are to be renewed, then assuming that the governor/fuel pump linkage has **not** been disturbed, fit new or serviced injectors according to the fitting instructions. Adjust link the (between the break back lever and the fuel pump control arm) ensuring equal lengths of thread show at each end of the turnbuckle.

If the governor/fuel pump linkage has been disturbed then the linkage will need to be reset (refer to **Sections BB4 & 5**).

Connect to the pump injector control arms, not forgetting to place the spacing collar between the ball joint and the arm. (**Fig. 20P**). Lightly tighten the capscrews at this stage.

**NOTE:** It was essential that the large bodied left hand thread ball joint was fitted at the break back lever end of the assembly to avoid interference with the rocker, but this is no longer necessary as the current ball joints are smaller and the policy now is to fit the left hand one to all injectors. (**Fig. 21P**).

**Key**
**(Fig. 19, 20 & 21P)**

1 Left hand threads (latest engines) (see **NOTE above**).
2 Right hand threads (all engines)
3 Collar
4 Injector tang
5 Control arm
6 M5 Capscrew
7 Adjustable link
8 Break back lever

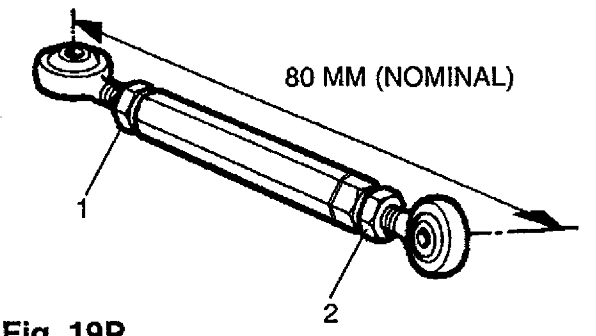



**Fig. 19P**

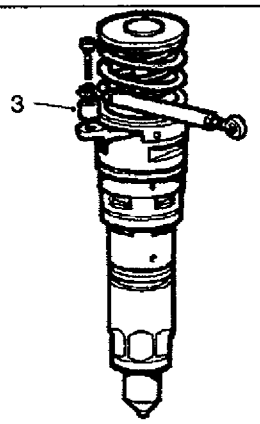



**Fig. 20P**

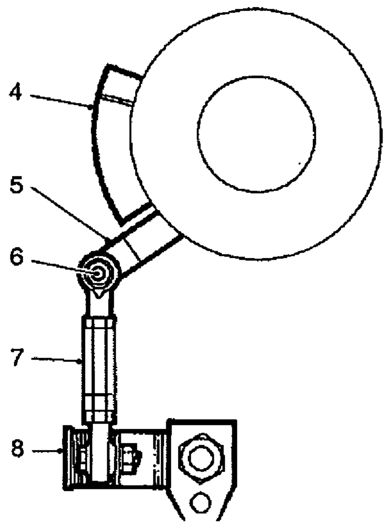



**Fig. 21P**

Bolt compression tool (Tool No. **T6253/147**) in place on all cylinder heads **Fig. 22P** and adjust screws until all pump injectors are lightly compressed. This makes movement of injector controls much easier and avoids the danger of the break-back levers opening up and falsifying the position of the injector control levers.

The break-back linkage must be closed on all injectors at all times during calibration procedure. See **Fig. 23P**.

With the governor actuator lever in position '2' on the Regulateurs Europa type 2100 (**Fig. 24P**) and the governor actuator pointer at 10% on the Heinzmann type E16 (**Fig. 26P**) the injector control arm No. A1 cylinder must be back towards break-back lever from the calibration mark in the **NO FUEL** position (see **Fig. 24P**).

**Key**
**(Fig. 24P)**

1 Approximate full load position
2 Calibration position
3 Injector tang
4 Approximate no fuel position

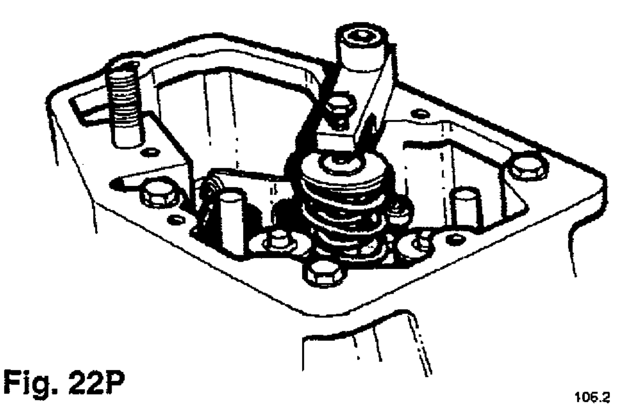


**Fig. 22P** 106.2

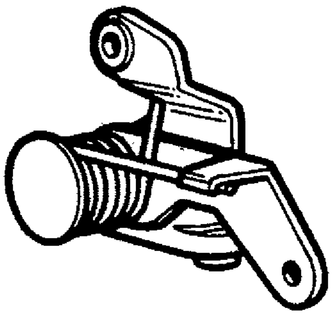


**Fig. 23P** 1070.2

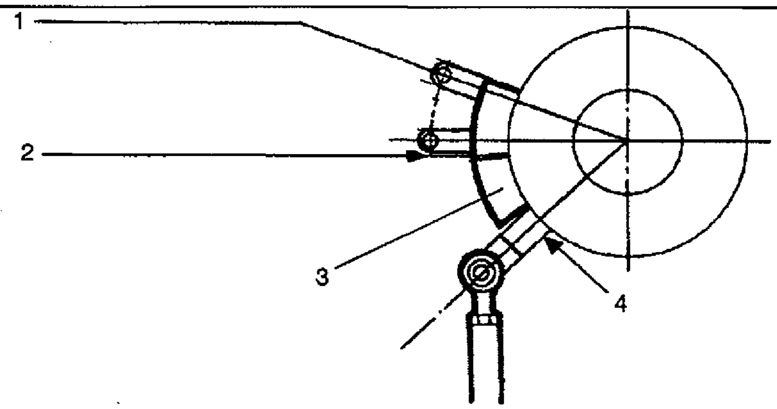


**Fig. 24P** 522.2

A service tool (**T6253/177**) must be used when calibrating the pump injectors, as shown in **Fig. 25P**.

The curved section of the calibration tool is held against the injector spring with the step at line 'A' held against the control arm (see **Fig. 25P**). Line 'B' on the calibration tool should then either coincide with the inscribed mark on the injector tang, or be further anti-clockwise viewed from the top, i.e. towards **NO FUEL**.

For engines fitted with Regulateurs Europa type RE2100 governors, which are conveniently scaled, **NO FUEL** position on the pumps must coincide with the governor lever in position '2' from the zero travel position (see **Fig. 26P**).

**Key**

**(Fig. 25P)**

1 Incorrect
2 Correct (no fuel)
3 Also satisfactory

**(Fig. 26P)**

1 No load position
2 Maximum fuel position

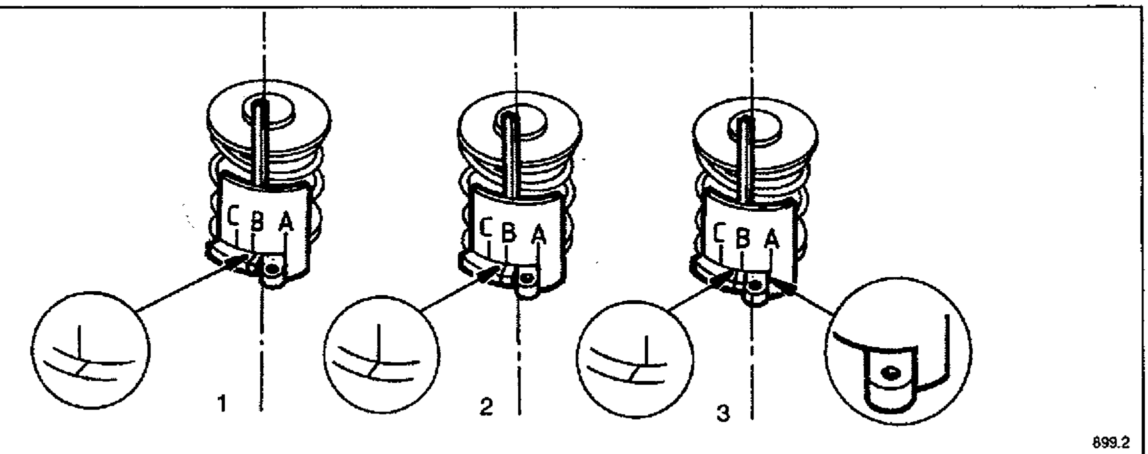



**Fig. 25P**

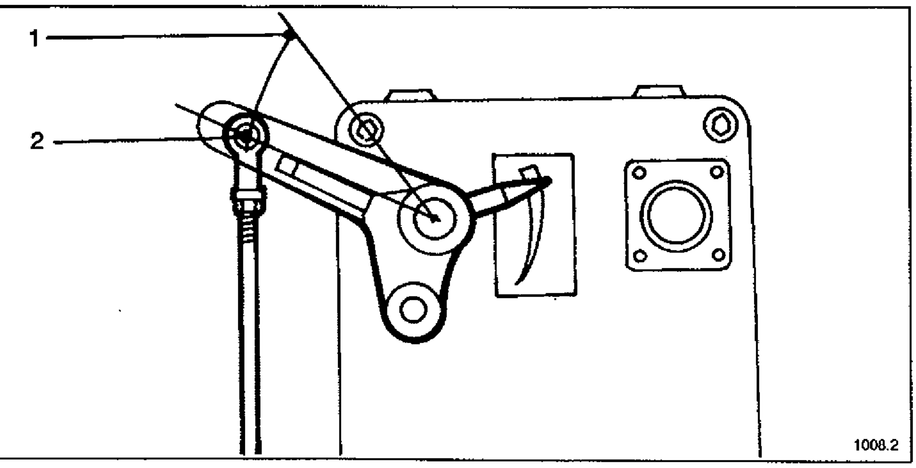



**Fig. 26P**

The link length of No. A1 cylinder injector (i.e. No. A1 cylinder is the first cylinder in the left hand bank viewed from opposite end to flywheel) must be adjusted such that the injector is in the **NO FUEL** position with the governor or actuator lever at position '2' on the Regulateurs Europa type 2100 and at 10% on the Heinzmann type E16. It is essential to ensure that equal lengths of thread show on the ball joint legs.

Set the governor/actuator lever so that No. A1 injector control arm is in the calibration position (see **Fig. 27P**). An assistant to hold the governor lever or stop control lever in the required position is invaluable, otherwise a carefully placed wedge will suffice. **Remove after use before attempting to start the engine.**

Adjust the link length on all other injectors, until they too are in the calibration position. This means slackening off the two locknuts and adjusting the distance between the ball joint centres by turning the turnbuckle, which has left and right hand threads.

Early engines were not fitted with left and right hand threaded turnbuckles, so adjustment means removing the capscrew at the ball joint to control arm end of the adjustable link, slackening off the two locknuts and either shortening or lengthening the ball joint centre distance until the control arm is in the calibration position when the link is re-fitted. Adjust each ball joint on individual links equally.

Check by moving the actuator to zero and bringing forward until No. 1 is at calibration. All other injectors must be in calibration otherwise damage to the engine may result.

It is now important to check manually that all the control arms can be moved to the **NO FUEL** position as **Fig. 25P**, **Section P16** using tool No. **T6253/177** when the governor lever is at position '2' on the Regulateurs Europa type 2100 (**Fig. 26P**) and the governor actuator pointer is at position 10% on the Heinzmann type E16 (**Fig. 28P**) (typical installation).

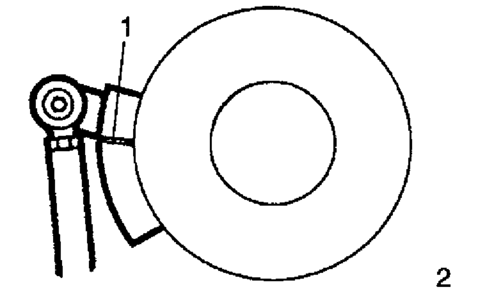



**Fig. 27P**

In the unlikely event of one or more injectors not complying, then the link length of the one in error must be adjusted until satisfactory movement is obtained, then this cylinder used as a master instead of No. 1 and the complete procedure repeated **(zero fuel and calibration).**

Check to see that at no point in their travel do the ball joints bind. (The ball joints at the end of each link should be at 90° to each other for correct operation). **Tighten all locknuts and capscrews.**

**Key**
**(Fig. 27P)**

**1** Calibration mark
**2** No. 1 Cylinder

**SEQUENCE OF EVENTS FOR CALIBRATION 'A'**
Set the link length on No. A1 injector.
Check No. A1 injector control arm goes to **NO FUEL** when the actuator level is at position '2' on the Regulateurs Europa type 2100 and then the actuator pointer is at position 10% on the Heinzmann type E16 using tool No. **T6253/177, Fig. 29P**.
With No. A1 injector in the calibration position (1 **Fig. 30P**) (obtained only by holding the governor actuator lever) adjust the link lengths of the other cylinders to bring them into calibration (see **Fig. 30P**).
Check all injectors can travel to **NO FUEL** by moving actuator lever to position '2' on the Regulateurs Europa type 2100 and position 10% on the Heinzmann E16 actuator pointer using tool No.**T6253/177**.
It is vital for safety purposes to avoid a run away situation that the actuator can bring the injectors to **NO FUEL**. (See **Fig. 31P** for acceptable positions). Position '2' on Regulateurs Europa and position 10% on the Heinzmann actuators.

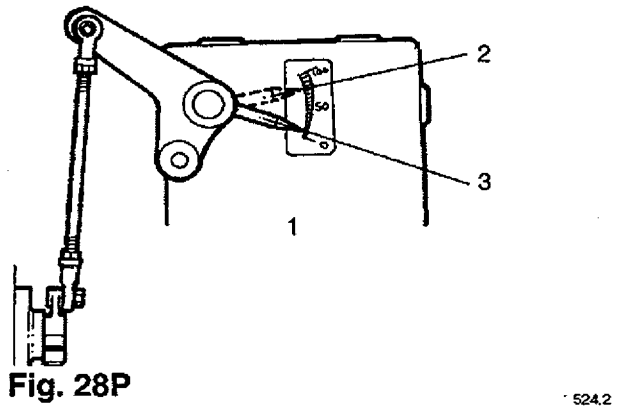


Fig. 28P

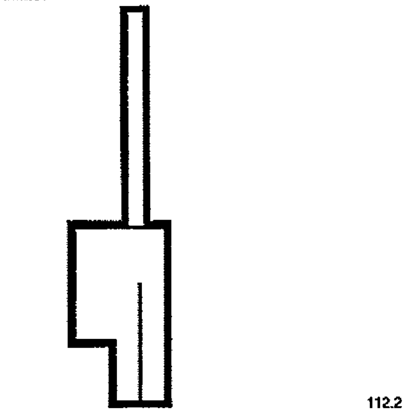


Fig. 29P

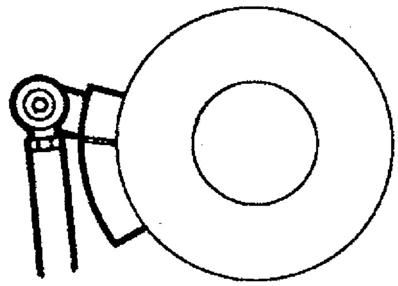


Fig. 30P

**Key**
**(Fig. 28P)**
**1** Heinzmann E16 governor actuator
**2** 80% full fuel position
**3** 10% shut off

**(Fig. 31P)**
**1** Incorrect
**2** Correct (no fuel)
**3** Also satisfactory

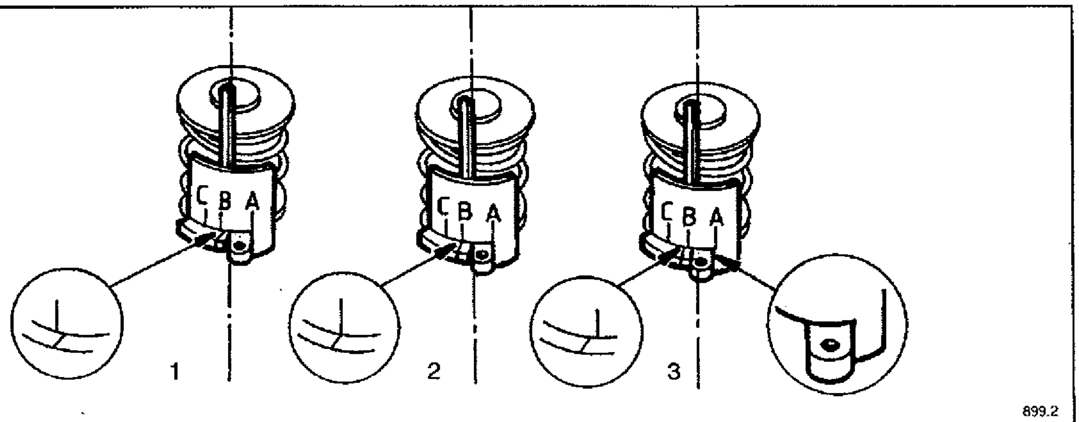


Fig. 31P

**TIGHTEN ALL SCREWS AND LOCKNUTS SECURELY ON LINKAGES, NOT FORGETTING CAPSCREWS HOLDING BALL JOINTS TO CONTROL ARMS.**

Remove the pump injector compression bars.

**Remove any wedges used in holding the governor levers during the calibration operation.**

Fit rockers, shaft, push rods, etc.

If you encounter any problems, contact your nearest Agent who will be pleased to advise and help.

**CALIBRATION (SUB-SECTION 'A' LATER INJECTORS 1 OR 2)**

**1 OR 2 INJECTORS**

If only 1 or 2 injectors are to be renewed, then assuming that the governor to fuel pump linkage has not been disturbed, fit new or serviced injectors according to the fitting instructions. Adjust the link(s) between the break back lever(s) and the fuel pump control arm(s) ensuring equal lengths of thread show at each end of the turnbuckle(s).

If the governor to fuel pump linkages have been disturbed, then these will need to be reset (refer to **Sections BB4 & 5**).

Connect the connecting link(s) to the pump injector control arm(s), not forgetting to replace the collar(s) between the ball joint(s) and the arm(s).

Compress pump Injector(s) 2-3 mm with Tools No. **T6253/147. Fig. 32P.**

This makes movement of controls much easier and obviates danger of the break-back linkage opening up and falsifying positions of levers.

Set No. A1 injector (or another injector already fitted if No. A1 is being renewed) to calibration mark **Fig. 33P** by moving governor lever or stop control lever. It may be necessary to have an assistant to hold this in place or use a carefully placed wedge.

**REMOVE THIS BEFORE STARTING THE ENGINE.**

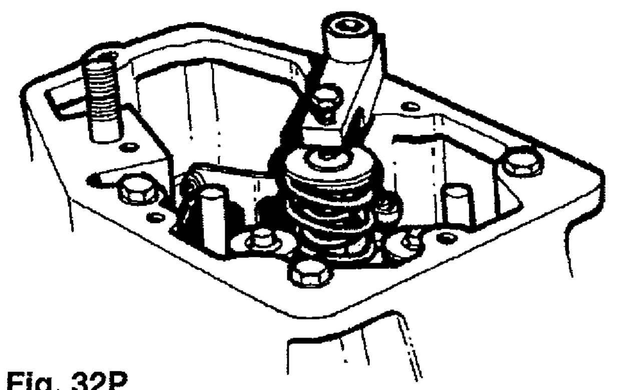


**Fig. 32P**

106.2

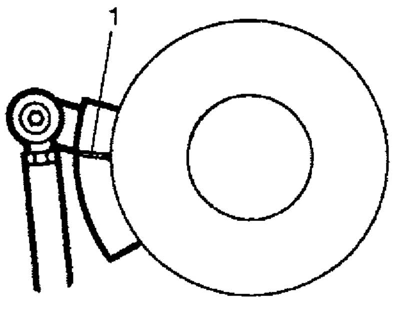



**Fig. 33P**

111.2

Check to see that any replaced injector is in calibration.

If not in calibration, adjust the link length by slackening off the right and left hand threaded locknuts and rotating the turnbuckle, retightening the locknuts when the correct length is achieved. Early engines did not have RH/LH threads and it was necessary to detach the link and refit it after adjustment to the injector control arm (not forgetting the collar) and checking the calibration again.

**Key**
**(Fig. 33P)**

1 Calibration mark

**Tighten all locknuts and capscrews after seeing linkage is free to rotate on ball joints. These should be at 90° to each other.**

With the governor lever at position '2' on the Regulateurs Europa type 2100 or the actuator pointer at 10% on Heinzmann type E16, the injector control arm on all injectors must be in the **NO FUEL** position see **Fig. 24P** use tool No. **T6253/177** to check as shown in **Fig. 29P** and **31P**. See also **Fig. 25P, Section P16** for operation.

**Remove all wedges, etc., that may have been used to position the governor controls.**

Remove the compression bar(s).

Fit the rockers, shafts and push rods.

If you encounter any problems, contact the nearest Agent, who will be pleased to help and advise.

**NOTE:** After a rebuild with new injectors, the engine must be run on full load (max. site load) and the fuel stops reset (see **Section BB5**). It may also be necessary to reset the governor controls.

**TIMING (SUB-SECTION 'B' LATER ROCKERS 1 OR 2 INJECTORS)**

Refer to Engine Nameplate for injection timing.

**EQUIPMENT**

Dial Test Indicator (DTI) Mounting pad or stand for DTI and a small tommy bar (3mm or $^1/_8$" diameter).

## 1 OR 2 INJECTORS

Refit the bridge pieces to the guides they were removed from, lightly oiling the stems. Ensure that they are correctly located on each valve. Loosen the locknut on each bridge piece, screw the adjuster out until the fixed side of the bridge piece rests on its valve, hold the top edge of the bridge piece with one hand, **Fig. 34P**, then screw the adjuster down until you feel it touch the other valve, thereby equalising valve lift.
Tighten the locknut without moving the adjuster.

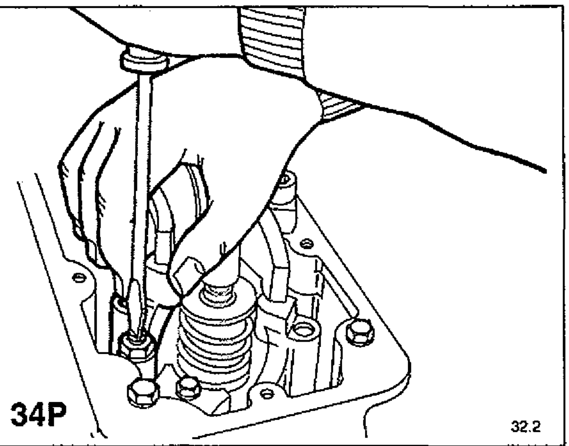


Fig. 34P

32.2

**WARNING** ⚠ FAILURE TO EQUALISE THE VALVE LIFT IN THIS WAY MAY LEAD TO BENDING AND CONSEQUENT FAILURE OF THE BRIDGE GUIDE, FOLLOWED BY FURTHER DAMAGE TO THE ROCKER GEAR AND CYLINDER HEAD ITSELF. ALSO IF FITTING NEW GUIDES AND/OR BRIDGE PIECES, CHECK THAT THE MATING PARTS DO ACTUALLY FIT TOGETHER AND MOVE FREELY, BEFORE OILING THEM AND CONTINUING WITH REASSEMBLY.

Before fitting the injector rocker, slacken off the adjusting screw by two turns at least, to avoid bottoming of the injector plunger. Build up the rockers, shafts, push rods and cups. Refit, tightening the retaining nut and capscrew down to the required torque (see **Torque Settings pages 38-40**). See **Fig. 35P**.

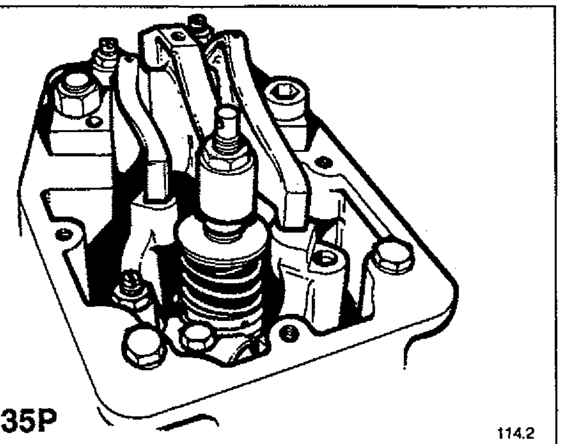


Fig. 35P

114.2

To set the valve clearances, set the engine on the firing stroke for that particular cylinder (refer to the tables below):
e.g. To adjust valves and bridge pieces on No. A1 cylinder, set No. A6 cylinder valves rocking (for 4012 engines) and No. A8 rocking (for 4016 engines).
With the appropriate valves rocking, loosen the locknut on the rocker adjuster, screw the adjuster out and slide a feeler gauge between the rocker and bridge piece **Fig. 36P**. Screw the adjuster down until it is bearing lightly on the feeler gauge. Tighten the locknut without moving the adjuster. The feeler gauge should be a slide fit (inlet and exhaust valve clearances are both 0.4 mm or 0.016" cold).

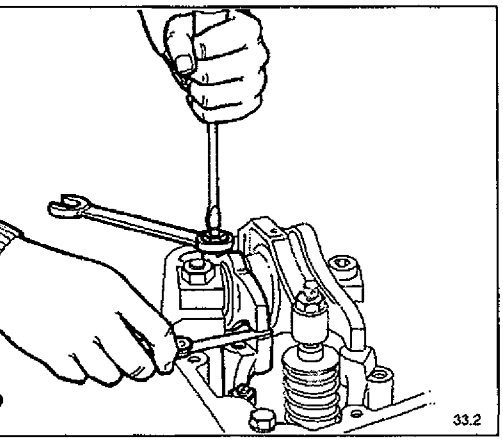


Fig. 36P

## 4012 ENGINES

| ROCKING ON CYLINDER NO. | CLEARANCES ON CYLINDER NO. | TIMING ON CYLINDER NO. |
|---|---|---|
| A6 | A1 | A3 |
| B1 | B6 | B4 |
| A2 | A5 | A6 |
| B5 | B2 | B1 |
| A4 | A3 | A2 |
| B3 | B4 | B5 |
| A1 | A6 | A4 |
| B6 | B1 | B3 |
| A5 | A2 | A1 |
| B2 | B5 | B6 |
| A3 | A4 | A5 |
| B4 | B3 | B2 |

## 4016 ENGINES

| ROCKING ON CYLINDER NO. | CLEARANCES ON CYLINDER NO. | TIMING ON CYLINDER NO. |
|---|---|---|
| A8 | A1 | A5 |
| B8 | B1 | B5 |
| A6 | A3 | A8 |
| B6 | B3 | B8 |
| A2 | A7 | A6 |
| B2 | B7 | B6 |
| A4 | A5 | A2 |
| B4 | B5 | B2 |
| A1 | A8 | A4 |
| B1 | B8 | B4 |
| A3 | A6 | A1 |
| B3 | B6 | B1 |
| A7 | A2 | A3 |
| B7 | B2 | B3 |
| A5 | A4 | A7 |
| B5 | B4 | B7 |

**NOTE:** No. A1 is injector furthest from flywheel, cylinders designated 'A' are on the left side of the engine when viewed from opposite end to flywheel.

**Key**
**(Fig. 37 & 38P)**
**1** Flywheel end
**2** Damper end

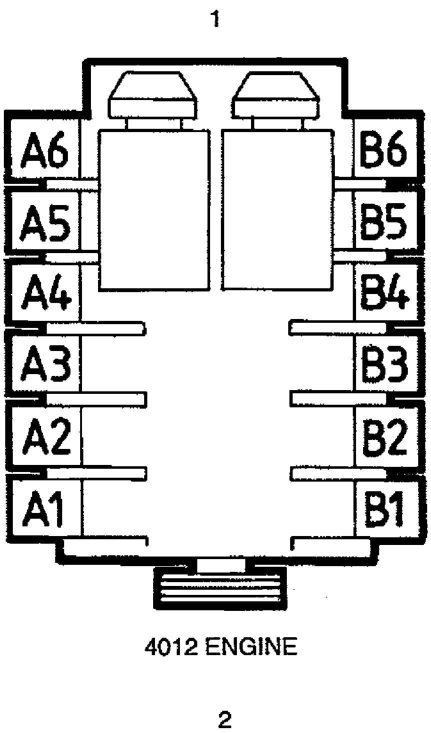



**Fig. 37P**

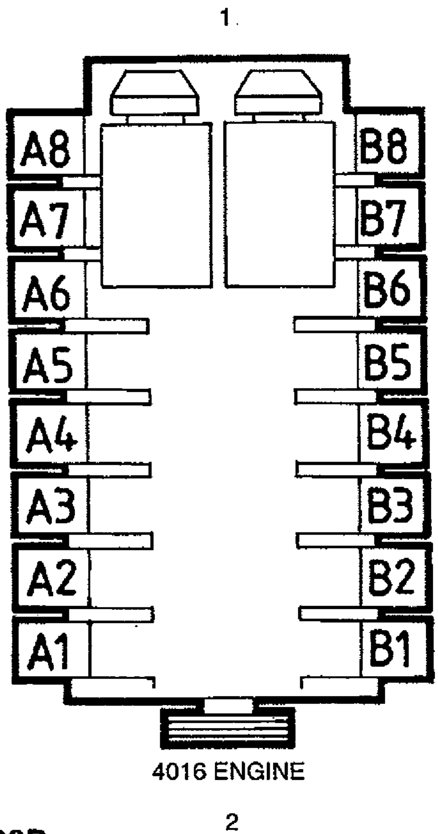



**Fig. 38P**

If the valves required to be rocking are closed, rotate the engine one revolution to bring the chosen valves to the rocking position.
Set the injector rocker of the replacement injector on the base circle of its cam, that is with the inlet and exhaust valves of the appropriate cylinder rocking (see table for 4012 and 4016 engines **Section P21**).
e.g. If No. A4 injector is being adjusted then the valves on cylinder No. A1 must be rocking for 4012 or No. A1 rocking for 4016 engines.
Mount the DTI so that the plunger is vertically above and concentric with the injector rocker adjuster, (see **Fig. 39P**).
After slackening the rocker adjuster locknut, rotate the adjuster clockwise with a tommy bar (see **Fig. 40P**) until the timing pin is felt to engage when light pressure is applied. Lightly tighten the locknut on the adjuster and **DISENGAGE** the timing pin. Now fully tighten the locknut. **Zero the dial test indicator (DTI).** Rotate the crankshaft in the normal direction of engine rotation, until the correct injection timing mark for that cylinder is reached and aligned with the timing pointer (**Fig. 41P**) for the injector being compressed.

**Key**
**(Fig. 39P)**
1 Tommy bar
2 Adjusting screw
3 Rocker adjuster locknut

**(Fig. 40P)**
1 Timing pin

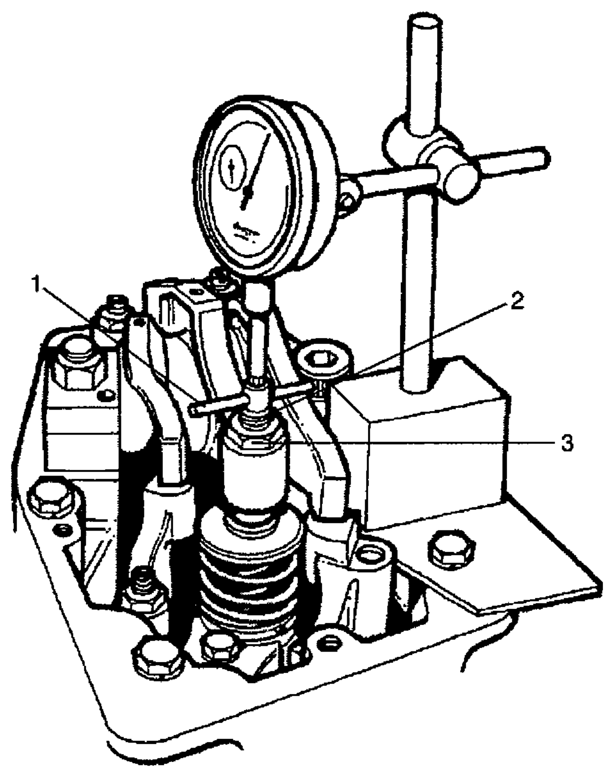


**Fig. 39P**

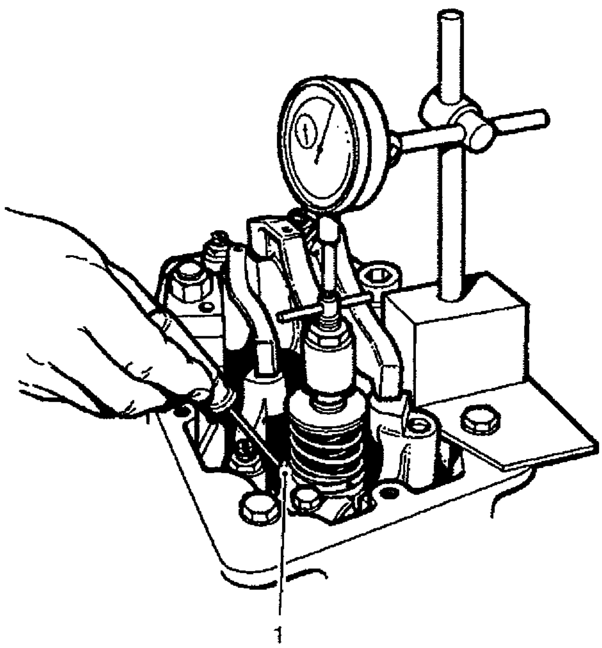


**Fig. 40P**

**4012 ENGINES**

| Flywheel Markings | Cylinder No. |
|---|---|
| SPILL - 16 | |
| SPILL - 18 | A1 & A6, B1 & B6, A2 & A5, B2 & B5 |
| SPILL - 20 | A3 & A4, B3 & B4, A1 & A6, B1 & B6 |
| SPILL - 22 | A2 & A5, B2 & B5, A3 & A4, B3 & B4 |

**4016 ENGINES**

| Flywheel Markings | Cylinder No. |
|---|---|
| SPILL - 16 | A1 & A8, B1 & B8, A3 & A6, B3 & B6 |
| SPILL - 18 | A7 & A2, B7 & B2, A5 & A4, B5 & B4 |
| SPILL - 20 | A1 & A8, B1 & B8, A3 & A6, B3 & B6 |
| SPILL - 22 | A7 & A2, B7 & B2, A5 & A4, B5 & B4 |

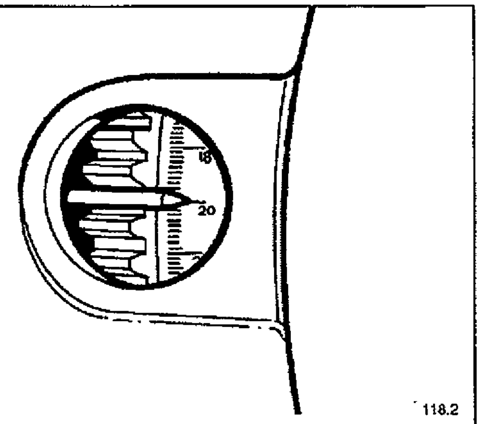


Fig. 41P

Reset adjuster until the DTI indicates that the injector has been compressed by 3 mm (0.118"). (According to timing on particular engines adjuster may need to be turned either clockwise or anti-ciockwise).
Tighten the locknut, remove the DTI and proceed to the next cylinder.

**BEFORE STARTING THE ENGINE:**
Check to see that the control linkages are free at all positions. If any tightness is found, rectify it immediately.
It is recommended that following removal and replacement of pump injectors that the engine is turned through two complete revolutions whilst the linkages are checked for freedom of movement.

## TIMING (SUB-SECTION 'B' LATER ROCKERS 3 OR MORE INJECTORS)

### 3 OR MORE INJECTORS

Refit the bridge pieces to the guides they were removed from, lightly oiling the stems. Ensure that they are correctly located on each valve. Loosen the locknut on each bridge piece, screw the adjuster out until the fixed side of the bridge piece rests on its valve, hold the top edge of the bridge piece with one hand (**Fig. 42P**) and screw the adjuster down until you feel it touch the other valve, thereby equalising valve lift.
Tighten the locknut without moving the adjuster.

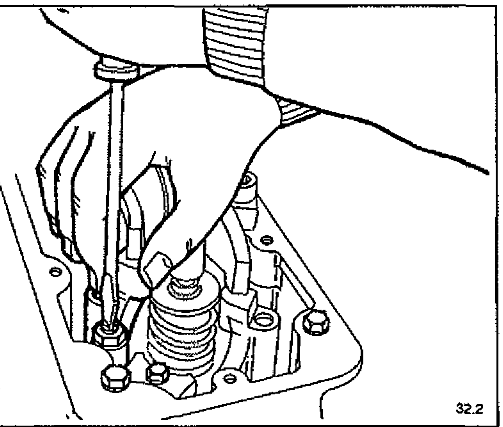


**Fig. 42P**

**WARNING** ⚠ FAILURE TO EQUALISE THE VALVE LIFT IN THIS WAY MAY LEAD TO BENDING AND CONSEQUENT FAILURE OF THE BRIDGE GUIDE, FOLLOWED BY DAMAGE TO THE ROCKER GEAR AND THE CYLINDER HEAD ITSELF. IF FITTING NEW GUIDES AND/OR BRIDGE PIECES CHECK THAT THE MATING PARTS DO ACTUALLY FIT TOGETHER AND MOVE FREELY, BEFORE OILING THEM AND CONTINUING WITH REASSEMBLY.

Before fitting the injector rocker, slacken the adjusting screw by two turns at least to avoid bottoming of the injector plunger. Build up the rockers, shafts, push rods and cups. Refit, tightening the retaining nut and capscrew down to the required torque. (See **Torque Settings page 38-40**).
The following setting method is used to reduce the number of times the engine has to be rotated.
Refer to and follow the sequence below:

## 4012 ENGINES

| VALVES ROCKING ON CYLINDER NO. | SET VALVE CLEARANCES ON CYLINDER NO. | SET INJECTOR TIMING ON CYLINDER NO. |
|---|---|---|
| A6 | A1 | A3 |
| B1 | B6 | B4 |
| A2 | A5 | A6 |
| B5 | B2 | B1 |
| A4 | A3 | A2 |
| B3 | B4 | B5 |
| A1 | A6 | A4 |
| B6 | B1 | B3 |
| A5 | A2 | A1 |
| B2 | B5 | B6 |
| A3 | A4 | A5 |
| B4 | B3 | B2 |

## 4016 ENGINES

| VALVES ROCKING ON CYLINDER NO. | SET VALVE CLEARANCES ON CYLINDER NO. | SET INJECTOR TIMING ON CYLINDER NO. |
|---|---|---|
| A8 | A1 | A5 |
| B8 | B1 | B5 |
| A6 | A3 | A8 |
| B6 | B3 | B8 |
| A2 | A7 | A6 |
| B2 | B7 | B6 |
| A4 | A5 | A2 |
| B4 | B5 | B2 |
| A1 | A8 | A4 |
| B1 | B8 | B4 |
| A3 | A6 | A1 |
| B3 | B6 | B1 |
| A7 | A2 | A3 |
| B7 | B2 | B3 |
| A5 | A4 | A7 |
| B5 | B4 | B7 |

**NOTE:** No. A1 is injector furthest from the flywheel, cylinders designated 'A' are on the left side of the engine when viewed from the opposite end to the flywheel.

**4012 ENGINES (FIG. 43P)**
Start with the valves on No. A6 cylinder (flywheel end) rocking and adjust the valve clearance on No. A1 cylinder as follows: Loosen the locknut on the rocker adjuster, screw the adjuster out and slide a feeler gauge between the rocker and bridge piece, Fig. 36P. Screw the adjuster down until the rocker is bearing lightly on the feeler gauge. Tighten the locknut without moving the adjuster. The feeler gauge should be a slide fit (inlet and exhaust valve clearances are both 0.4 mm or 0.016"cold). Repeat for the other two valves. Set the timing pin on No. A3 injector as follows: Slacken the rocker adjuster locknut, rotate the adjuster clockwise with a tommy bar (see **Fig. 40P**) until the timing pin is felt to engage when light pressure is applied. Lightly tighten the locknut on the adjuster and disengage the pin.

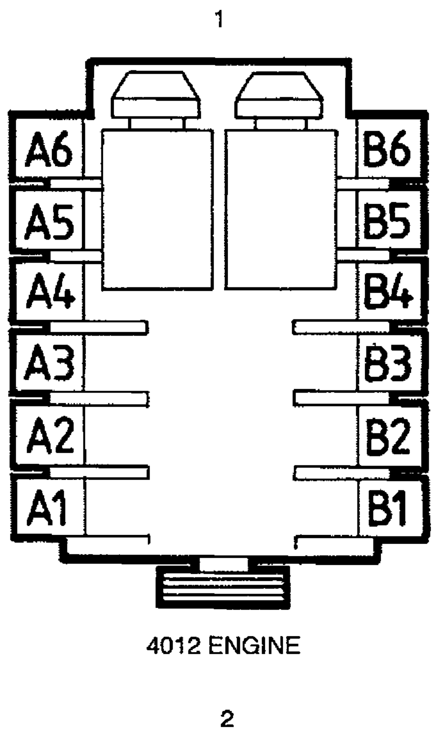



**Fig. 43P** 525.2

**4016 ENGINES (FIG. 45P)**
Start with the valves on No. A8 cylinder (flywheel end) rocking and adjust the valve clearance on No. A1 cylinder as follows: Loosen the locknut on the rocker adjuster, screw the adjuster out and slide a feeler gauge between the rocker and bridge piece, **Fig. 36P**. Screw the adjuster down until the rocker is bearing lightly on the feeler gauge. Tighten the locknut without moving the adjuster. The feeler gauge should be a slide fit (inlet and exhaust valve clearances are both 0.4mm or 0.016" cold). Repeat for the other two valves. Set the timing pin on No. A5 injector as follows: Slacken the rocker adjuster locknut, rotate the adjuster clockwise with a tommy bar (see **Fig. 40P**) until the timing pin is felt to engage when light pressure is applied. Lightly tighten the locknut on the adjuster and disengage the pin.

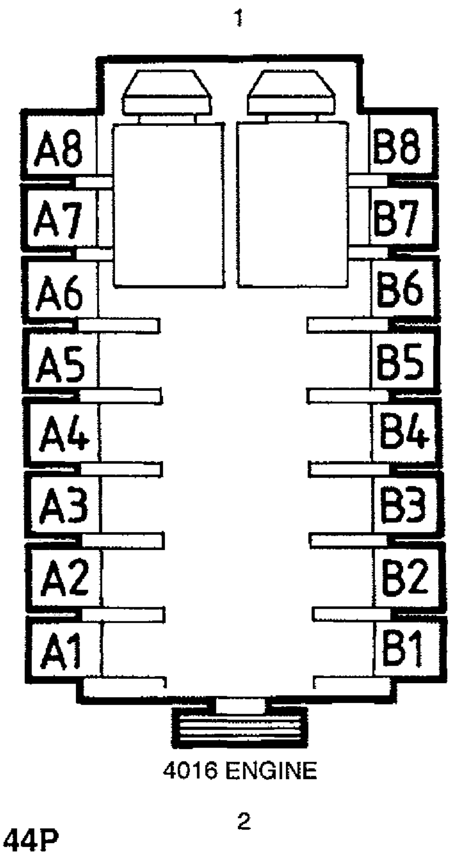



**Fig. 44P** 526.2

**Key (Fig. 43 & 44P)**
**1** Flywheel end **2** Damper end

### 4012 AND 4016 ENGINES

Follow the appropriate sequence in **Section P24** until ali cylinders are set. After setting the timing pins to the sequence do not turn the engine further at this stage. Now refer to the engine nameplate for the actual injection timing for your engine.

Set up the DTI so that the plunger is vertically above and concentric with the rocker adjuster of the next cylinder to fire (if the sequence has been followed this will be No. A1 for both the 4012 and 4016 engines) refer to **Fig. 45P. Zero the dial test indicator (DTI).** Turn the engine to the injection timing required for this cylinder, e.g. 20° No. A1 firing, in the direction of normal engine rotation. The dial test indicator above No. A1 injector will have started to move. Slacken the injector rocker adjuster locknut carefully and turn the adjuster with the tommy bar until the DTI shows that the injector is compressed by 3 mm (0.118"). Now fully tighten the locknut.

**NOTE:** The adjuster may need to be turned in either direction to achieve the correct reading of 3 mm (0.118") on the DTI. Tighten the locknut. Remove the DTI and before turning the engine further, set up the DTI on the injector end of the injector rocker of the next cylinder to fire and zero the DTI. If the sequence is followed this will be No. B6 for the 4012 or No. B1 for the 4016 (see **Section P24**).

Set the flywheel to the injection timing mark for this cylinder (e.g. 20° before TDC No. B6 or No. B1 depending whether you are working on a 4012 or 4016 engine), and adjust as for No. 1 cylinder.

Continue through the sequence given in the tables on **Section P24** until all injectors are set.

**NOTE:** Should some injectors already be fitted, it is recommended that they be included in the above sequence of setting and checking.

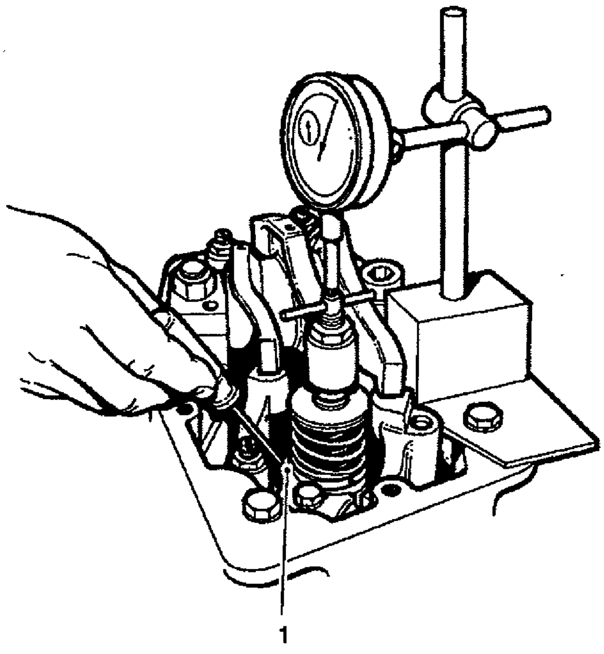



**Fig. 45P**

**Key**
**(Fig. 45P)**
1 Timing pin

**CALIBRATION (SUB-SECTION 'C' EARLIER INJECTORS 3 OR MORE)**

**NOTE: Sections P26 - 31** refer to earlier 4012 series oniy (see Table on **Section P14**).

**3 OR MORE INJECTORS**

If 3 or more injectors are to be renewed, then assuming that the governor to fuel pump linkage has not been disturbed, fit new or serviced injectors according to fitting instructions. Adjust the link (between the break back lever and the fuel pump control arm) ensuring that equal lengths of thread show at each end of turnbuckle.

If the governor to fuel pump linkage has been disturbed, then this linkage will also need to be reset (see **Sections BB4 & 5**).

Connect the links to the pump injector control arms, not forgetting to place the spacing collars between the ball joints and arms. Lightly tighten the capscrews at this stage.

**Key**

**(Fig. 46P)**

**1** Turnbuckle with left & right hand threads
**2** 80 mm nominal

**(Fig. 47P)**

**1** Collar

**(Fig. 48P)**

**1** Injector tang
**2** Control arm
**3** M5 Capscrew
**4** Adjustable link
**5** Break back lever

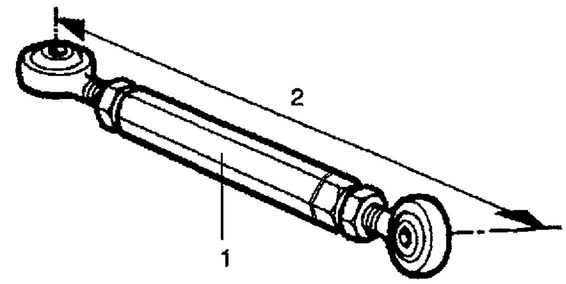



**Fig. 46P**

103.2

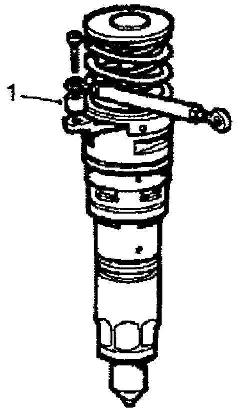



**Fig. 47P**

104.2

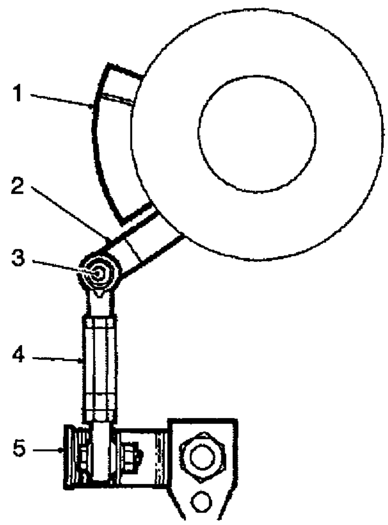



**Fig. 48P**

105.2

Bolt the compression bar (Tool No. **T6253/147**) in place on all cylinder heads, **Fig. 49P**, and adjust the screws until all pump injectors are lightly compressed. This makes movement of the injector controls much easier and avoids the danger of the break-back levers opening up and falsifying the position of the pump injector control levers.

The break-back linkage must be closed on all injectors at all times during the calibration procedure. See **Fig. 50P**.

With the governor actuator lever in position '2' on the Regulateurs Europa type 2100 (**Fig. 53P**), and the governor actuator pointer at 10% on the Heinzmann type E16 (**Fig. 55P**), the injector control arm No. A1 cylinder must be back towards break-back lever from the calibration mark in the **NO FUEL** position (see **Fig. 51P**).

Service tool No. **T6253/172**, must be used when setting up calibration for the earlier injectors, (see **Fig. 52P**).

**NOTE: The service tool for the later injectors T6253/177 must not be used.**

The curved section of the calibration tool is placed against the injector spring with its inscribed mark coincident with that on the injector tang. The control arm must then be positioned at the edge of the tool for the no fuel setting. This is the absolute minimum position, but the lever may be set further away from the edge of the tool towards **NO FUEL**. (See **Fig. 52P**).

**Key**

**(Fig. 51P)**

1 Full fuel position
2 Calibration mark
3 Injector tang
4 No fuel position

**(Fig. 52P)**

1 No fuel position edge of tool
2 No fuel

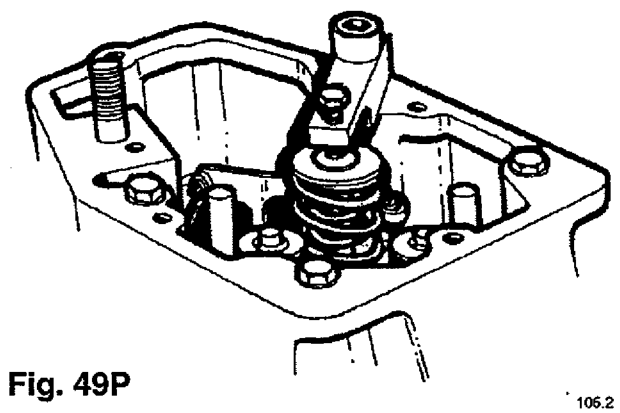


Fig. 49P

106.2

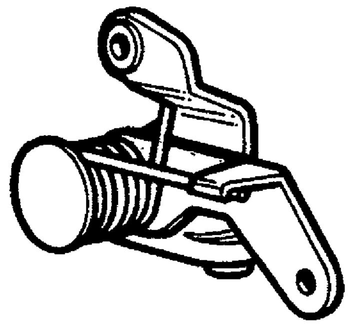


Fig. 50P

1070.2

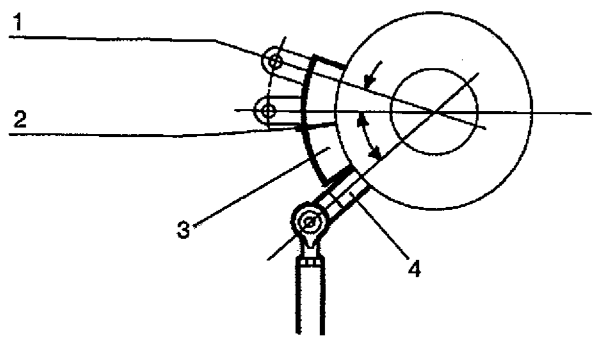



Fig. 51P

581.2

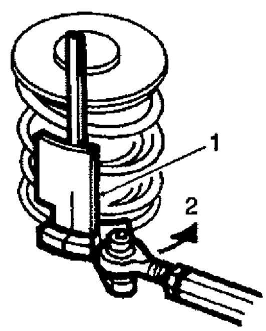



Fig. 52P

109.2

For engines fitted with Regulateurs Europa type RE2100 governor, which are conveniently scaled, the **NO FUEL** position on the pumps should coincide with the governor lever in position '2' from the zero travel position (see **Fig. 53P**).

**Key**
**(Fig. 53P)**
**1** No load position
**2** Maximum fuel position

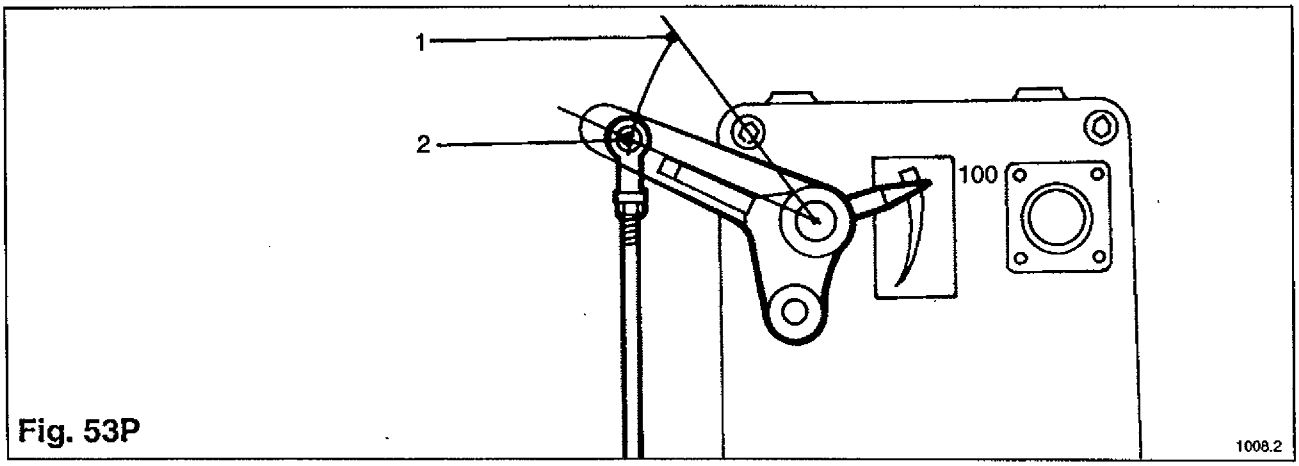



**Fig. 53P**

The link length of No. A1 cylinder injector (i.e. No. A1 cylinder is the first cylinder in the left hand bank viewed from opposite end to flywheel) must be adjusted so that the injector is in the **NO FUEL POSITION** with the governor lever on actuator at position '2' on the Regulateurs Europa type 2100 or at 10% on the Heinzmann type E16.
It is essential that equal lengths of thread show at each end of the turnbuckle on the ball joint legs.
Set the governor or actuator lever so that No. 1 injector control arm is in the calibration position (see **Fig. 54P**). An assistant to hold the governor lever or stop control lever in the required position is invaluable, otherwise a carefully placed wedge will suffice.

**REMOVE THE WEDGE AFTER USE BEFORE ATTEMPTING TO START THE ENGINE.**

Adjust the link length on all other injectors, until they too are in the calibrated position. On early engines this means removing the capscrew at the ball joint to control arm end of the adjustable link, slackening off the two locknuts and either shortening or lengthening the bail joint centre distance until the control arm is in the calibration position when the link is re-fitted. Adjust each ball joint on individual links equally and take care not to omit the spacing collar between each link and its control arm. Later engines have right and left hand threaded turnbuckles and ball joints which make this adjustment easier and safer.
Check by moving the actuator to zero and bringing forward until No.1 is at calibration. All other injectors must be in calibration otherwise damage to the engine may result.
It is now important to check manually that all the control arms can be moved to the **NO FUEL** position as **Fig. 52P, Section P28** using tool No. **T6253/172** when the actuator lever is at position '2' on the Regulateurs Europa type 2100 (**Fig. 53P**) or the governor actuator pointer is at position 10% on the Heinzmann type E16 (**Fig. 55P**).

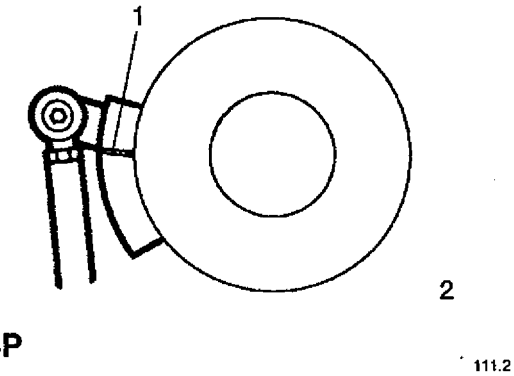


**Fig. 54P**

In the unlikely event of one or more injectors not complying, then the link length on one in error must be adjusted until satisfactory movement is obtained, then this cylinder is used as the master instead of No. 1 and the complete procedure repeated (Zero setting and calibration).
Check to see that at no point in their travel do the ball joints bind. (The ball joints at the end of each link should be at 90° to each other for correct operation). **Tighten all locknuts and capscrews.**

Key
**(Fig. 54P)**
**1** Calibration mark
**2** No. 1 cylinder

**SEQUENCE OF EVENTS FOR CALIBRATION 'C'**

Set link length on No. A1 injector.

Check No. A1 injector control arm goes to **NO FUEL** when the actuator lever is at position '2' on the Regulateurs Europa type 2100 or when the actuator pointer is at position 10% on the Heinzmann type E16 using tool No. **T6253/172**.

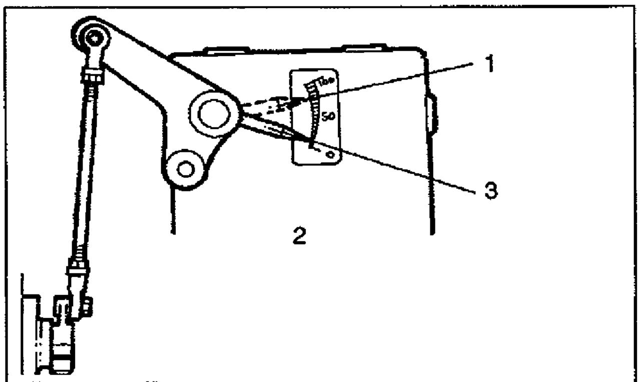



**Fig. 54.1P**

**Key**

**(Fig. 54.1P)**

**1** 80% Fuel position

**2** 10% Shut off

**3** Heinzmann E16 governor actuator

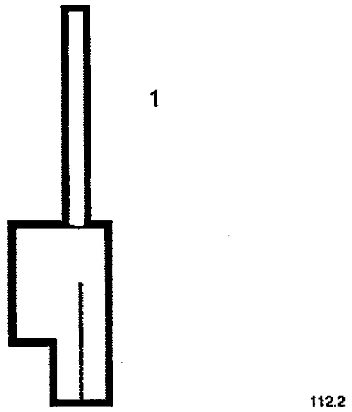



**Fig. 55P**

**(Fig. 55P)**

**1** Setting tool No. T6253/172

With No. A1 injector at calibration (obtained only by holding over governor/actuator lever) adjust the link lengths of the other cylinders to bring them into calibration (see **Fig. 56P**). Check that all injectors can travel to the **NO FUEL** position by moving the actuator lever to position '2' on the Regulateurs Europa type 2100 or to the 10% mark on the Heinzmann E16 actuator pointer using tool No. **T6253/172**.
It is vital for safety purposes to avoid a run away situation that the actuator can bring all the injectors to **NO FUEL**. (See below for acceptable settings) for position '2' on the Regulateurs Europa governor or the 10% mark on the Heinzmann actuator.

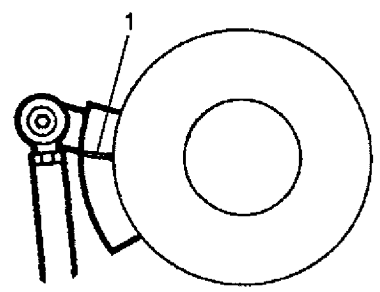



**Fig. 56P**

**Key**
**(Fig. 56P)**
1 Calibration position

**(Fig. 57P)**
**1** Incorrect
**2** Correct (no fuel)
**3** Also satisfactory

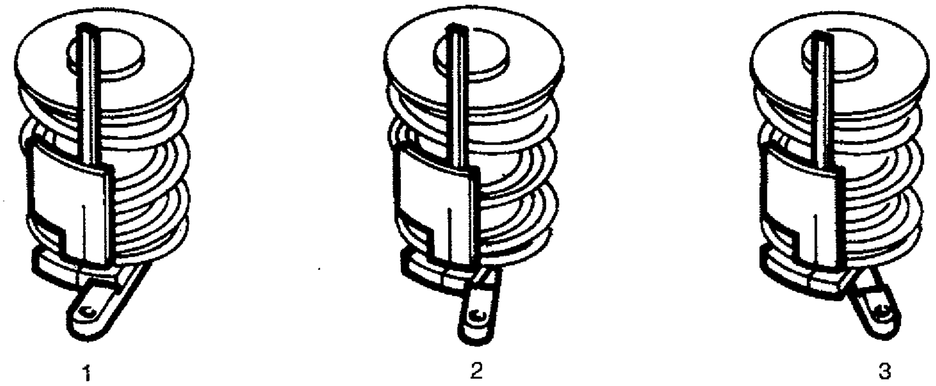



**Fig. 57P**

**TIGHTEN ALL SCREWS AND LOCKNUTS SECURELY ON LINKAGES, NOT FORGETTING THE CAPSCREWS HOLDING THE BALL JOINTS TO THE CONTROL ARMS.**
Remove the compression bars.

**Remove any wedges use in positioning the linkage during calibration.**
Fit the rockers, shafts, push rods, etc.
If you encounter any problems contact your nearest Agent who will be pleased to advise and help.

**CALIBRATION (SUB-SECTION 'C' EARLIER INJECTORS 1 OR 2)**
**1 OR 2 INJECTORS**
If only 1 or 2 injectors are to be renewed, then assuming that the governor to fuel pump linkage has not been disturbed, fit new or serviced injectors according to the fitting instructions. Adjust each link (between the break back lever and fuel pump control arm) ensuring that equal lengths of thread show at each end of the turnbuckle.
If the governor to fuel pump control shaft linkage has been disturbed then this linkage will need to be reset (refer to **Sections BB4 & 5**).
Connect the link to each pump injector control arm, not forgetting to place the collar between the balljoint and the arm.
Compress the pump injector(s) 2-3 mm with Tool No. **T6253/147 Fig. 58P.**
This makes the movement of the controls much easier and avoids the danger of the break-back linkage opening up and falsifying the position of the levers.
Set No. A1 injector (or another injector already fitted if No. A1 is being renewed) to the calibration mark by moving the governor lever or stop control lever. It may be necessary to have an assistant to hold it in place or use a carefully placed wedge.
**Remove the wedge before starting the engine.**

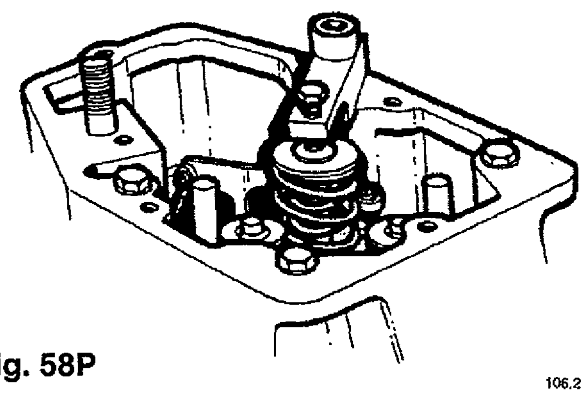


**Fig. 58P**

106.2

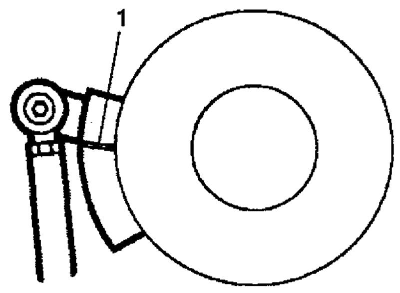


**Fig. 59P**

111.2

Check to see that any replaced injector is in calibration.
If not in calibration adjust the link length by removing the ball joint from the injector lever, slackening the locknuts and screwing the ball joints in or out of the turnbuckle. Move each joint an equal amount to ensure an equal length of thread showing.
Replace the link after adjustment on the injector control arm (not forgetting the collar) and check the calibration again. Later engines have right and left hand threaded turnbuckles and ball joints which make this adjustment easier and safer.

Key
**(Fig. 59P)**
**1** Calibration mark

**Tighten all locknuts and capscrews** after seeing that the linkage is free to rotate on all ball joints. These should be at 90° to each other at the ends of the turnbuckle.
With the governor lever at position '2' on the Regulateurs Europa 2100 or at the 10% mark on the Heinzmann type E16 actuator, the injector control arm on all injectors must be in the **NO FUEL** position, see **Fig. 51P**. Use tool No. **T6253/172** to check as shown on **Fig. 57P**. See also **Figs. 52P** and **Fig. 41P** for operation.
**Remove all wedges, etc., that may have been used to position the governor controls.**
Remove the compression bar(s).
Fit the rockers, shafts and push rods.
If you encounter any problems contact your nearest Agent, who will be pleased to help and advise.
**NOTE:** After a rebuild with new injectors the engine must be run on full load (i.e. max. site load) and the fuel stops reset (see **Sections BB4 & 5**). Also it may be necessary to reset the governor controls.

**TIMING (SUB-SECTION 'D' EARLIER ROCKERS 1 OR 2 INJECTORS)**
Refer to engine nameplate for injection timing.

**EQUIPMENT**
Dial Test Indicator (DTI) and face pad **T6253/143**. Mounting pad or stand for DTI.

**1 OR 2 INJECTORS**
Fit the bridge pieces to the guides from which they were removed and check that each bridge piece is seated correctly, lightly oiling the stems. Loosen the locknut on each rocker bridge, screw the adjuster out until the fixed side of the rocker bridge rests on its valve, hold the top edge of the rocker bridge with one hand, **Fig. 60P**, then screw the adjuster down until you feel it touch the valve, thereby equalising the valve lift.
Tighten the locknut without moving the adjuster.

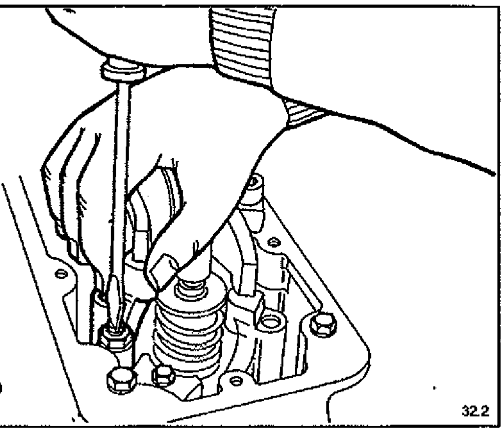


**Fig. 60P**

**WARNING** ⚠ FAILURE TO EQUALISE THE VALVE LIFT IN THIS WAY MAY LEAD TO BENDING AND CONSEQUENT FAILURE OF THE BRIDGE GUIDE, FOLLOWED BY FURTHER DAMAGE TO THE ROCKER GEAR AND THE CYLINDER HEAD ITSELF. ALSO IF FITTING NEW GUIDES AND/OR BRIDGE PIECES, CHECK THAT THE MATING PARTS DO FIT TOGETHER AND MOVE FREELY, BEFORE OILING THEM AND CONTINUING WITH REASSEMBLY.

Before fitting the injector rocker slacken off the **push rod end** adjusting screw by two turns at least to avoid bottoming of the injector plunger. Now slacken the locknut on the **injector end** of the rocker and set the head of the adjusting screw to 8 mm above the top face of the locknut, dimension 'A'. Build up the rockers, shafts, push rods and cups. Refit, tightening the rocker shaft retaining nut and capscrew to the required torque (see **pages 20 - 21 and Fig. 61P**).
To set the valve clearances set the engine on the firing stroke for that particular cylinder (refer to the table on **Section P34**).
e.g. To adjust the valves and bridge pieces on No. A1 cylinder, set No. A6 cylinder valves rocking (for 4012 engine see **Fig. 64P**; the 16 cylinder engine never had the early rockers).
With the appropriate valves rocking, loosen the locknut on the adjuster, screw the adjuster out and slide a feeler gauge between the rocker and rocker bridge **Fig. 62P**. Screw the adjuster down until the rocker is bearing lightly on the feeler gauge and tighten the locknut without moving the adjuster. The feeler gauge should be a slide fit. Inlet and exhaust valve clearances are both 0.4 mm (0.016").

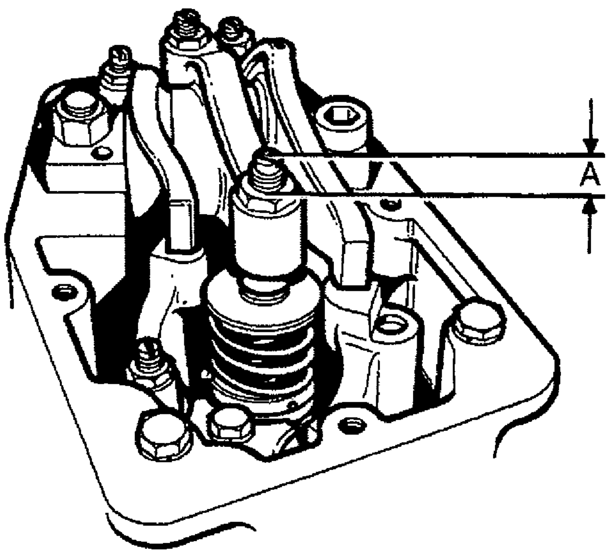


**Fig. 61P** 119.2

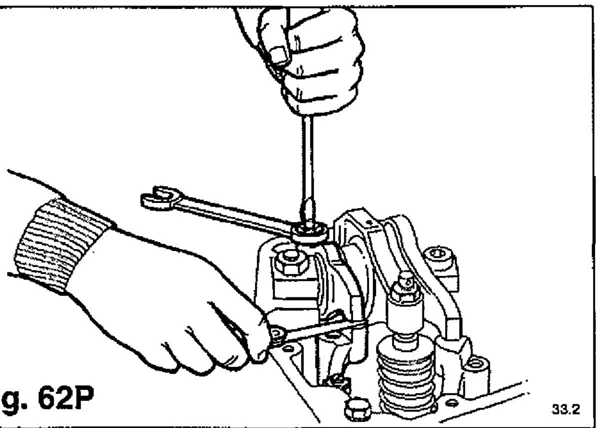


**Fig. 62P** 33.2

**Key**
**(Fig. 63P)**
**1** Face pad (T6253/143)

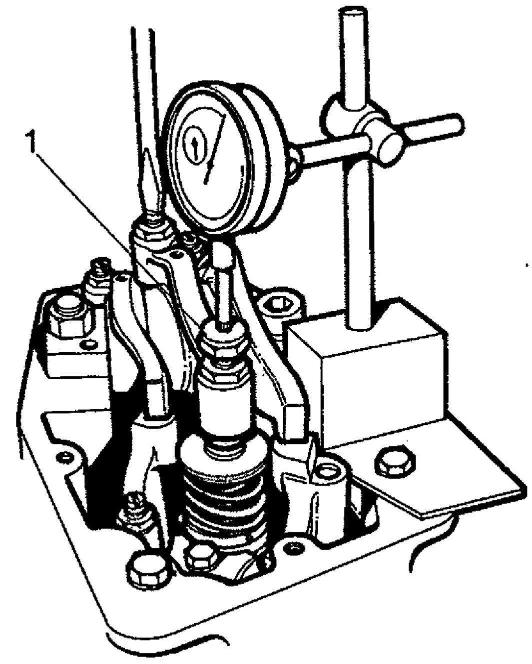



**Fig. 63P** 121.2

**4012 ENGINES FITTED WITH EARLIER ROCKERS (4016 WAS NOT FITTED WITH THESE)**

| VALVES ROCKING ON CYLINDER NO. | SET VALVE CLEARANCES ON CYLINDER NO. | SET INJECTOR TIMING ON CYLINDER NO. |
|---|---|---|
| A6 | A1 | A3 |
| B1 | B6 | B4 |
| A2 | A5 | A6 |
| B5 | B2 | B1 |
| A4 | A3 | A2 |
| B3 | B4 | B5 |
| A1 | A6 | A4 |
| B6 | B1 | B3 |
| A5 | A2 | A1 |
| B2 | B5 | B6 |
| A3 | A4 | A5 |
| B4 | B3 | B2 |

**NOTE:** No. A1 is injector furthest from flywheel, cylinders designated 'A' are on the left side of the engine when viewed from opposite end to flywheel.
If the valves required to be rocking are closed, rotate the engine one revolution to bring them to the rocking position.
Set the injector rocker of the replacement injector on the base circle of its cam, that is with the inlet and exhaust valves of the appropriate cylinder rocking. (See table for 4012 engine).
e.g. If No. A4 injector is being adjusted then the valves on cylinder No. A1 must be rocking.
Set the DTI to that the plunger is vertically above and concentric with the face pad (**T6253/143**) on the injector rocker adjuster (See **Fig. 63P**).

After slackening the rocker adjuster locknut, (**push rod end**), rotate the adjuster clockwise with a screwdriver (see **Fig. 65P**) until the timing pin is felt to engage when light pressure is applied. Lightly tighten the locknut on the adjuster and **disengage the pin. Zero the dial test indicator (DTI).** Rotate the crankshaft in the normal direction, until the correct injection 'spill' timing mark for that cylinder is reached and aligned with the timing pointer (**Fig. 66P**) for the injector being compressed.

**Key**
**(Fig. 64P)**
1. Flywheel end
2. Damper end

**(Fig. 65P)**
1. Adjuster
2. Timing pin

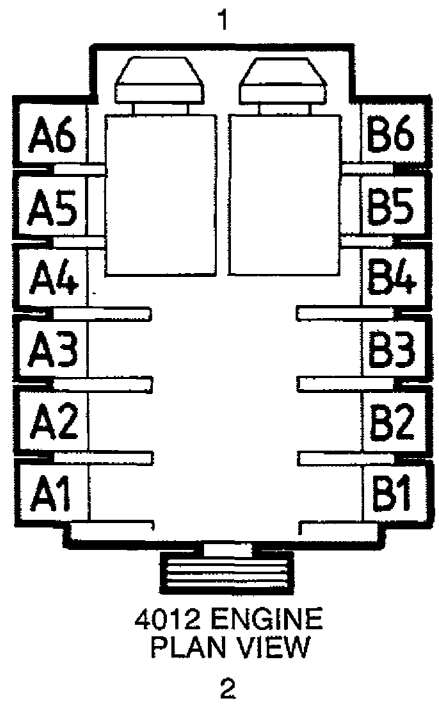



**Fig. 64P** 525.2

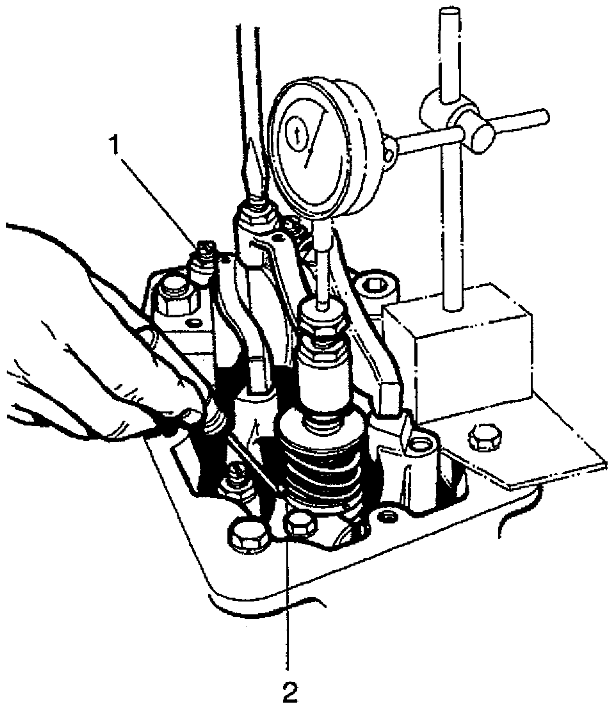



**Fig. 65P** 122.2

**4012**

| Flywheel Markings | Cylinder No. |
|---|---|
| SPILL - 16 | |
| SPILL - 18 | A1 & A6, B1 & B6, A2 & A5, B2 & B5 |
| SPILL - 20 | A3 & A4, B3 & B4, A1 & A6, B1 & B6 |
| SPILL - 22 | A2 & A5, B2 & B5, A3 & A4, B3 & B4 |

Reset the adjuster until the DTI indicates that the injector has been compressed by 3mm (0.118"). (According to timing on particular engines, the adjuster may need to be turned either clockwise or anti-clockwise).
Fully tighten the locknut, remove the DTI and proceed to the next cylinder.
**Before Starting the Engine:** Check to see that the control linkages are free at all positions. If any tightness is found, rectify it immediately.
It is recommended that following the removal and replacement of any pump injectors that the engine is turned through two complete revolutions whilst the linkages are checked for free movement.

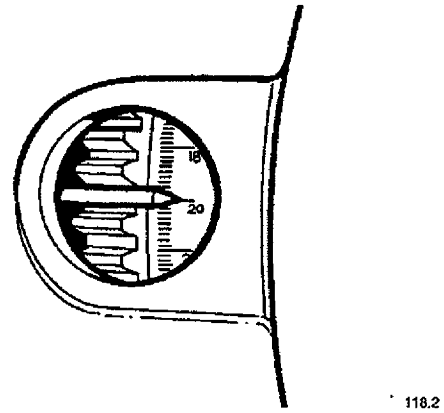



Fig. 66P

## 3 OR MORE INJECTORS

Fit the bridge pieces to the guides from which they were removed, lightly oiling the stems. Loosen the locknut on each rocker bridge, screw the adjuster out until the fixed side of the rocker bridge rests on its valve, hold the edge of the rocker bridge with one hand, **Fig. 67P**, then screw the adjuster down until you feel it touch the valve, thereby equalising the valve lift. Tighten the locknut without moving the adjuster.

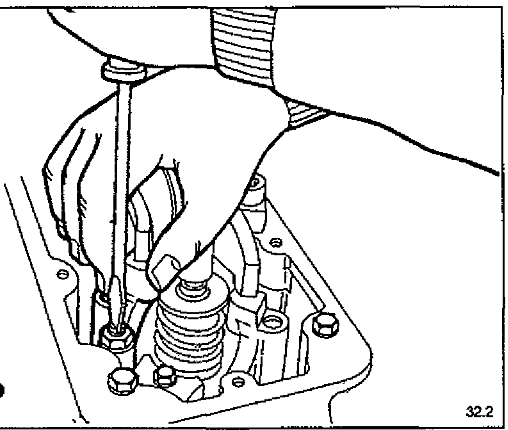



**Fig. 67P**

**WARNING** ⚠ FAILURE TO EQUALISE THE VALVE LIFT IN THIS WAY MAY LEAD TO BENDING AND CONSEQUENT FAILURE OF THE BRIDGE GUIDE, FOLLOWED BY FURTHER DAMAGE TO THE ROCKER GEAR AND THE CYLINDER HEAD ITSELF. ALSO IF FITTING NEW GUIDES AND/OR BRIDGE PIECES, CHECK THAT THE MATING PARTS DO ACTUALLY FIT TOGETHER AND MOVE FREELY, BEFORE OILING THEM AND CONTINUING WITH REASSEMBLY.

Before fitting the injector rocker, slacken the adjusting screw (found at the injector end of the rocker) by two turns at least to avoid bottoming of the injector plunger. Now slacken the locknut on the injector end of the rocker and set the head of the adjusting screw to 8 mm above the top face of the locknut dimension 'A'. See **Fig. 61P**. Build up the rockers, shafts, push rods and cups. Refit, tightening the rocker shaft retaining nut and capscrew to the required torque (see **pages 38-40**).

The following setting method is used to reduce the number of times the engine has to be rotated. Refer to and follow the sequence below:

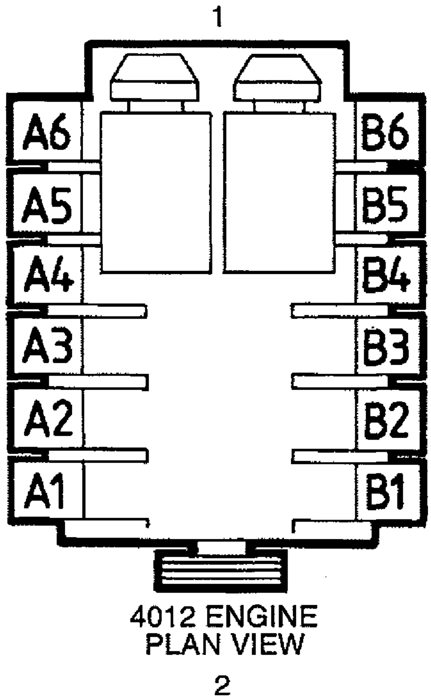



**Fig. 68P**

525.2

**4012 ENGINES**

| VALVES ROCKING ON CYLINDER NO. | SET VALVE CLEARANCES ON CYLINDER NO. | SET INJECTOR TIMING ON CYLINDER NO. |
|---|---|---|
| A6 | A1 | A3 |
| B1 | B6 | B4 |
| A2 | A5 | A6 |
| B5 | B2 | B1 |
| A4 | A3 | A2 |
| B3 | B4 | B5 |
| A1 | A6 | A4 |
| B6 | B1 | B3 |
| A5 | A2 | A1 |
| B2 | B5 | B6 |
| A3 | A4 | A5 |
| B4 | B3 | B2 |

**NOTE:** No. 1 is injector furthest from flywheel, cylinders designated 'A' are on the left side of the engine when viewed from opposite end to flywheel. See **Fig. 68P.**

**Key**
**(Fig. 68P)**
**1** Flywheel end
**2** Damper end

Start with the valves rocking on No. A6 cylinder (flywheel end) and adjust the valve clearances on No. A1 cylinder as follows:
Loosen the locknut on the rocker adjuster, screw the adjuster out and slide a feeler gauge between the rocker and bridge piece, **Fig. 62P**. Screw the adjuster down until the rocker is bearing lightly on the feeler gauge and tighten the locknut without moving the adjuster. The feeler gauge should be a slide fit (inlet and exhaust valve clearances are both 0.4 mm or 0.016" cold). Repeat for the other two valves.
Set the timing pin on No. A3 injector as follows:
Slacken the injector rocker adjuster locknut. Rotate the adjuster clockwise with a screwdriver (see **Fig. 69P**) until the timing pin is felt to engage when light pressure is applied. Lightly tighten the locknut on the adjuster and disengage the pin. Now tighten the locknut fully.
Follow the appropriate sequence until all cylinders are set. After setting the timing pins to the sequence do not turn the engine further at this stage.
Now refer to engine nameplate for actual injection timing on your engine.
Set up the DTI and the face pad **(T6253/143)** and ensure that the DTI plunger is square to the face pad on the injector end of the injector rocker of the next cylinder to fire (if the sequence has been followed this will be No. A1). Refer to **Fig. 69P.**
**Zero the dial test indicator (DTI).** Turn the engine to the injection timing required for this cylinder e.g. 20° No. A1 firing in the direction of normal rotation. No. A1 injector will have started to compress. Slacken the injector rocker adjuster locknut carefully and turn the adjuster with a screwdriver until the DTI shows the injector to be compressed by 3 mm (0.118").

**Key**
**(Fig. 69P)**
**1** Adjuster
**2** Timing pin

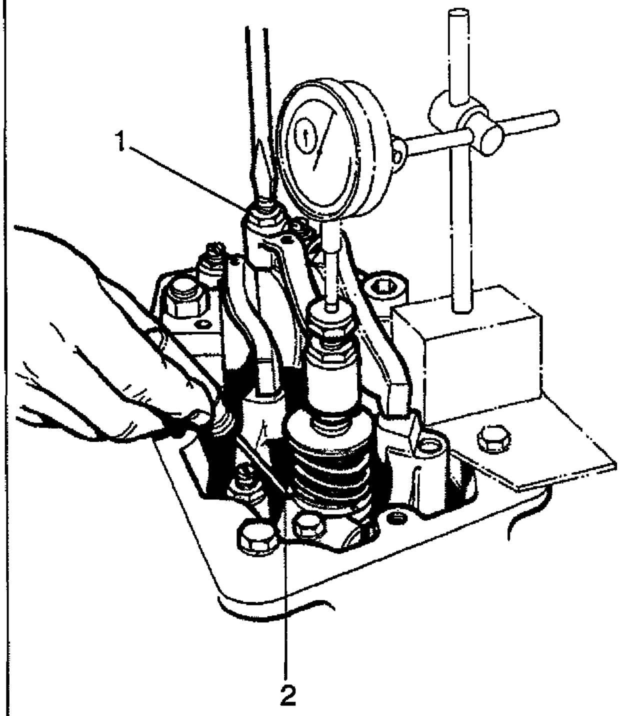


**Fig. 69P**

**NOTE:** The adjuster may need to be turned in either direction to achieve the correct reading of 3 mm (0.118") on the DTI. Tighten the locknut. Remove the DTI and before turning the engine further, refit the DTI on the injector end of the injector rocker of the next cylinder to fire and zero the DTI. if the sequence is followed this will be No. B6 (see table on **Section P36**). Adjust as for No. A1 cylinder setting the flywheel to the injection timing mark for this cylinder (e.g. 20° before TDC No. B6 on a 4012 engine).
Repeat the following sequence until all injectors are set.
1A-6B-5A-2B-3A-4B-6A-1B-2A-5B-4A-3B.
**NOTE:** Should some injectors already be fitted, it is recommended that they be included in the above sequence of setting and checking.

## PRIMING THE FUEL SYSTEM ON THE EARLIER 4012 AND 4016 SERIES ENGINES

Loosen the union connection on the fuel feed pipe from the fuel filter, **Fig. 70P**.

Operate the priming pump by pressing the rubber button (**Fig. 71P**) and continue priming until air free fuel flows from the union. Re-tighten the union.

Then slacken off the vent plugs located at the front end of 'A' and 'B' bank fuel return rails, **Fig. 72P** and continue priming until air-free fuel flows. Tighten the vent plugs.

**Key**
**(Fig. 71 & 72P)**
**1** Priming pump
**2** Strainer
**3** Vent plug

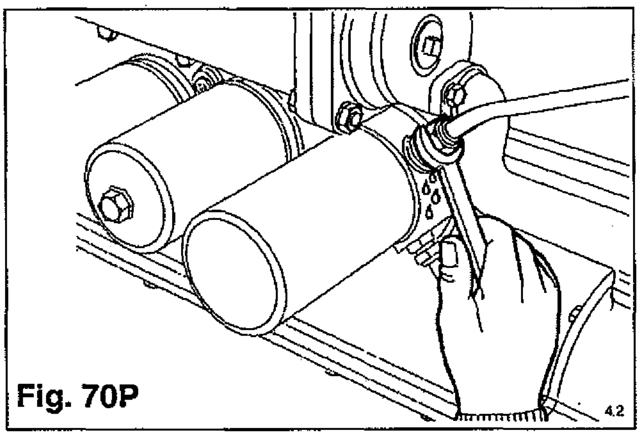


Fig. 70P

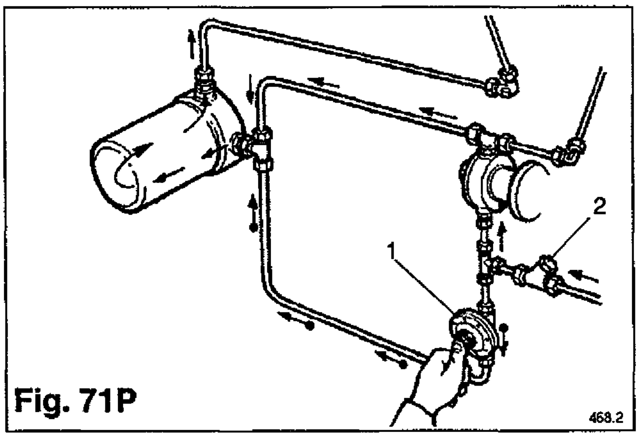


Fig. 71P

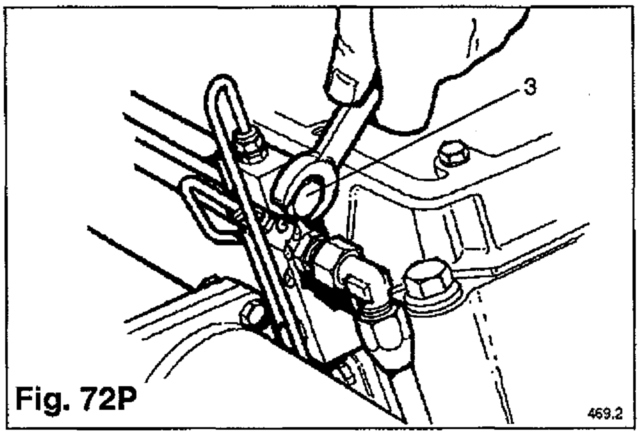


Fig. 72P

## PRIMING THE FUEL SYSTEM FITTED WITH CHANGE-OVER FUEL FILTERS

Loosen the union connection on the fuel pipe from the fuel filter **Fig. 73P**.

Operate the priming pump by pressing the rubber button **Fig. 71P**. Continue priming until air free fuel flows from the union. Retighten the union, then slacken off the vent plugs, located at the front end of 'A' and 'B' bank fuel return rails **Fig. 72P** and continue priming until air free fuel flows. Tighten the vent plugs.

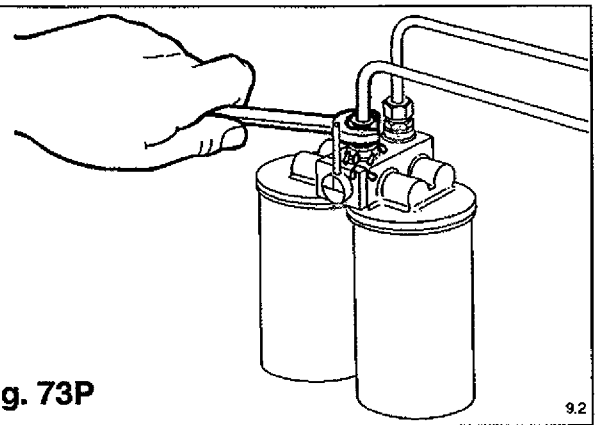


Fig. 73P

## PRIMING THE CIRCUIT 12 AND 16 CYLINDER ENGINES

It is possible for air to be introduced to the system in two possible cases.

1 When changing the fuel filters if this is the case keep the starter motors turning (purging the fuel system) until the engine is started.

2 If the engine is out of fuel then the circuit must be filled. This is obtained by taking out the vent plug in number 6 and 12 or 8 and 16 fuel blocks and gravity feed the system from the fuel tank to the fuel inlet.

**NOTE:** If the fuel tank is in an elevated position it is possible that the circuit can pressurise. To elevate this a 24 volt none return valve is an option. If fitted the gravity feed inlet must be started after the none return valve.

If the priming pump is fitted see **Fig. 74 & 75P**.

**Key**
**(Fig. 74P)**
**12 Cylinder**

**1** Fuel inlet
**2** Fuel filter
**3** Fuel inlet
**4** Fuel lift pump
**5** Fuel outlet
**6** Fuel feed
**7** 'A' bank feed
**8** 'B' bank feed
**9** Fuel feed to rocker box
**10** Fuel return valve
**11** Fuel return from cylinder head

**(Fig. 75P)**
**16 Cylinder**

**1** Fuel inlet
**2** Strainer
**3** Lift pump inlet
**4** Lift pump outlet
**5** Fuel feed to filter 'A' bank
**6** Fuel feed to filter 'B' bank
**7** Filter inlet 'A' bank
**8** Filter inlet 'B' bank
**9** Filter outlet
**10** Filter outlet
**11** Fuel feed to rail 'A' bank
**12** Fuel feed to rail 'B' bank
**13** Vent plug
**14** Fuel relief valve
**15** Fuel supply to rocker box
**16** Fuel return from injectors

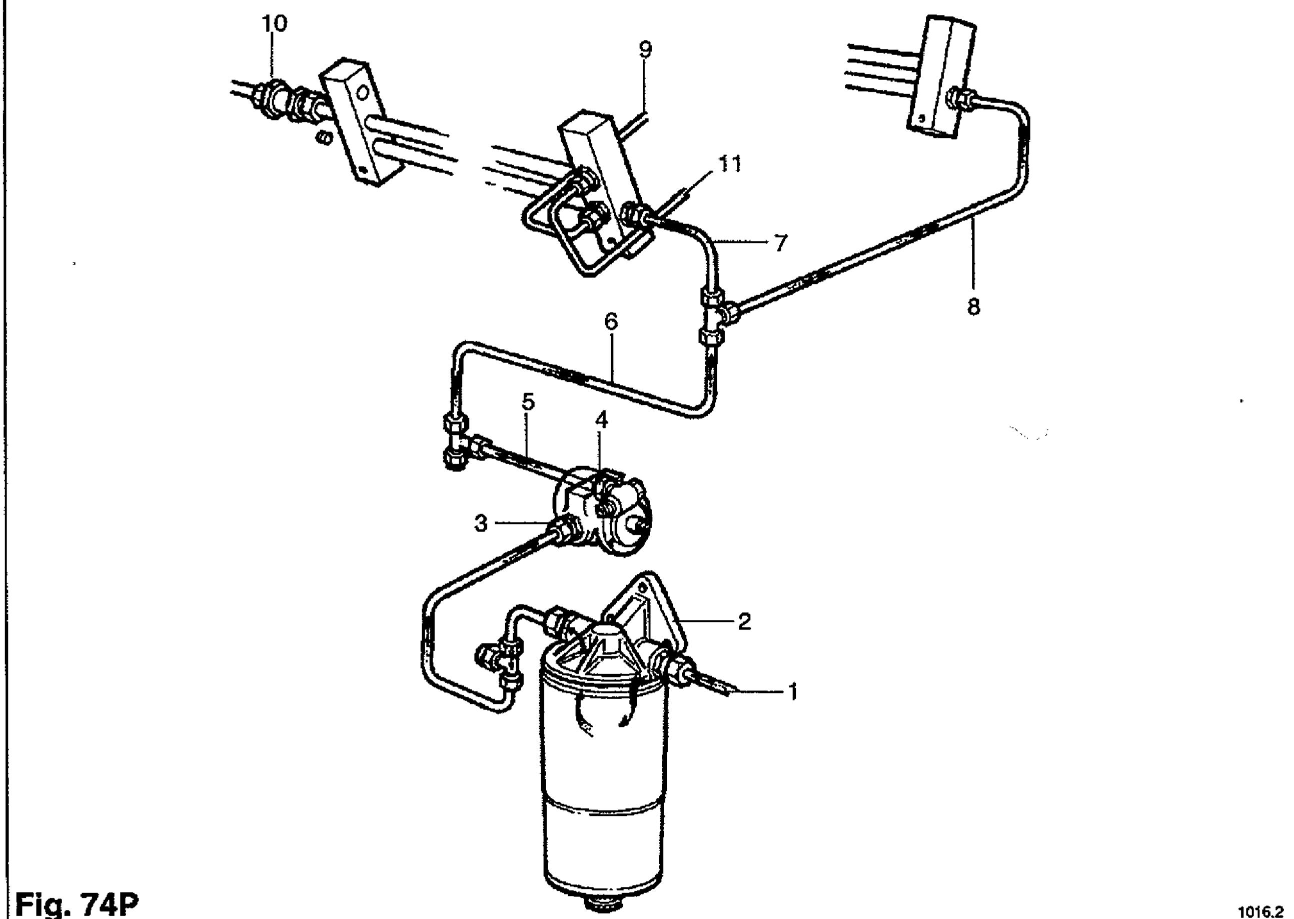



Fig. 74P

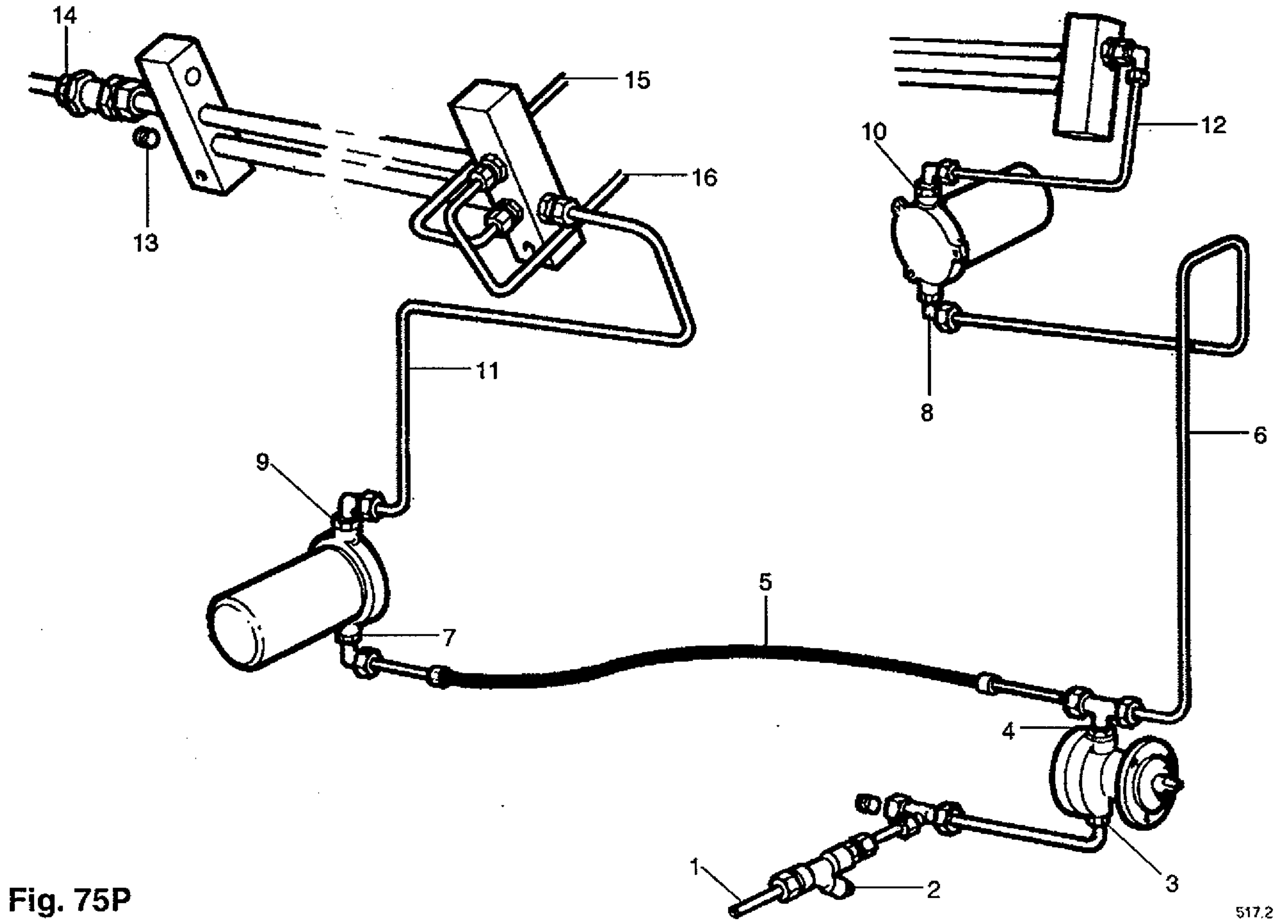



Fig. 75P

## PRIMING THE FUEL SYSTEM AS FITTED ON THE LATER 4012 ENGINES

Loosen the union connection on the fuel feed pipe to the cylinder head on the fuel rail (front end). **Fig. 76P**.

**NOTE:** The latest fuel filter is fitted on the suction side of the lift pump, which is the reason for not bleeding the system at the filter.

Operate the priming pump by pressing the rubber button **Fig. 77P.** Continue priming until air free fuel flows from the union. Re-tighten the union.

**Key**
**(Fig. 77P)**

1 Normal fuel flow
2 Priming circuit

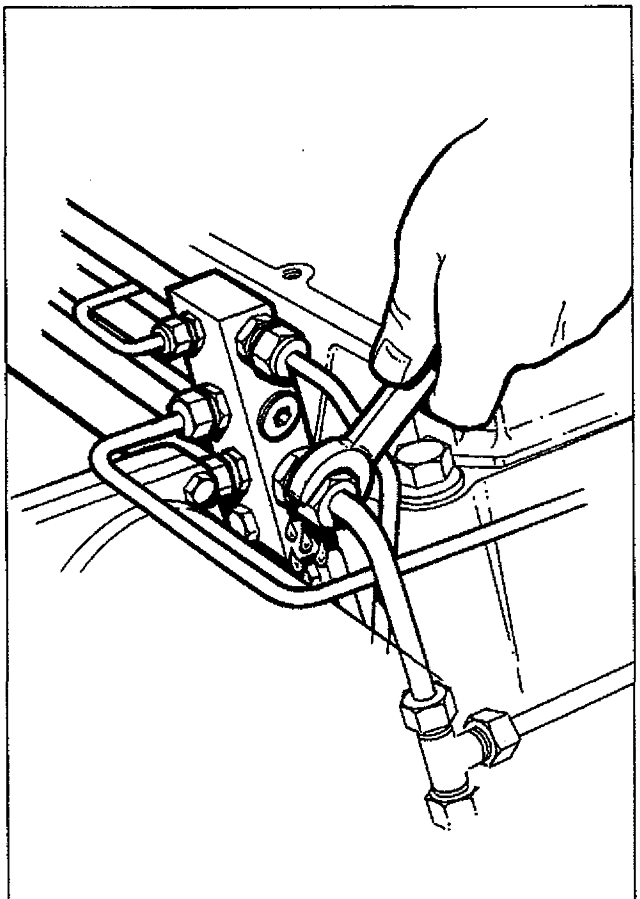


Fig. 76P 470.2

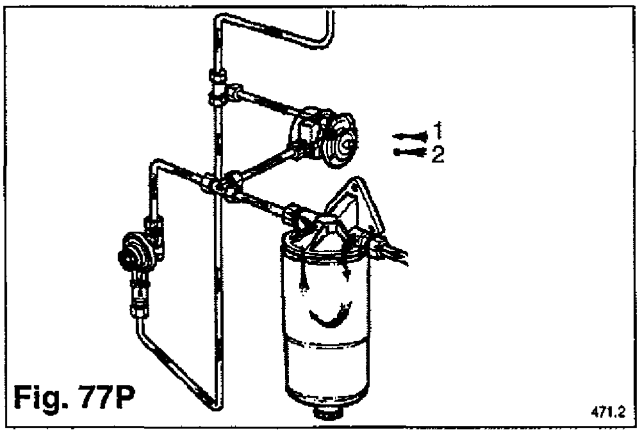



Fig. 77P 471.2

## DRAINING THE COOLANT

Drain the coolant from the engine by opening the drain taps which are sited on the ends of the oil coolers **Fig. 1Q**.

## REMOVING THE MANIFOLDS

Take out the bolts holding the inlet manifold to the cylinder head **Fig. 2Q**. Loosen the bolts holding the rest of the manifold. This will allow sufficient clearance for a cylinder head to be removed without removing the manifold from the engine. Repeat this operation on the dry exhaust manifold **Fig. 3Q**.

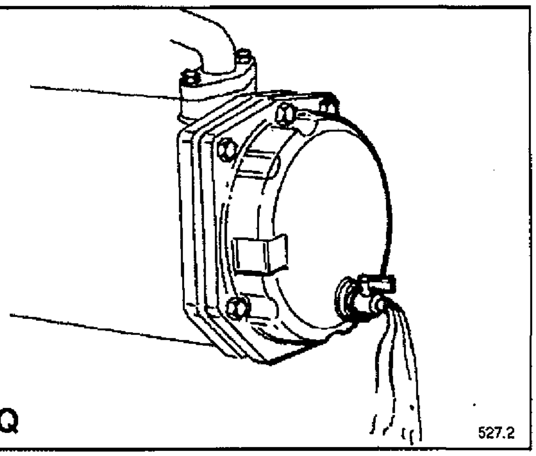


**Fig. 1Q** 527.2

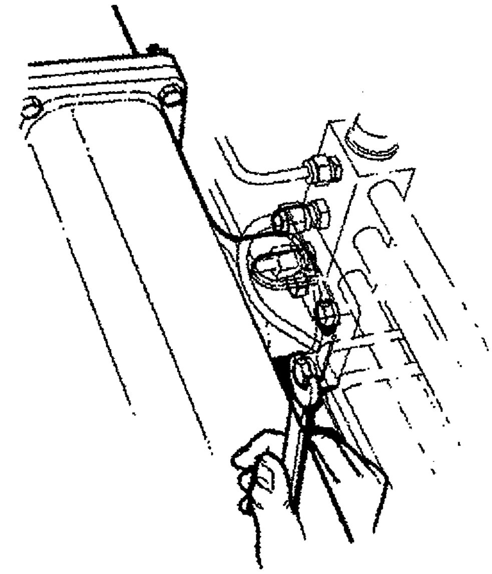


**Fig. 2Q** 124.2

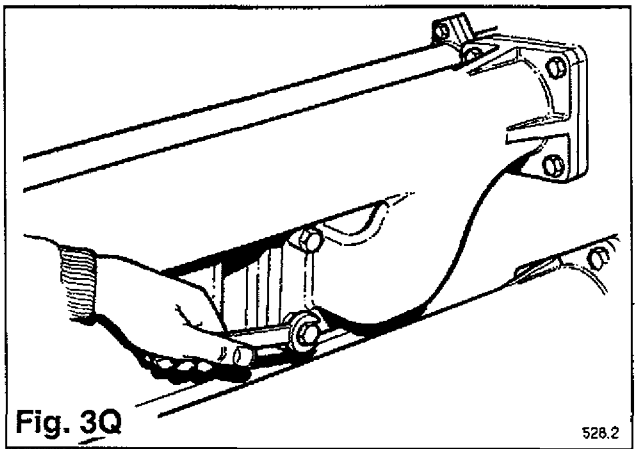


**Fig. 3Q** 528.2

## EXHAUST MANIFOLD

The exhaust manifold is made up of 3 or 4 sections per bank and they are joined together by fitting stainless steel expansion bellows bolted between the mating flanges. See **Figs. 4Q** and **5Q**.

Later engines are fitted with improved quality (2 ply) bellows, which are indistinguishable to the naked eye from the original type but are fitted in exactly the same way using the special bolts and locknuts specified in the **Illustrated Spares Catalogue.**

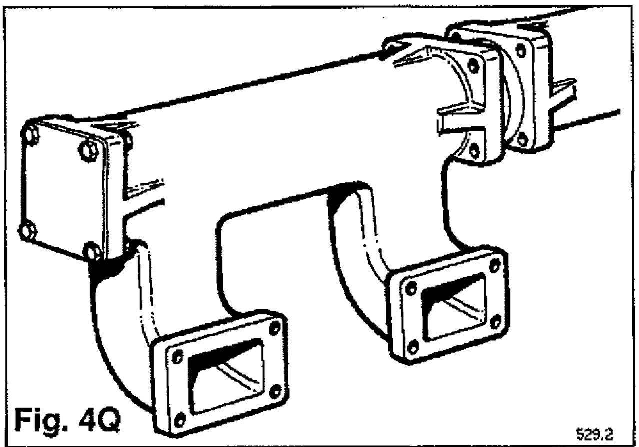


Fig. 4Q 529.2

**NOTE:** The expansion joints need not be disturbed when removing the cylinder heads. However, if they have to be removed, then it is essential that the stainless steel bellows be fitted correctly, i.e. with the arrow marked on one flange pointing in the direction of the gas flow, as shown in **Fig. 5Q**.

If removing a section of the manifold, support the piece to be removed with a lifting sling. After removing the bolts holding the exhaust manifold to the cylinder head (see **Fig. 3Q**), and the four bolts at each end of the manifold section, carefully lift that section of the manifold complete with bellows off the engine. In the case of major work on the engine, it is permissible to remove the manifold as a complete assembly from each bank.

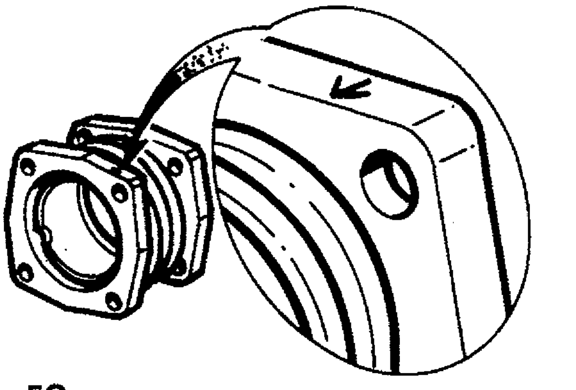


Fig. 5Q 1071.2

## REMOVING WATER RAILS

Drain the coolant, and remove the appropriate section of the water rail only, to allow sufficient space for the cylinder head to be removed. **Fig. 6Q.**

Loosen the screws and bolts of the appropriate sections of the inlet and exhaust manifolds, then remove the screws from the water rail flanges.

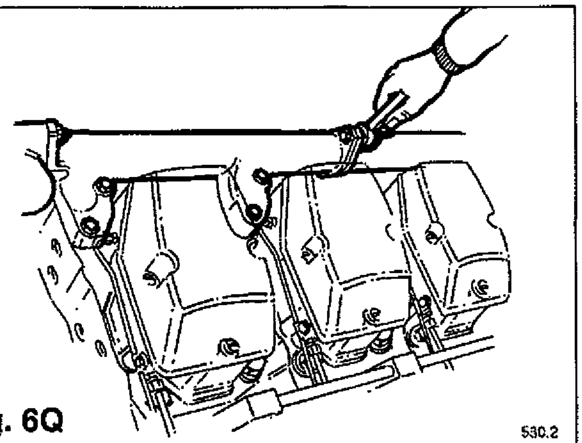


Fig. 6Q 530.2

## REMOVING THE FUEL AND OIL PIPES

Remove the oil feed pipe to the rockers; this includes the steady clip and bolt **Fig. 7Q**. Remove the fuel pipe **Fig. 8Q**.

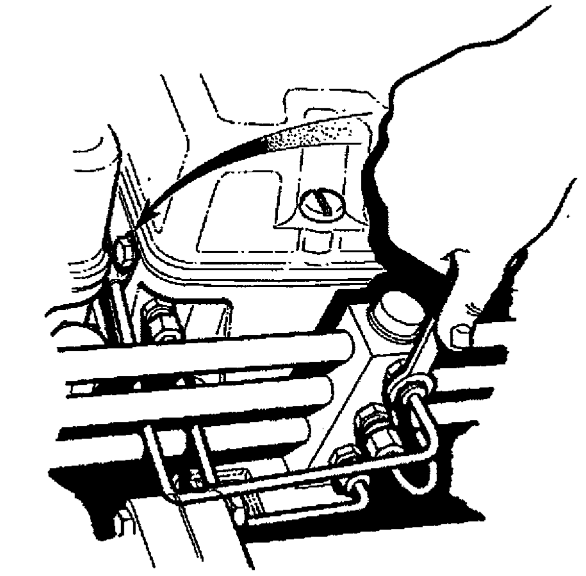


**Fig. 7Q** 129.2

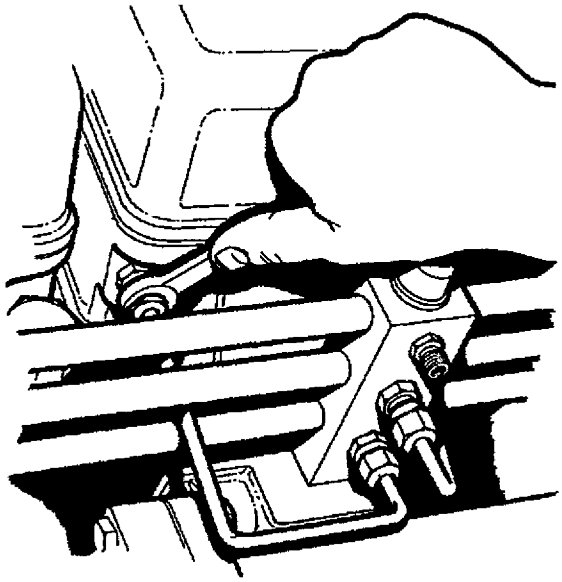


**Fig. 8Q** 130.2

Remove the fuel return pipe **Fig. 9Q**.
Remove the bolt holding the appropriate fuel rail connector block to the cylinder head **Fig. 10Q**.

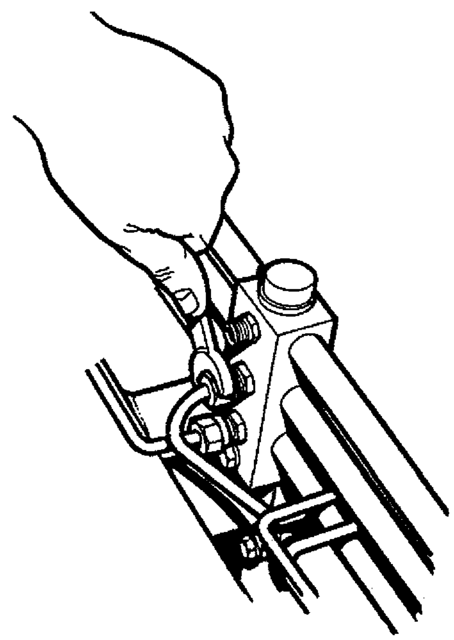


**Fig. 9Q** 131.2

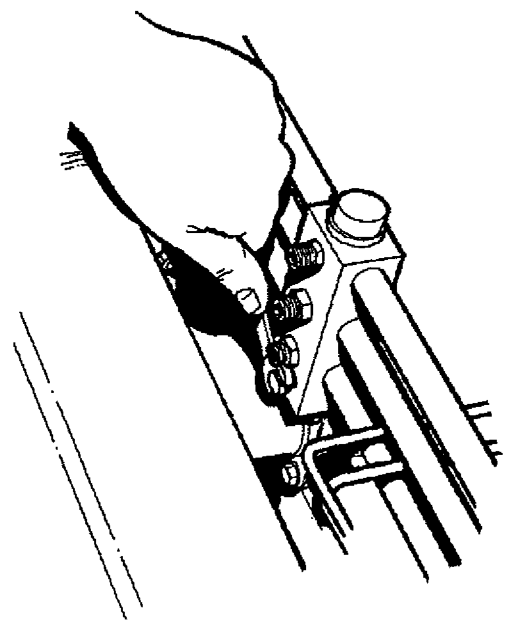


**Fig. 10Q** 132.2

## REMOVING A ROCKER ASSEMBLY AND ROCKER BOX

Remove the rocker box cover by taking out the 4 slot head screws **Fig. 11Q**.

**NOTE:** If water is found to be leaking from the stud, (due to deterioration of the sealing compound) remove the stud **Fig. 13Q item 5**, thoroughly clean and degrease the threads, and coat with Loctite Hydraulic Seal 542 before refitting.

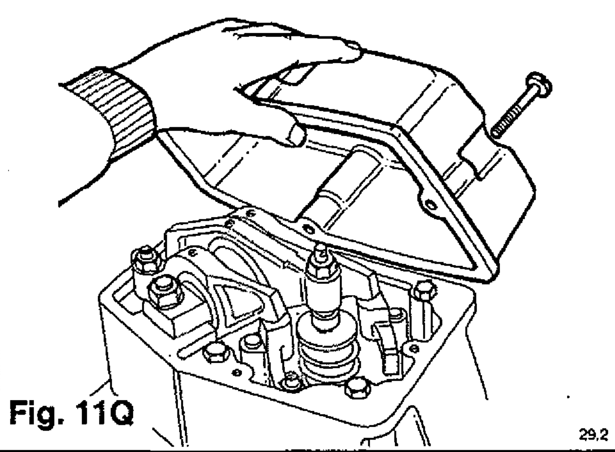


Fig. 11Q

Remove the nut and capscrew retaining the rocker shaft, then lift off the rocker assembly.
**NOTE:** It is not advisable to change individual components.
Take care not to drop the hardened cup between the injector rocker and the injector.
Take out all three push rods plus the inlet and exhaust rocker bridges marking them for reassembly in the same order **Fig. 12Q**.
**NOTE:** Interchangeability of rockers and bridge pieces from early to late engine or visa versa is not possible.
Remove the 4 rocker box bolts in the order shown. A light tap with a hide mallet may be needed to free the rocker box from its joint **Fig. 13Q**.

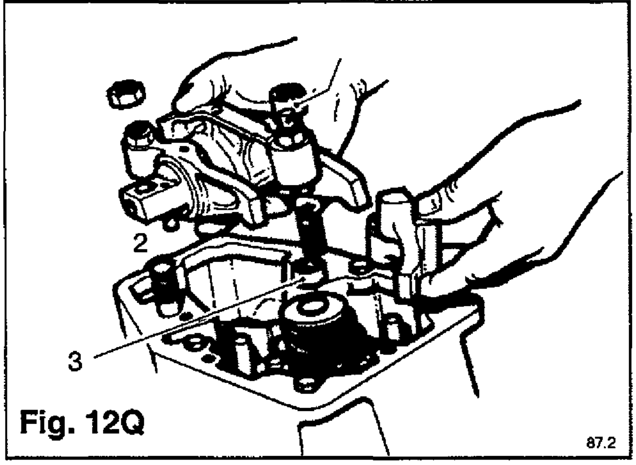


Fig. 12Q

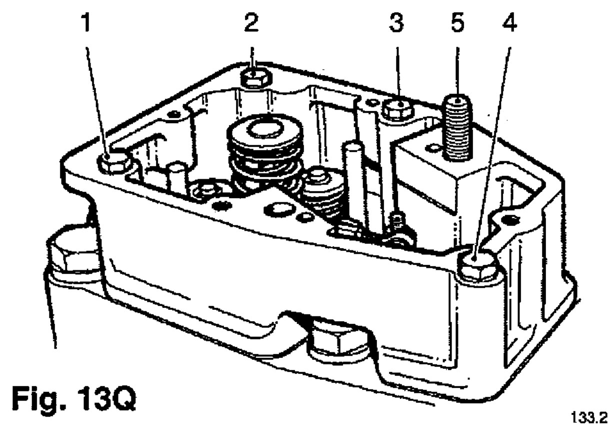


Fig. 13Q

## CYLINDER HEAD REMOVAL

Disconnect the fuel control link from the break-back lever, **Fig. 14Q** and remove the link by disconnecting it at the bottom end through the camshaft openings in the crankcase (to avoid bending it) then remove the injector (Refer to **Sections P2** and **P3**).

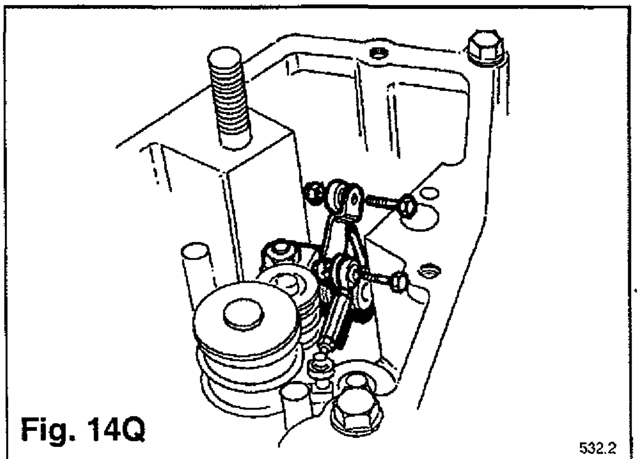


Fig. 14Q

**Key**
**(Fig. 12Q)**
**1** Capscrew
**2** Stud
**3** Hardened cup

Undo the cylinder head bolts in the order shown **Fig. 15Q**.
Each time that a cylinder head bolt is undone it should be marked with a centre punch dot (see **Fig. 16Q**). Any bolt showing two dots before removal should be renewed.

**Key**
**(Fig. 16Q)**
**1** After first removal (dot when removing)
**2** After second removal (dot when removing)
**3** After third removal renew bolt

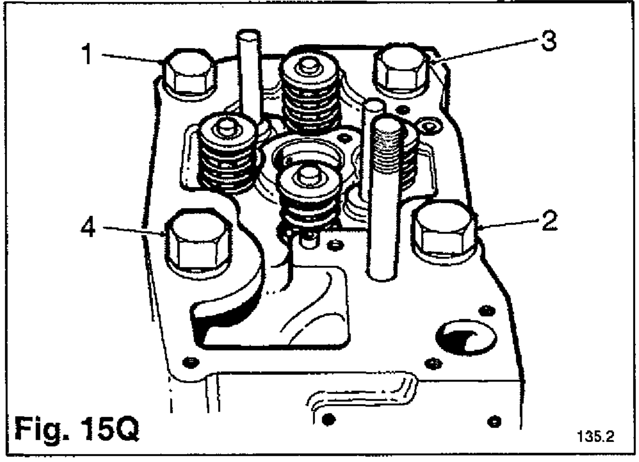


**Fig. 15Q**

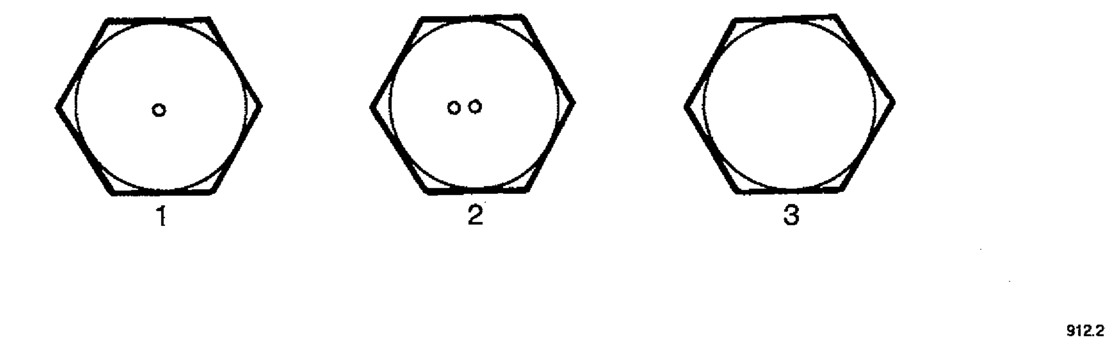


**Fig. 16Q**

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT.

The cylinder head is too heavy for lifting by hand and it needs to be lifted vertically. A special tool Part No. **T6253/237 Fig. 17Q** is available and when used in conjunction with a suitable hoist the cylinder head may be lifted safely away.
Discard the flame ring and the old 'O' rings. **Fig. 18Q**

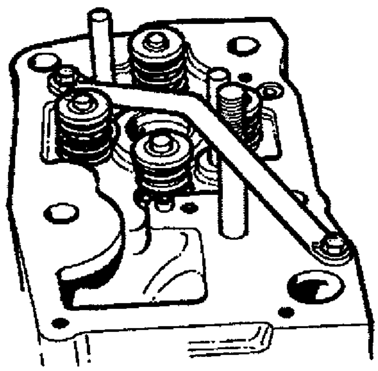


**Fig. 17Q** 136.2

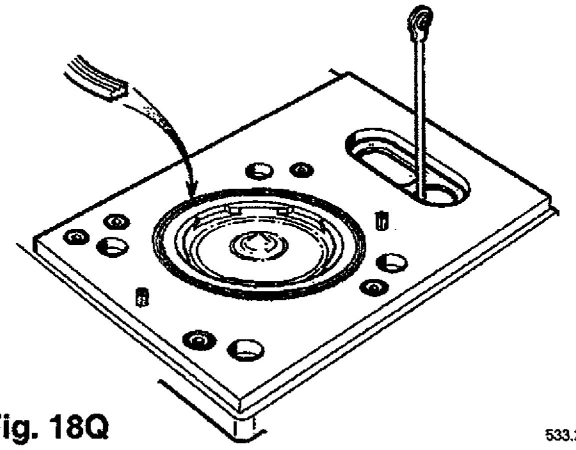


**Fig. 18Q** 533.2

Remove the four retaining capscrews from the sandwich plate and screw two M10 screws into the two threaded jacking holes (see **Fig. 20Q**). The sandwich plate may now be removed by evenly tightening the two jacking screws until the plate is pulled off the two dowels.

Earlier engines had sandwich plates without retaining capscrews and some with no jacking holes. In this case, the sandwich plate should be prised off by means of two cranked levers (see **Fig. 19Q**).

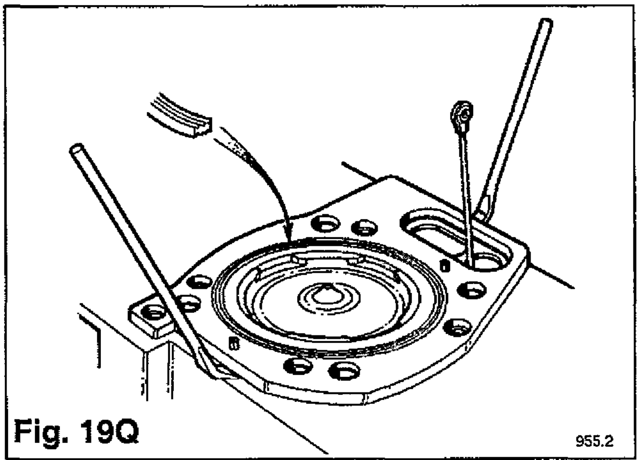


**Fig. 19Q** 955.2

**Key**
**(Fig. 20Q)**

1 Retaining capscrew
2 Jacking screw

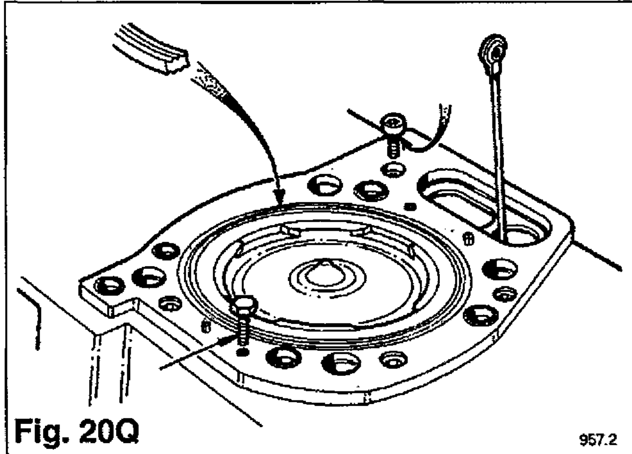


**Fig. 20Q** 957.2

Clean the carbon deposit from the top of the piston with a suitable wood or plastic scraper, taking care not to allow carbon particles to fall between the piston and cylinder wall, as this may cause the piston rings to stick. Clean the top of the cylinder block with kerosene (paraffin) and cover over to stop the entry of dust, etc.
Early engines have their sandwich plates bored to accept rubber bushes with internal stiffeners (see **Fig. 22Q**). All engines are fitted with plastic inserts for the large 'O' rings.

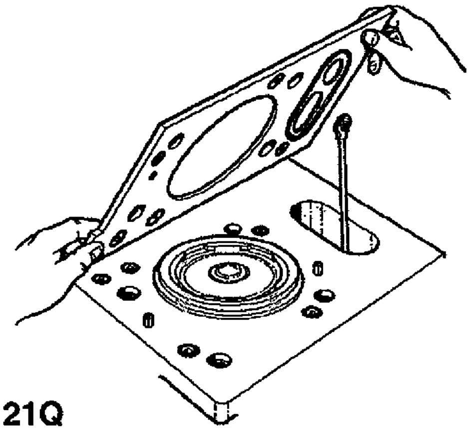


**Fig. 21Q**

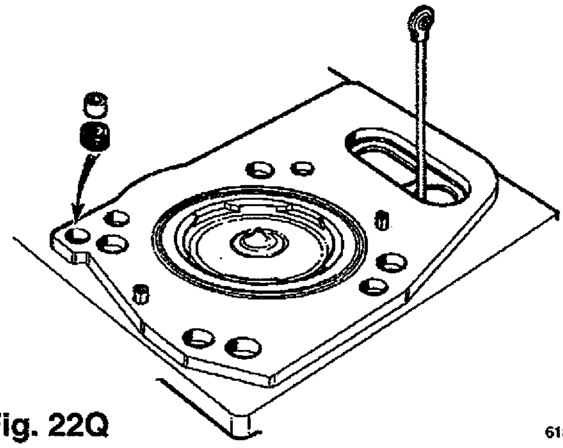


**Fig. 22Q**

## REMOVING VALVES

Turn the cylinder head onto its side. Prise out the push rod 'O' ring and its insert, then mark the valves to ensure correct re-assembly **Fig. 1R**.

**NOTE:** The 'O' ring insert is fitted to later engines, but may be added to early engines to improve oil sealing capability.

Using **T6253/243** valve spring compressor, compress the valve spring and remove the split collets. Then slowly release the pressure on the spring and retaining collar and withdraw the valve from the cylinder head. Keep all these items together. **Fig. 2R**.

After removing the valves, clean the carbon deposits from the combustion face and the ports, being careful not to scratch any machined surface. Wash the cylinder head and dry, using compressed air if available.

**WARNING** ⚠ ALWAYS WEAR EYE PROTECTION WHEN REMOVING VALVE SPRINGS AND WHEN USING COMPRESSED AIR.

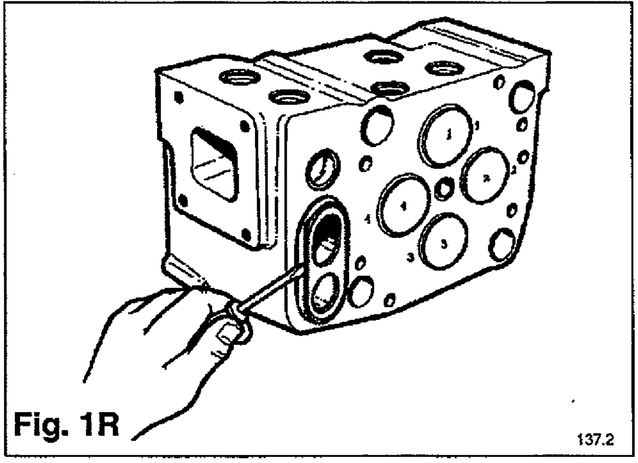


**Fig. 1R**

137.2

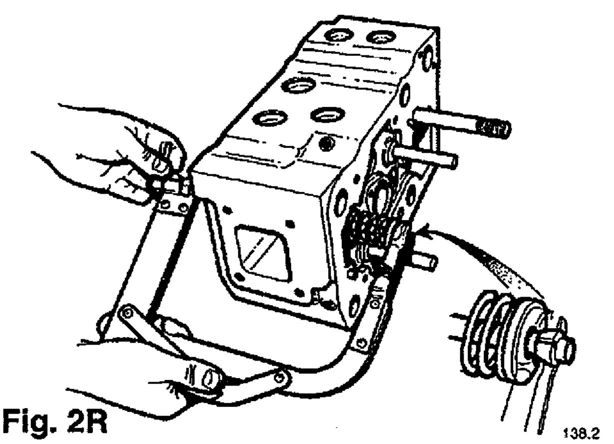


**Fig. 2R**

138.2

## SERVICING VALVES, VALVE SEATS AND GUIDES

Scrape the carbon deposit from the valve head and stem, wash and wipe dry. Examine the seating face for pitting, burning or cracking, and the valve stem for score marks or a wear ridge near the collet groove. If any of these conditions are apparent replace the valve. **Fig. 3R**. Also check the valve stem diameter.

**Key (Fig. 3R)**

1 Unsuitable for further service

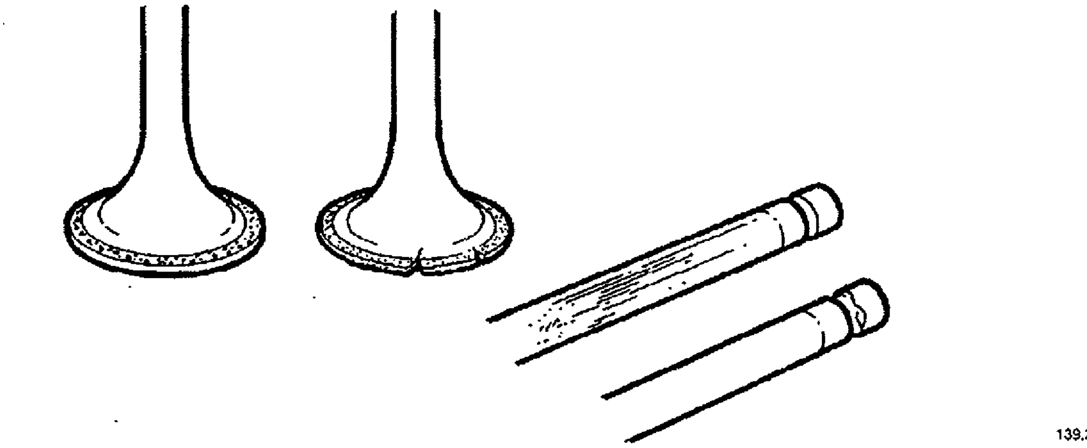


**Fig. 3R**

139.2

if the valve is serviceable except for some pitting of the seat, it can be reground at an angle of 30° to 30° 30' (removing the minimum amount of metal) to give a clean seat. **Fig. 4R**. If dimension 'A' is less then 1 mm after regrind, the valve is unfit for further service and should be discarded.

For the next operation, two blocks of hardwood or aluminium are needed to support the cylinder head with the combustion face upwards. Examine the valve seats for pitting, burning or cracking. If the seats are serviceable but with some pitting they may be refaced using valve seat cutting tool Part No. **T6253/245A and B** (see **Fig. 5R**) removing only the minimum amount of metal. The self-centering tapered arbor ensures the proper alignment of the valve seat with the valve stem guide. If the seats are not serviceable, the cylinder head may be replaced by a service exchange unit or new valve seats as described in **Section R9**.

Checking each valve in turn, by replacing the appropriate valve into the cylinder head, holding it 10 mm out of the head with an engineers square alongside and check the valve rock **Fig. 6R**. If it is in excess of 0.5 mm, replace that valve guide. For valve guide replacement see **Section R5**.

If the valve and guide clearance is within the set limit, push the valve down onto its seat. Place a straight edge across the head of the valve, in order to check the valve height relative to the combustion face of the cylinder head, which should be flush or a maximum of 1mm below **Fig. 7R**. If a valve is below the limit, a new valve should be tried on the seat in question. If the new valve is still below the limit, then the valve seat must be replaced.

**Key**
**(Fig. 7R)**
**1** Correct valve height
**2** Maximum of 1 mm below head face

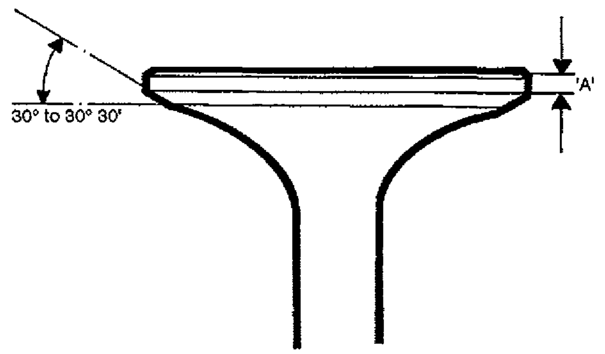



**Fig. 4R** 140.2

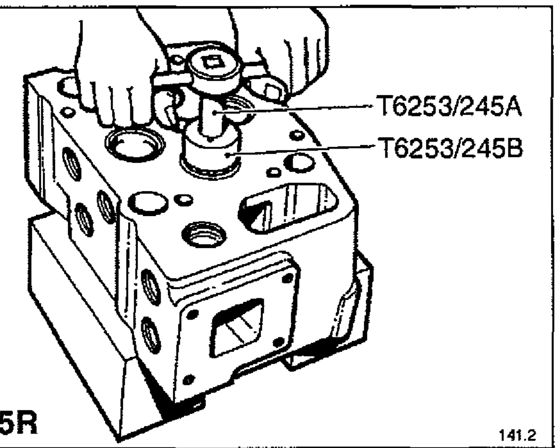



**Fig. 5R** 141.2

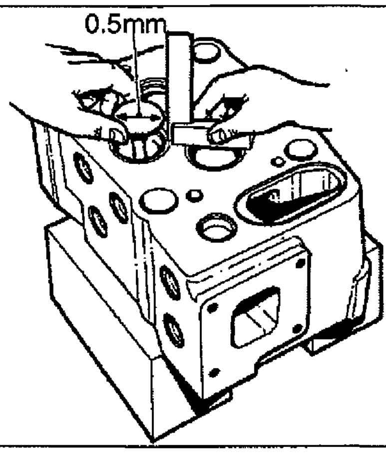



**Fig. 6R** 142.2

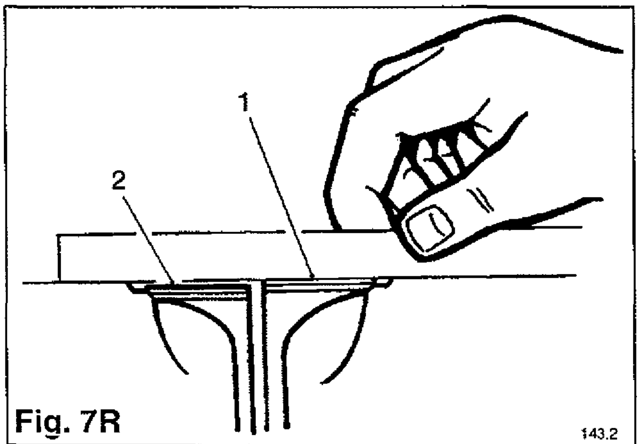



Fig. 7R 143.2

As the valve seat insert fitting tool locates in the cylinder head in place of the valve guide, the guide must be removed. Using **T6253/307** and with the head mounted in a suitable press, carefully push out the valve guide **Fig. 8R**. It should then be discarded even if it is within the recommended tolerance.

Lay the cylinder head on end, then using a hand held grinder, cut into the valve seat in question, being very careful not to damage the cylinder head, **Fig. 9R**. Using a long chisel down the port, tap out the insert. Clean any grindings from the port, check that the seat bore is free from burrs and the valve guide bore is clean and free from carbon. The difficult insert may have a bridge welded across it so that it can be prised out with a crow bar.

**WARNING** ⚠ IT IS ESSENTIAL THAT PROTECTIVE GLOVES ARE WORN WHEN HANDLING FROZEN PARTS.

Now lay the cylinder head, combustion face up, on the blocks used earlier. **THE NEW VALVE SEAT MUST BE FROZEN IN LIQUID NITROGEN TO GIVE THE NECESSARY CONTRACTION.** It is then fitted onto valve seat fitting tool **T85002/4** 48 mm diameter valves (or **T85117/3** 52 mm diameter valves) which is carefully located in the valve guide bore and the seat is then hammered home. **Fig. 10R.**

**Key**
**(Fig. 8R)**
**1** Valve guide removal tool (T6253/307)

**(Fig. 10R)**
**1** Fitting tool
**2** Valve seat

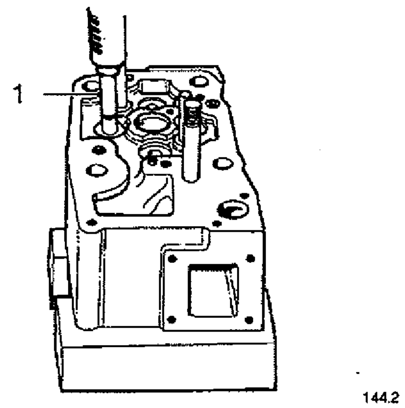


Fig. 8R

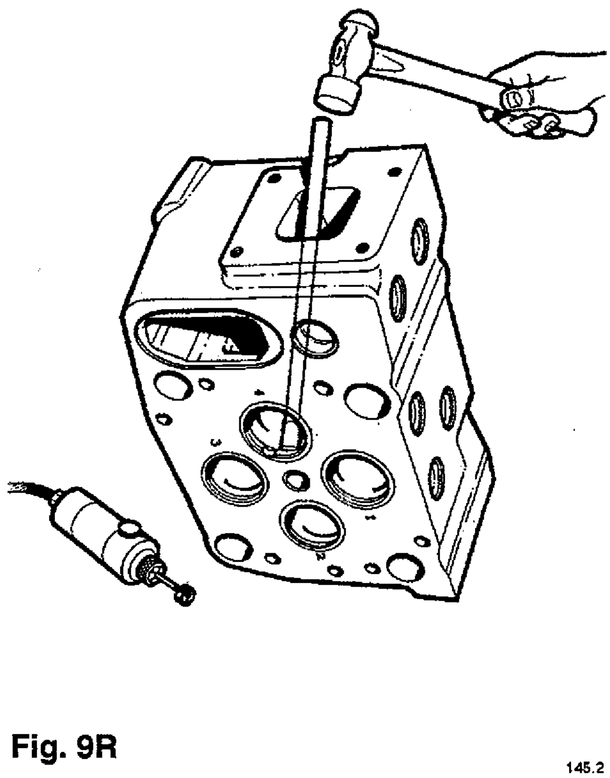


Fig. 9R

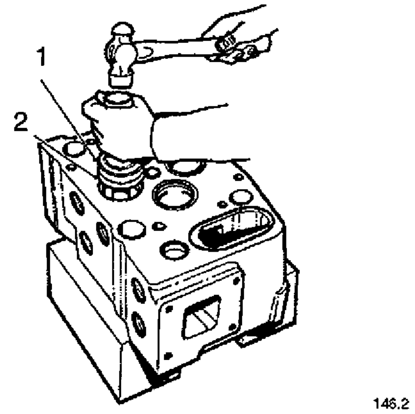


Fig. 10R

Check the valve guide bore is free from burrs and carbon. Mount the cylinder head in the press, rocker box side up. Fit the new valve guide using tool No. **T85002/3**. Carefully align the guide with its bore **Fig. 11R**. Bring the press down gently onto the fitting tool, continually checking that the guide is parallel with its bore. Use of the above tool automatically ensures that the 9mm dimension is achieved as shown in **Fig. 12R**. Inlet and exhaust valve guides are all set to this dimension.

Place the cylinder head back on the blocks, combustion face upwards, with valve guides and seats checked for further service. Each individual valve must be lapped into its seat. To hold the valve during the lapping process one of the universally available sucker type tools should be used. Fit the appropriate valve to the sucker and apply a smear of medium carborundum paste evenly around the seat **Fig. 13R**.

**WARNING** ALWAYS WEAR EYE PROTECTION, WHEN USING COMPRESSED AIR.

Push the valve onto its guide and using a semi-rotary motion, lap the valve onto its seat **Fig. 14R**. Wash away all traces of carborundum paste. The seat on the valve and in the cylinder head should have a grey continuous line-of-contact. Check the seat with 'engineers blue'. Finally wash the inlet and exhaust ports and blow them out dry and clean with compressed air.

**Key**
**(Fig. 11R)**
**1** Fitting tool
**2** Valve guide

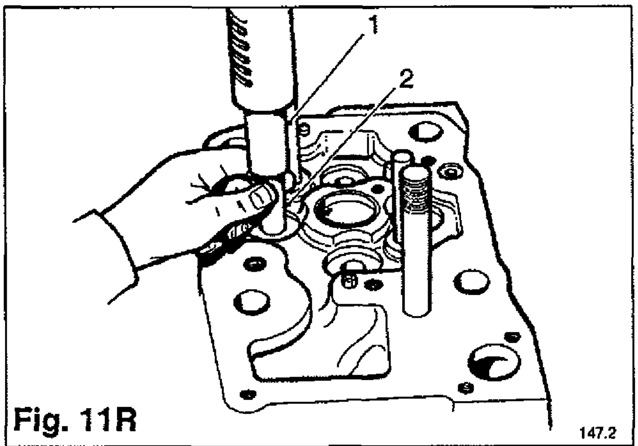



**Fig. 11R**

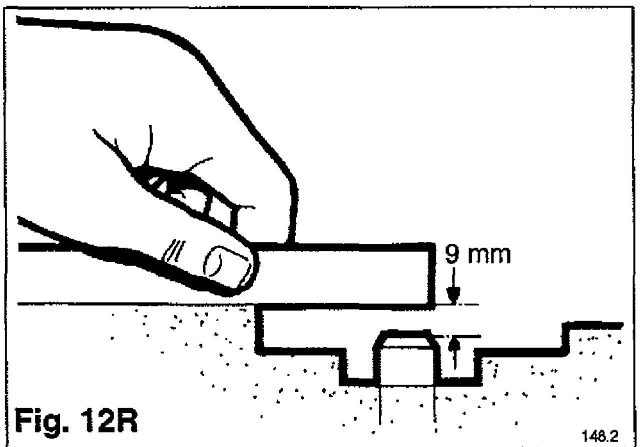



**Fig. 12R**

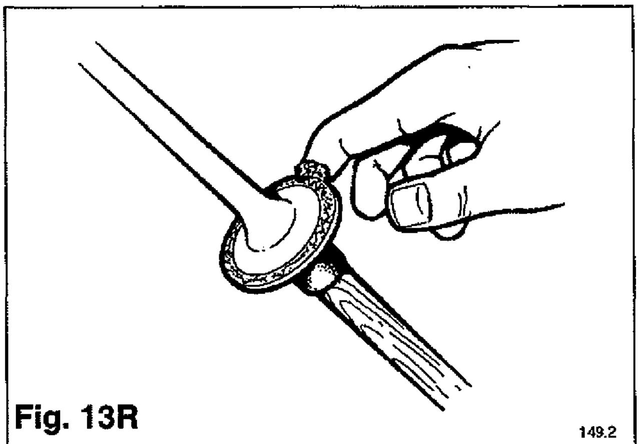



**Fig. 13R**

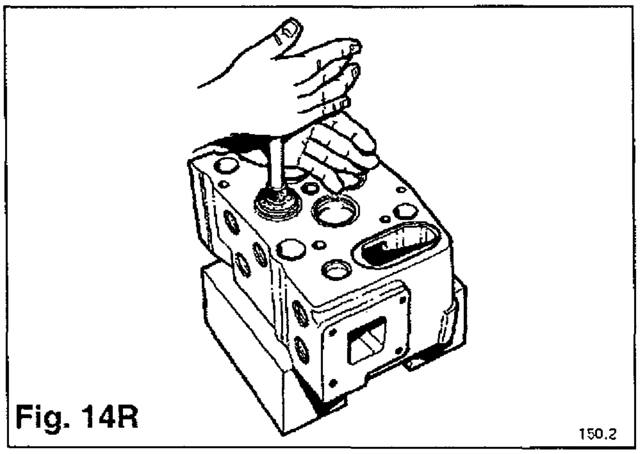



**Fig. 14R**

## VALVE REPLACEMENT

Lay the cylinder head on its side. Coat the valve stem with oil, push the valve down onto its seat, check the valve spring's free length, if it is less than 55.66 mm replace it with a new one. Compress the valve spring using **T6253/243**, down to a point where the collet groove on the valve stem is clear of the spring retainer, **Fig. 15R**. A dab of grease on the inside of the collets will hold them on the valve stem while the spring is slowly released. Be sure that the collets have located in the spring retainer.

The rockers, push rods and rocker shaft, etc., are not likely to need replacement during the normal life of the engine, but it is advisable to check for excessive wear, cracking or chipping at the push rod contact point or the valve stem contact face. If any is found, renew all components.

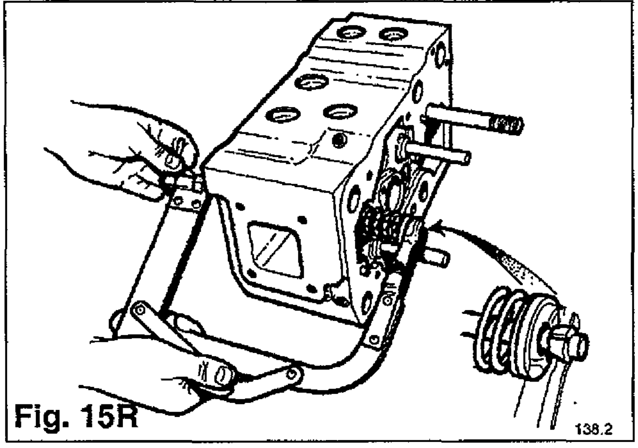



Fig. 15R

## REMOVING THE INJECTOR BUSH

If water is found to be leaking from between the cylinder head and the injector, or if the injector bush is damaged in any way, it must be replaced.

Using a 22 mm diameter drill having a 60° angled point, drill out the swaging of the injector bush **Fig. 16R**, taking care not to drill into the cylinder head.

Screw a $1^3/_8$" UNF tap into the injector bush, then lay the cylinder head combustion face up on blocks of wood **Fig. 17R**. Insert a mild steel rod from the combustion side of the cylinder head until it contacts the tap then carefully knock out the injector bush.

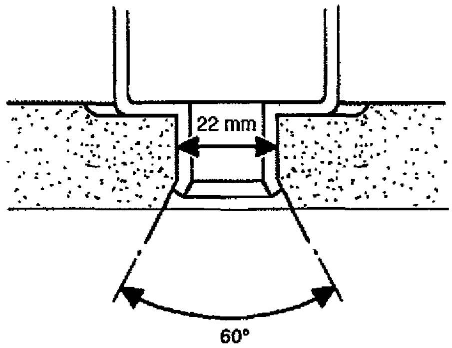



Fig. 16R

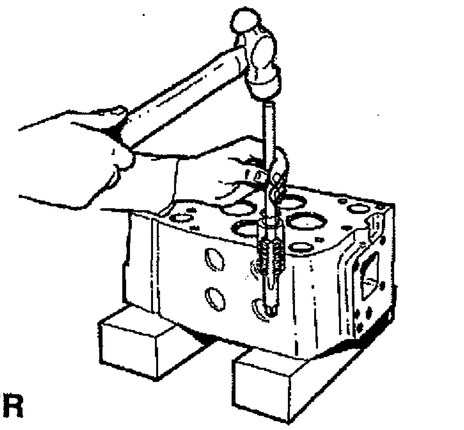



Fig. 17R

Remove the injector bush 'O' ring and discard. **Fig. 18R**. Clean any rust or carbon deposits from the injector bush aperture.

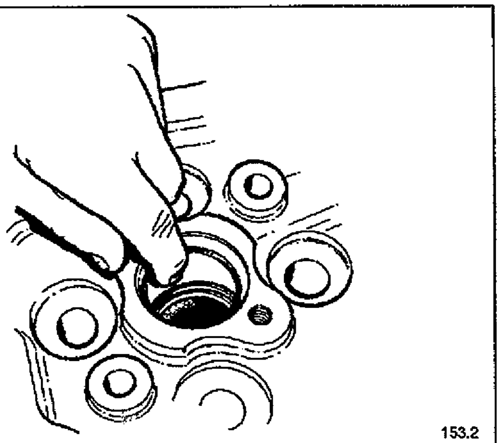


Fig. 18R

153.2

## REPLACING THE INJECTOR BUSH

Fit a new 'O' ring into the recess in the injector bush aperture holding it in position with silicone grease. Slide the new injector bush onto the fitting tool Part No. **T85002/2** then fit the locating sleeve into the end of the drift **Fig. 19R**.

Carefully push the injector bush into its aperture making sure that the 'O' ring has stayed in position. When the injector bush has located in the combustion side of the cylinder head, this may be felt with the free hand, very carefully hammer the bush home **Fig. 20R**. The end of the tube should be 1.5 mm from the lower face of the head **Fig. 21R**.

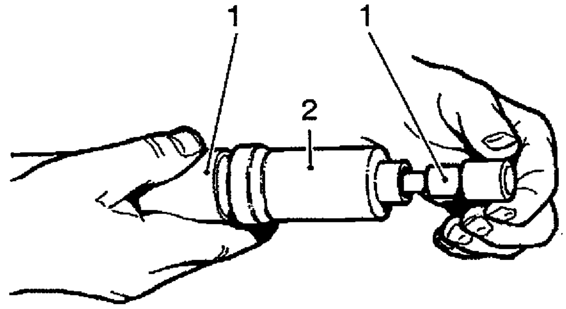



Fig. 19R

154.2

**Key**
**(Fig. 19R)**

**1** Fitting tool
**2** Injector bush

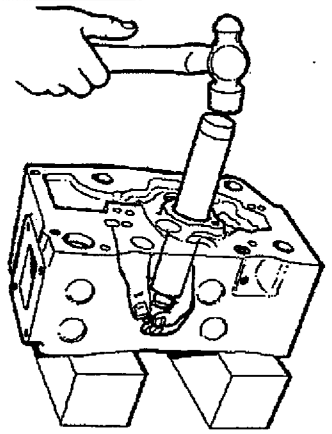


Fig. 20R

155.2

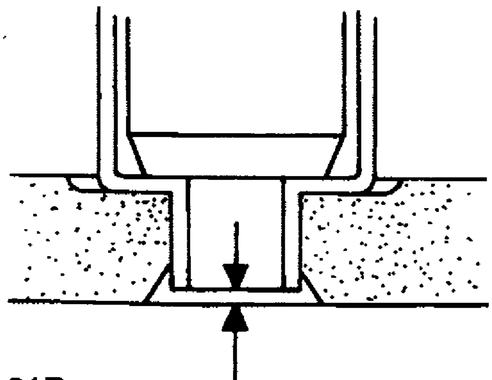


Fig. 21R

156.2

Invert the cylinder head and, using Special Tool No. **T85002/6**, expand the lower end of the injector bush to give a gas and water tight seal.
Check that the end of the tube is no more than 1.5 mm from bottom of head, **Fig. 21R**.
Reposition cylinder head the correct way up, and using Special Tool No. **T85002/58**, expand upper end of the injector bush to give a gas and water tight seal.
**NOTE:** The pressure exerted on the bush is automatically controlled by the above tools when they rotate in the bush, so when resistance to rotation eases, the bush will have been expanded to the necessary limits.
Remove the bush expander tools and lay the cylinder head on its side.
With the new injector bush correctly fitted, the end of the bush will protrude into the angled recess in the combustion side of the cylinder head. Using special tool No. **T6253/156** swage out the injector bush into the recess **Fig. 23R**. Apply a torque of 55 Nm (40 lb.ft).
Reposition the cylinder head the correct way up. Using the injector bush facing cutter tool Part No. **T85002/7**, lightly skim the inner bottom face of the injector bush **Fig. 24R**.

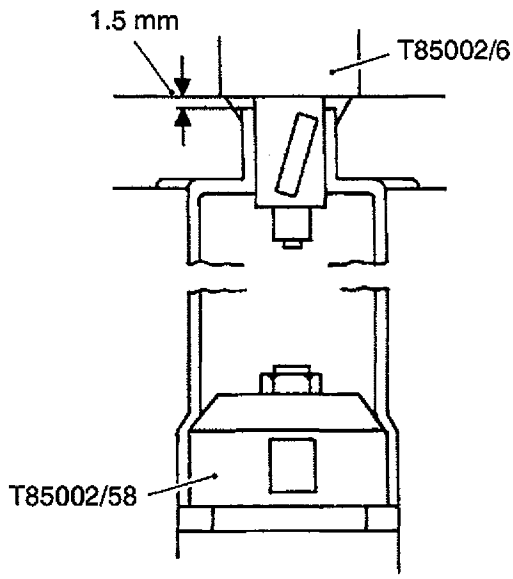



Fig. 22R

157.2

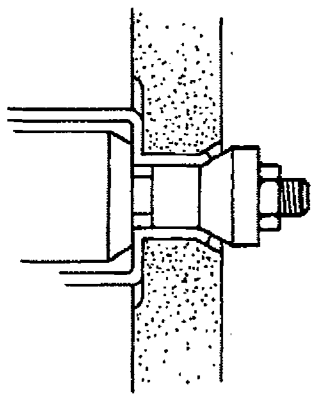


Fig. 23R

158.2

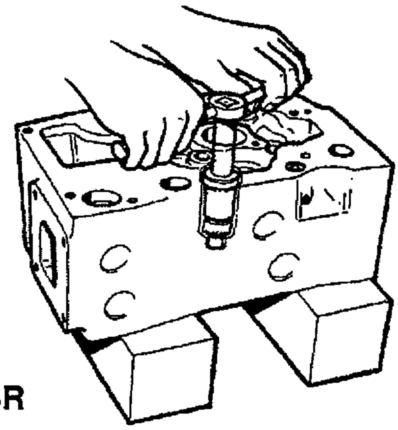


Fig. 24R

159.2

Remove the swarf then check the injector bush depth using gauge part no. **T85002/14** relative to deck height. This final dimension should be 122.6 ± 0.105 mm (4.827" ± 0.004") face the injector bush down to the correct depth and remove all traces of swarf. **Fig. 25R**.

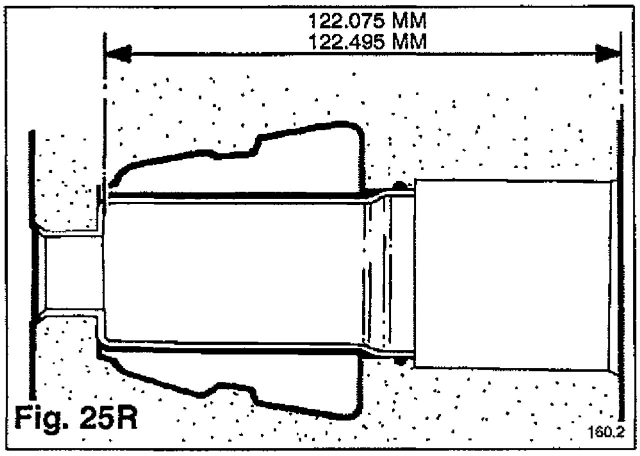


**Fig. 25R**

## REPLACING CORE PLUGS

With the cylinder head fully stripped condition, check all core plugs if leakage or corrosion is apparent, the core plugs must be replaced. Old core plugs may be removed from their bores by careful use of a small sharp chisel **Fig. 26R**. Clean any corrosion or lime build up from the bores.

Put the new core plug onto a suitably sized bar and smear Loctite 270 Studlock onto the outside of the new core plug. Line the core plug up with its bore and carefully hammer it home **Fig. 27R**. If the appropriate equipment is available for water testing, the maximum pressure to be applied is 6.9 bar (100 lb/in$^2$) using hot water (70-90°C).

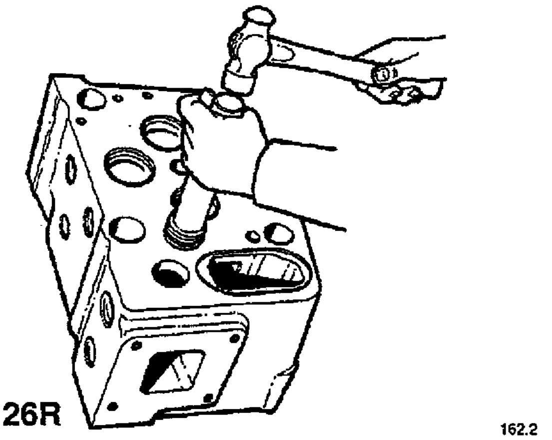


**Fig. 26R**

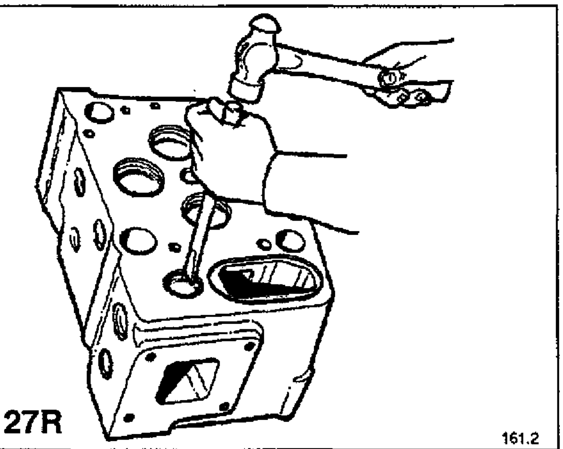


**Fig. 27R**

Fit the first push rod tunnel 'O' ring and its plastic insert into the recess in the sandwich plate, holding the 'O' ring in position with bearing grease (see **Fig. 28R**).

Ensure that both the face of the cylinder block and the underside of the sandwich plate are clear of any particles of carbon and place the 5 'O' rings in the recesses of the water holes before fitting the sandwich plate.

Locate the sandwich plate on the two dowels (See **Fig. 29R**), which should be lubricated with high temperature grease such as PBC (Poly-Butyl-Cuprysil) and tap the plate fully down onto the crankcase.

Sandwich plates fitted to the latest engines are retained by 4 capscrews, (see **Fig. 30R**), which should be fitted with Loctite 542 Hydraulic Seal applied to the underside of the capscrew heads only. The capscrews should be started in their threads, tightened evenly with a ratchet wrench and then immediately tightened to a torque of 48 Nm (35lb ft).

Fit the flame ring into the liner flange recess, as shown in **Fig. 30R** and add 5 more 'O' rings to the water holes in the sandwich plate.

**Key**
**(Fig. 28R)**
**1** 'O' ring
**2** Insert

**(Fig. 30R)**
**1** Apply loctite here
**2** Jacking screw

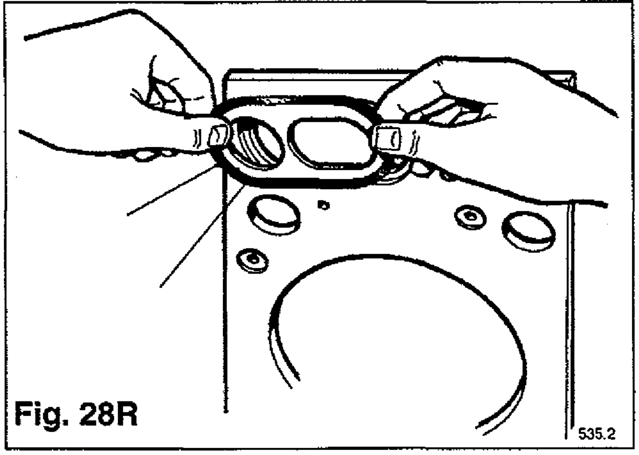



**Fig. 28R**

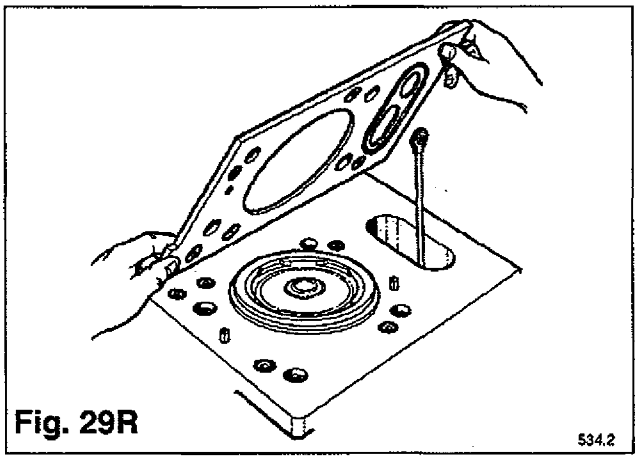



**Fig. 29R**

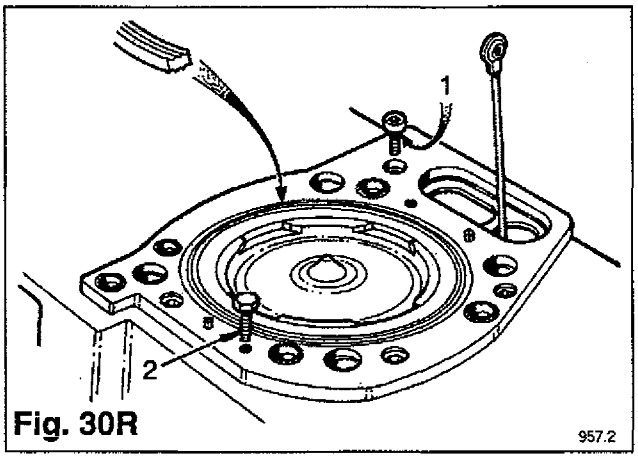



**Fig. 30R**

Early engines have their sandwich plates bored to accept rubber bushes with internal stiffeners (see **Fig. 31R**) and they are not retained by capscrews. All engines are fitted with plastic inserts for the large 'O' rings.
Press into the sandwich plate the five assembled rubber bushes and internal stiffeners. Fit the second push rod tunnel 'O' ring and its plastic insert into the recess in the combustion face of the cylinder head, holding it in position with bearing grease (see **Fig. 32R**). Fit the cylinder head lifting tool **T6253/237** (see **Fig. 15Q**) and hoist the cylinder head into position. Then gently lower it, being careful not to foul the fuel control link (see note below), and locate it on the dowels which protrude through the sandwich plate, also making sure that the push rod tunnel 'O' ring is still in its correct position.

**NOTE:** Whilst the fuel control link is shown in position in **Fig. 29R** to **Fig. 32R**, it is recommended that it is fitted after replacing the cylinder head to avoid damaging this relatively delicate part.

When the cylinder head is in position, remove the lifting tool. Check that the cylinder head bolt threads are clean, undamaged and in good condition.

**Key**
**(Fig. 32R)**
**1** Adhesive

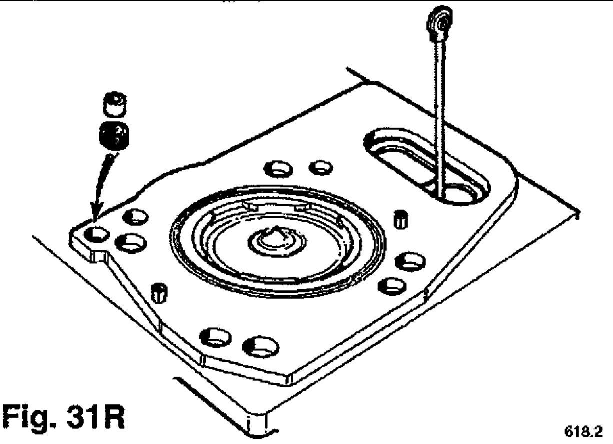


Fig. 31R

618.2

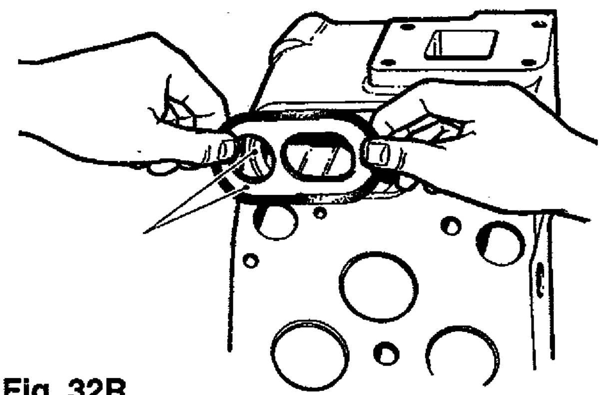


Fig. 32R

164.2

**EARLIER TYPE CYLINDER HEAD BOLTS (SEE FIG. 34.1R)**
Using PBC (Poly Butyl Cuprysil) grease, coat the threads and both sides of the washers fitted under the bolt heads, before starting them in the crankcase. The bolts should be tightened in the order shown in **Fig. 34R** and as instructed in **Table 1R** (below).

**LATER TYPE CYLINDER HEAD BOLTS WITH WAISTED SHANKS (SEE FIG. 34R)**
Using PBC (Poly Butyl Cuprysil) grease, apply one 'stripe' to the threads (as shown in **Fig. 34R**), coat both sides of the washers fitted under the bolt heads, before starting them in the crankcase.
**NOTE:** It is important not to exceed the amount of PBC grease recommended above.
The bolts should be tightened in the order shown in **Fig. 33R** and as instructed in **Table 1R** (below).
Renew any bolts that bear two centre punch dots, see **Section Q6 Fig. 17Q.**

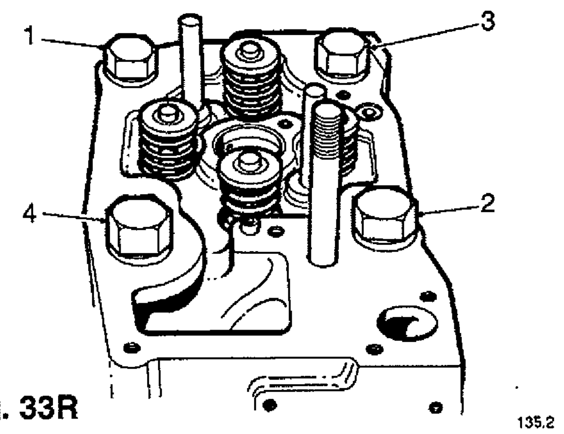


**Fig. 33R**

Key
**(Fig. 34R)**
**1** Earlier cylinder head bolts
**2** Later cylinder head bolts
**3** Apply PBC grease as shown here
**4** Head stamped with 'W' to identify the later (waisted bolt)

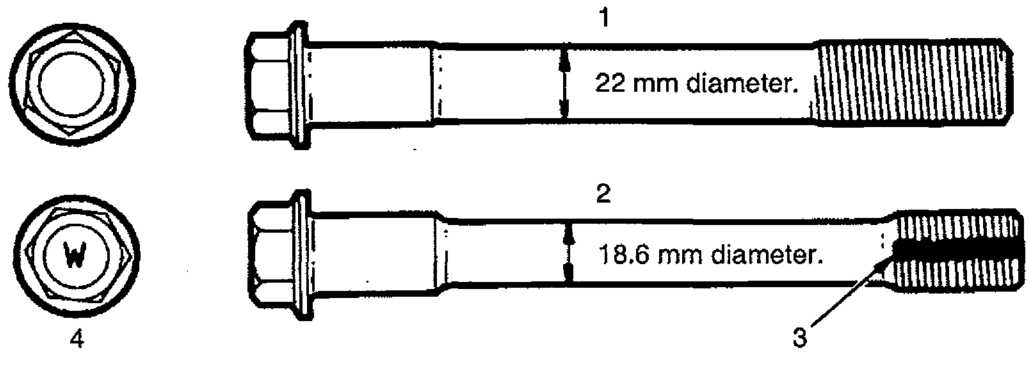


**Fig. 34R**

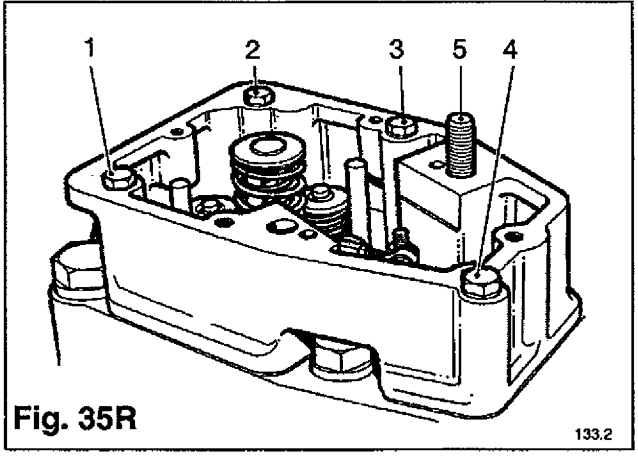



Fig. 35R

**TABLE 1R** **ALL CYLINDER HEAD BOLTS TO BE TIGHTENED AS FOLLOWS**

Tighten all four bolts evenly in the sequence shown in **Fig. 33.**

| Step | Earlier bolts | Later bolts with waisted shanks |
|---|---|---|
| 1 | With a ratchet wrench until just tight | |
| 2 | to 135 Nm (100 lb ft) | |
| 3 | to 271 Nm (200 lb ft) | |
| 4 | to 540 Nm (400 lb ft) | |
| 5 | to 750 Nm (550 lb ft) | to 723 Nm (530 lb ft) |

**Caution: It is important not to exceed the maximum torque given above, especially in the case of later type bolts with waisted shanks.**
Earlier or later bolts should be fitted as complete sets and should not be mixed.
If there is any doubt as to the type of any particular bolt, then that bolt should be replaced.
Fit the injector with reference to **Section P13**. Adjust the control linkage in accordance with the type of rockers and injectors fitted, see **Section P14.**
Clean any oil from the top face of the cylinder head and any old gasket material from the mating surface. Refit the fuel control link to the break-back lever. Place a new joint on top of the cylinder head, locating it on the two dowels fixed in the cylinder head face. Jointing compound is necessary. Fit the rocker box, locating it also on the two dowels. Clean and lubricate with engine oil the threads of the 4 rocker box bolts then screw them down through the rocker box and tighten them to the required torque in the order shown (see **Torque Settings pages 38-40) Fig. 35R.**
Refit the rockers, reset the clearances and time the injector. Again refer to **Section P14** for the type of rockers and injectors fitted.
**NOTE:** Interchangability of rockers and bridge pieces from early to later engines or visa versa is not possible, due to differences in materials and manufacture.

Disconnect the starter motor batteries and use the barring over tool **SE253** to turn the engine for this operation **Fig. 1S**. First remove the dust cover by unscrewing the retaining screw. Then using a socket and ratchet wrench press against the spring loaded bolt head until the internal pinion engages with the flywheel ring gear and crank the engine to the desired position.

As each cylinder has an individual cylinder head the removal of a piston only requires the removal of the relative cylinder head, see **Sections Q1 to Q6**.

Remove the appropriate side covers and the oil cooler (if necessary), crank the engine over to a convenient position where the con rod end float with feeler gauges before removing the 'big end' cap. Each time that a con rod bolt is undone, it should be marked with a centre punch dot (see **Fig. 2S**). **Any bolt showing three dots prior to removal should be replaced.**

Remove the carbon from the top of the cylinder liner. Remove the 'big end' cap and shell bearing from the connecting rod. Rotate the crankshaft until the piston is at Top Dead Centre (TDC). Insert tool **T6253/212** into the valve recesses (see **Fig. 4S**), and gently expand it into the piston. Carefully lift the piston and connecting rod out of the cylinder. Replace the 'big end' cap and shell bearing in the connecting rod, screwing the bolts in finger tight to hold the cap in position.

**NOTE:** 'Big end' caps are not interchangeable and must be fitted the right way round.

Ensure that connecting rod and caps have matching identification numbers.

**Key**
**(Fig. 1S)**
1 Cranking device

**(Fig. 2S)**
1 After 1st removal (dot when removing)
2 After 2nd removal (dot when removing)
3 After 3rd removal (dot when removing) renew next time
4 After 4th removal renew bolt

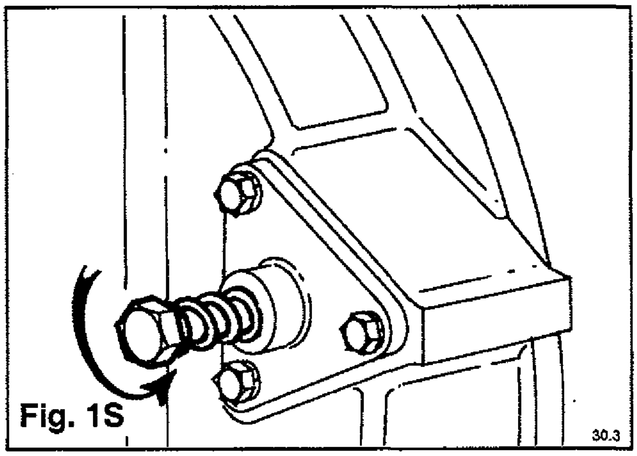



Fig. 1S

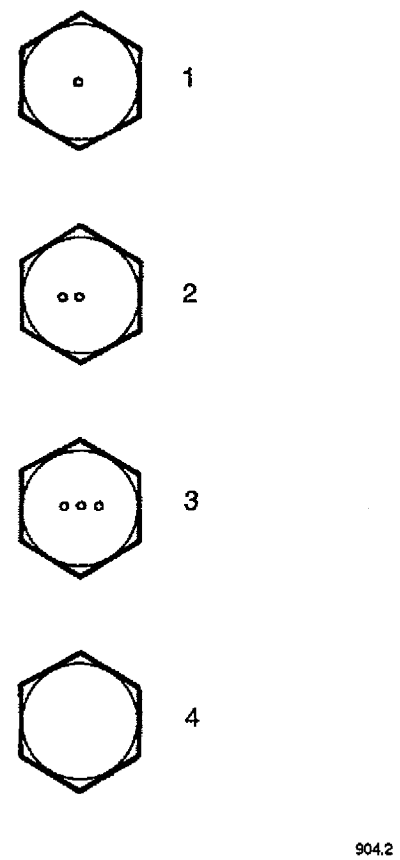



Fig. 2S

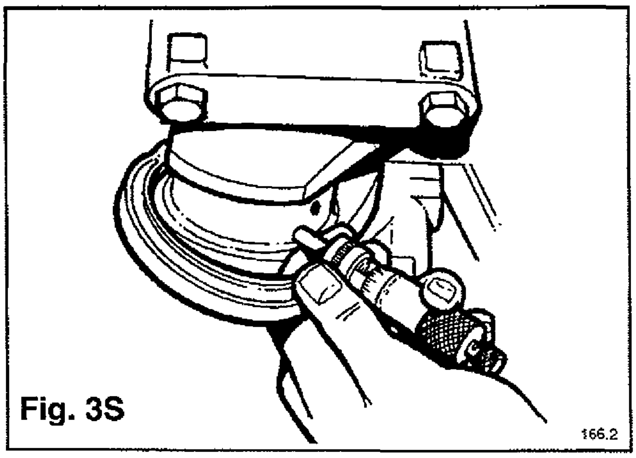



Fig. 3S

At this point check the big end shell bearings for score marks, bruising or any other damage to the soft bearing surface.
Check that the 'big end' journal has no score marks and using a suitable micrometer, check that it is within the recommended limits (see **pages 38-40**) and **Fig. 3S**.
Remove, using tool **T6253/238**, and discard the gudgeon pin circlips **Fig. 4S**. If the gudgeon pin is a tight fit in the piston it will be necessary to immerse the piston in hot water for a few minutes after which the gudgeon pin can easily be pushed out.

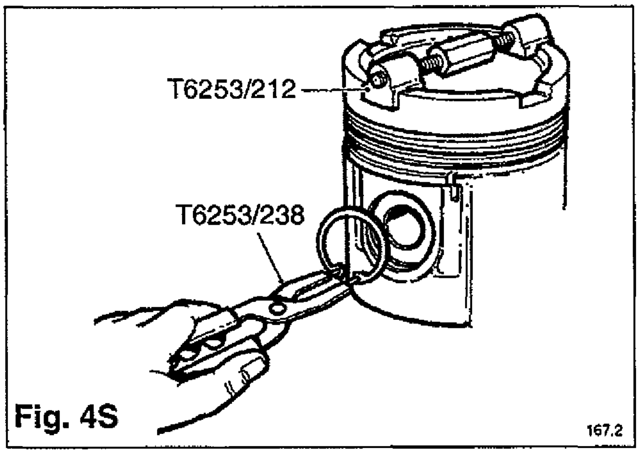


Fig. 4S

**NOTE:** If the gudgeon pin has become worn below the limits shown in the **Wear and Renewal Limits** table (**pages 41-42**), the piston and gudgeon pin must be replaced. **Fig. 5S.**

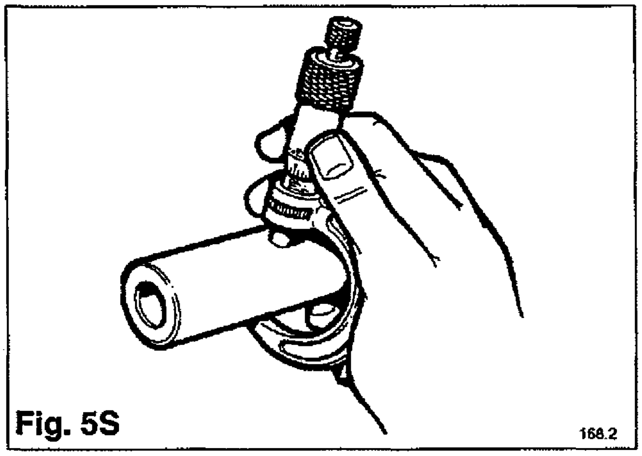


Fig. 5S

Using piston ring pliers **T6253/256** carefully remove the piston rings, laying them down in order of removal, as they should be re-fitted in their original grooves if they are found to be serviceable. **Fig. 6S.**
Visually check the pistons for seizure marks or cracks, etc. If any are found, the piston should be replaced.
If the pistons look serviceable they should be carefully cleaned, removing carbon deposits from the ring grooves, oil holes and the piston crown. Use a wire brush not emery cloth for this operation. Check that the ring grooves are smooth and within the limits given in the following table.
All engines incorporate a tapered top ring which need not be measured. For the second and third ring measurements see **pages 41-42 Wear and Renewal limits.**

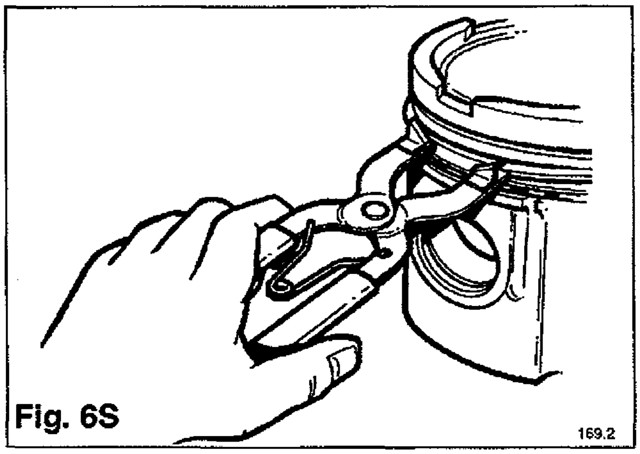


Fig. 6S

Visually check the piston rings for cracks or score marks. If any are found, discard the ring. If the piston rings look serviceable, clean the carbon from the inside edge and check the width given in the table above, see **Fig. 7S**.
Fit the piston rings in their grooves (see note) and using feeler gauges check that the piston ring side clearances are within acceptable limits see **page 36**. If new piston rings cannot rectify excessive clearance, a new piston and rings must be fitted **Fig. 8S**.
**NOTE:** Where piston rings are marked with 'TOP' on one side of the ring, these should be fitted with this marked side uppermost. The second ring is internally stepped and must be fitted with step uppermost. The oil control ring is not marked, so this ring may be fitted either side up, as it is symmetrical, but if refitting a used ring ensure that it is fitted the same way as it came off.
Before checking rings gaps, visually inspect the cylinder liner for score marks, or any other damage. Check that the liner bore is in accordance with the Wear and Renewal limits (see **pages 41-42**).
If the liner is serviceable break the glaze on its surface in the following way:-
Cover the crankshaft with, e.g. aluminium foil, to protect it from any particles falling down the cylinder bore. Using a good quality honing oil to operate the honing brush **Fig. 9S** at 300 to 500 revolutions per minute, moving the brush up and down through the entire cylinder ONCE EVERY SECOND for about 15 seconds. This will give the liner surface its proper roughness or 'cross hatch'. Do not mix the oil with paraffin nor use aluminium foil. After the process carefully clean the liner. This MUST be done by washing the liner with HOT SOAP solution which will dissolve all the residue of honing oil that may remain in the liner surface. DRY the liner with paper towels until paper remains dry and clean.

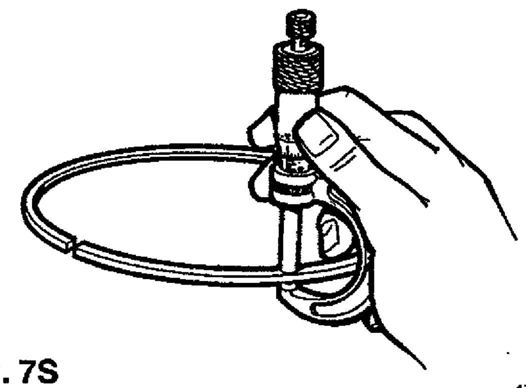


**Fig. 7S**

170.3

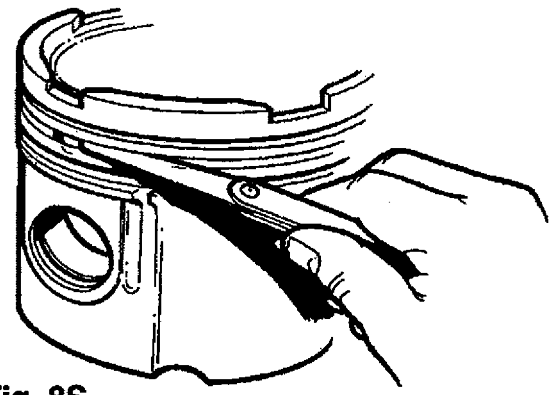


**Fig. 8S**

171.2

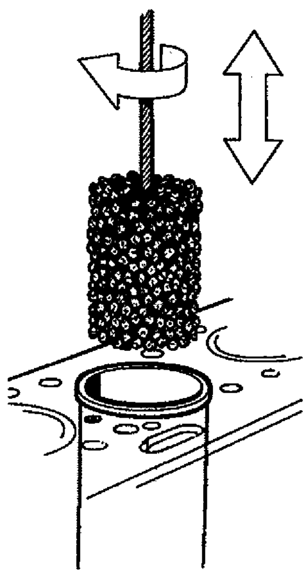


**Fig. 9S**

172.2

It is necessary that the ring gap of a new or used piston ring is checked by placing it squarely in the lower inch (25 mm) of the bottom of the cylinder liner. The piston may be used to locate the ring in the bore, positioning it perfectly. Using feeler gauges, check that the ring gaps are in accordance with the **Wear and Renewal Limits pages 41-42. Fig. 10S.**

Check the 'small end' bush of the con rod for scoring or seizure marks and that it is within the Wear Limits **(pages 41-42). Fig. 11S.** If the bush has to be replaced, a special tool Part No. **T6253/159** is necessary for the removal and fitting of the bush. The new bush is pre-finished and does not need reaming.

The connecting rods should be checked for cracks by means of the magnetic particle system using ultra violet light, or at least by the dye penetrant and developer process before proceeding with any further examination. Assuming that no cracks have been found by either of these methods, continue with the normal dimensional inspection of the connecting rods.

**NOTE:** All new engine connecting rod assemblies are supplied within defined weight bands and matched set tolerances. (The weight is painted on the shank of each connecting rod). When a spare connecting rod is required it is recommended that **Perkins Power Part Distribution Centre** is contacted, so that the spare connecting rod is supplied to match the weights of the other connecting rods, according to our records. If the gudgeon pin is tight, heat the piston in hot water for a few minutes. Liberally coat the gudgeon pin, the 'small end' bush and the gudgeon pin bosses of the piston with clean engine oil. Push in the gudgeon pin, carefully locating it in the 'small end' bush. No excessive force is needed. Fit new circlips and check that the piston is fitted correctly relative to the con rod. See **Fig. 12S**. Particularly of the position of the cooling jet cut out.

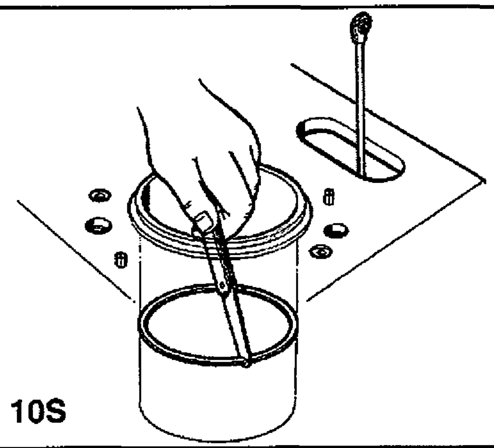


Fig. 10S

617.2

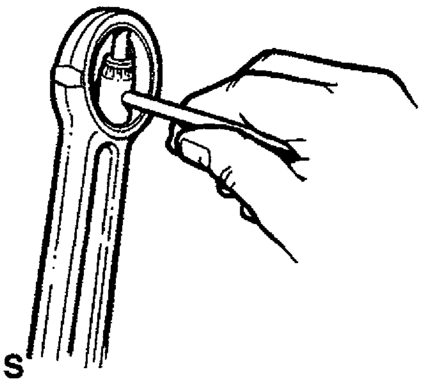


Fig. 11S

174.2

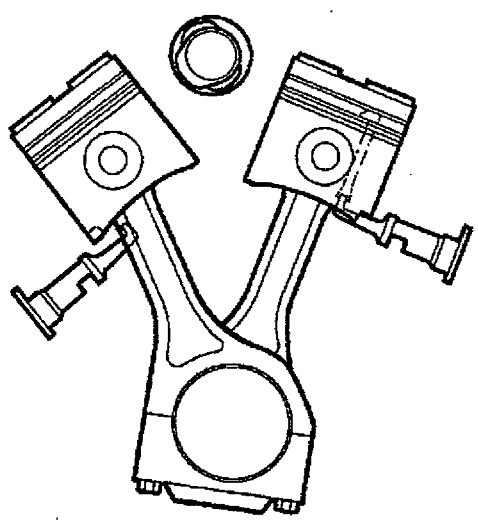


Fig. 12S

537.2

Coat the piston ring grooves and the piston rings with clean engine oil. Refit the piston rings in their correct grooves with the ring gaps spaced equidistantly around the piston. Remove the 'big end' cap. Make sure that the shell bearing in the con rod is clean and its surface is coated with clean engine oil. Ensure that the lug on the shell bearing is located in the con rod, **Fig.13S**. Coat the cylinder liner with clean engine oil. Check the big end nip .003"/.008" by fitting the connecting rod to its respective crankshaft bearing pin, tightening the cap bolts to the recommended torque, slackening a bolt on one side only and then measuring the gap with feeler gauges. However, as this is difficult to do on the engine, the con rod is normally removed, cleaned, the bearings fitted, the cap tightened down and slackened on the bench.

Slide the piston ring compressing tool Part No. **T6253/139** or a standard universal tool up to the bottom ring, and lower the con rod into the cylinder bore.

Carefully locate the piston in the bore and gently push it down, at the same time guiding the 'big end' onto the crank pin. **Fig. 14S.** Prevent the con rod dowels from contacting the crankshaft by the application of plastic tape.

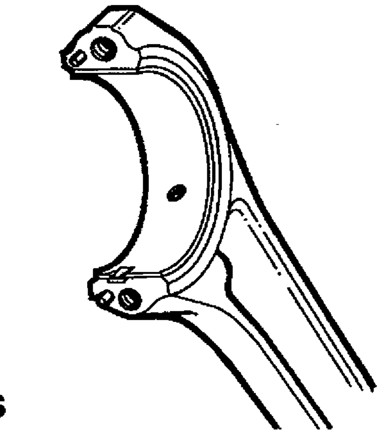



**Fig. 13S**

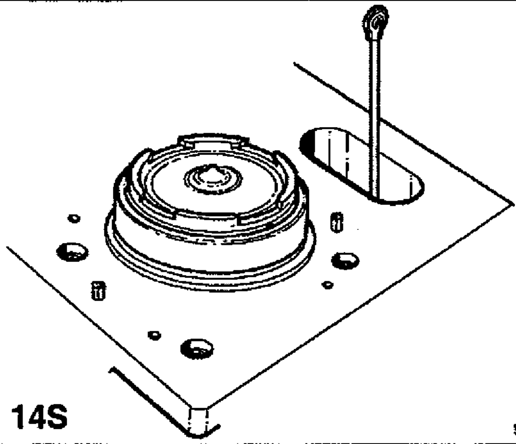



**Fig. 14S**

Check that the 'big end' cap is clean, the shell bearing is correctly located and its surface is coated with clean engine oil. Fit the 'big end' cap **Fig. 15S** or **16S**, making sure that the identifying numbers on rod and cap are on the same side.
Lubricate the conn rod bolt threads and under the heads using engine oil. Tighten the conn rod bolts using the following steps.

| STAGE | TORQUE |
|---|---|
| 1 | 80 lb.ft (110 Nm) |
| 2 | 160 lb.ft (215 Nm) |
| 3 | 210 lb.ft (285 Nm) |

**NOTE:** Conn rod bolts should only be changed three times (see **Section S1** for details).
Refit the side doors using new gaskets, refit the cylinder heads, etc., see **Section R9 - 11.** Fill the sump with the correct grade of oil and the cooling system with the correct mixture of inhibitor/anti-freeze and water see **page 28.**
Ensure that the engine switch on the control panel is in the 'stop' position. Press the starter button to crank the engine over until the oil pressure gauge registers.
Continue after this for a further 10 seconds to ensure that the oil has reached the turbochargers.
Visually check the engine for fuel, water or oil leaks. Set the engine switch on the control panel to the 'idle' position with the main breaker in the 'OFF' position. Alternatively, on engines for variable speed applications, set the governor control to the 'idle' position, with the load disengaged where possible.
Press the starter button and the engine should start immediately. Check the oil pressure. Check again for fuel and oil leaks and that the ammeter in the instrument panel is showing charge to the engine batteries. Allow the engine to run for five minutes at rated speed, checking that the instruments are reading correctly, then stop the engine. Check oil and coolant, fill up to correct levels.

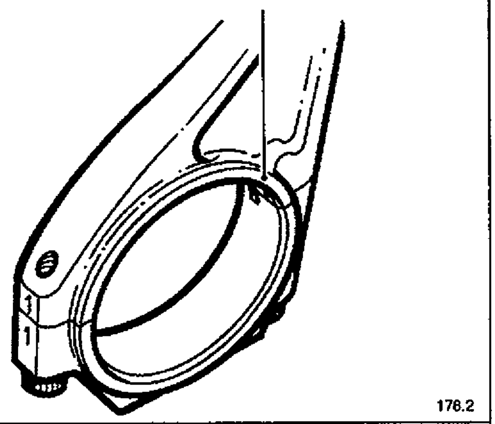



**Fig. 15S**

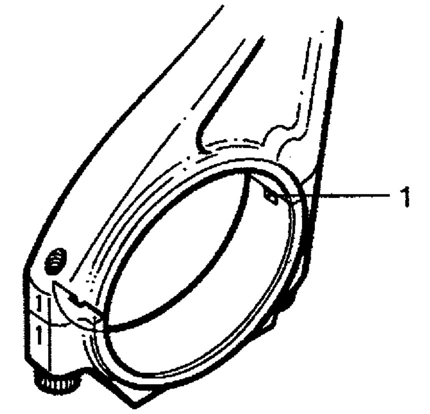



**Fig. 16S**

**Key**
**(Fig. 15S)**
**1** Locating lugs on same side on non up-rate engines

**(Fig. 16S)**
**1** Locating lugs on opposite sides on up-rate engines

The piston cooling jets are situated on each side of the crankcase, they pick up oil from galleries cast in the crankcase and spray it up to the underside of the pistons (see **Figs. 10S and 1T**).

**NOTE:** Before attempting to remove a piston cooling jet the appropriate piston should be positioned on T.D.C. to ensure that the balance weight or piston skirt does not obstruct the piston cooling jet. This procedure should be followed for both removing and refitting the piston cooling jets.

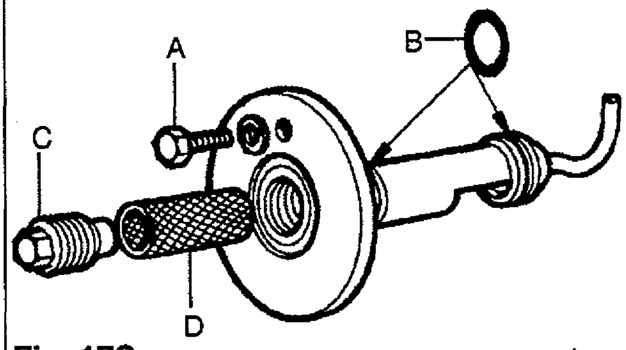


Fig. 17S

## REMOVING AND CLEANING PISTON COOLING JETS

Using a suitable solvent clean the outer face and the immediate area around the piston cooling jet, a necessary precaution to stop dirt etc entering the oil gallery.

Take out the retaining screw 'A' pull the jet from the crankcase and discard the 'O' rings 'B'. Clean the jet in a suitable solvent. Check the gauze filter and the oil spray hole are clear. If the jet is blocked or the gauze contaminated the jet can be dismantled for thorough cleaning. Unscrew the plug 'C' and remove the gauze '**D**'. After cleaning if there is any doubt about the oil flow through the jet replace it, as a diminished oil spray pattern could cause severe piston damage. Re-assemble the jet using Loctite 342 sealing compound on the thread of the plug 'C' and tighten to 15lbf 2Nm.

## REFITTING PISTON COOLING JETS

Fit new 'O' rings to the jet and lubricate with clean engine oil, push the jet into its aperture in the crankcase until its shoulder is square with the crankcase then refit and tighten the retaining screw to the required torque (see **Torque Settings on pages 38-40**). Refer to **Fig. 10S**.

**WARNING** ⚠ DO NOT USE JOINTING COMPOUNDS ON OIL CIRCUITS TO COOLING JETS.

## REMOVING A CYLINDER LINER

The appropriate cylinder head, piston and crankcase inspection cover should be removed, see **Sections Q1** to **Q6**. Thoroughly clean the top surface of the cylinder block, fit the liner removal tool No. **T6253/152**, being careful not to damage the piston cooling jet, which protrudes into the base of the liner, (the liner removal tool base plate is cut away to avoid this) and carefully withdraw the liner **Fig. 1T**.

**NOTE:** It is recommended that the piston cooling jet be removed prior to the use of the liner removal tool. However this is not essential if extreme care is taken. If, in spite of all precautions, the cooling jet is damaged in the removal or replacement of the liner, it must be replaced by a new one as described in **Section T2.**

A small quantity of residual water and rust will be released when the liner is withdrawn. Protect the crankshaft falling debris.

Clean any particles of rust, scale, etc., from the inside of the cylinder block, (especially if the crankshaft is in position), and from all bearing surfaces.

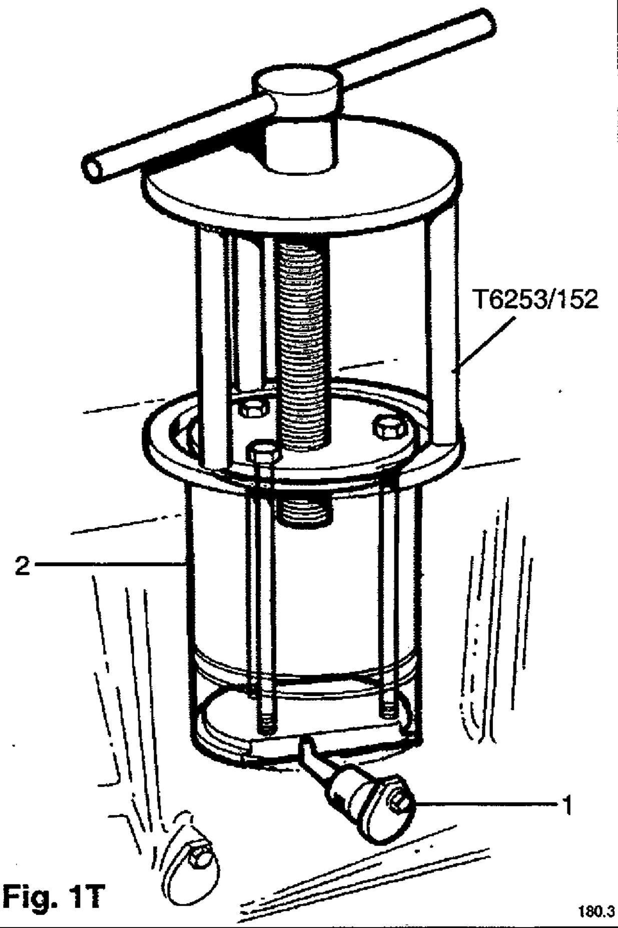



**Fig. 1T**

## REPLACING A CYLINDER LINER

With all internal surfaces perfectly clean, fit the two 'O' rings and lubricant on to the new cylinder liner and lightly coat the inside of the cylinder block where the 'O' rings seat with silicone grease or soft soap. This will aid liner fitting by allowing the 'O' rings to slide more easily into position. (Do not smear lubricant on the 'O' rings as this will coat the top surface of the cylinder block affecting the sealing properties of the Loctite used in the next operation).

**Key**
**(Fig. 1T)**
**1** Piston cooling jet
**2** Liner

## REFITTING A CYLINDER LINER

Coat the top case lip with Loctite 638 and using extreme care and without undue force press the liner home, then clamp the liner in position using liner clamping tool No. **T6253/200** (see **Fig. 2T**) leaving it for a minimum of 3 hours to allow the Loctite sealant to cure before fitting the piston, cylinder head, etc. Check the flame ring groove (2) depth in the liner flange (3) relative to the sandwich plate face (1) **Fig. 3T**, which must be the same depth all around the groove.

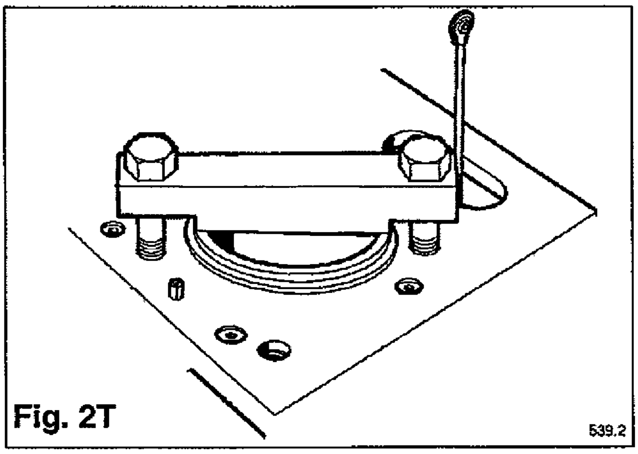


Fig. 2T

539.2

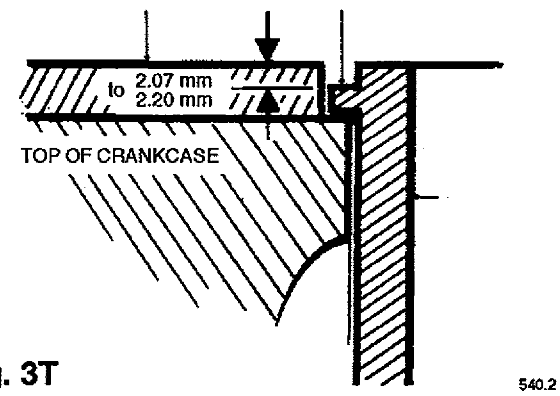



Fig. 3T

540.2

## THE PISTON COOLING JETS

The piston cooling jets are situated on both sides of the crankcase. They are supplied with oil from galleries cast in the crankcase and spray it up to the underside of the piston. (See **Fig. 1T**).

**NOTE:** Before attempting to remove a piston cooling jet, the piston should be positioned on T.D.C to ensure that a balance weight or piston skirt does not obstruct the jet. This procedure should be followed for both removing and refitting each cooling jet.

## REMOVING THE PISTON COOLING JETS

**Warning:** FITTING AN IMPERFECT PISTON COOLING JET MAY RESULT IN SEVERE ENGINE DAMAGE.

Take out the single retaining setscrews and carefully pull the jet from the crankcase and plug the aperture to stop the ingress of dirt, etc. Discard the 'O' rings, wash the jet and check that the oil spray hole is clear. If there is a blockage, it should be cleared if possible with compressed air. Inspect the jet for signs of overheating chipping and cracking etc. Check the jets for distortion every 10,000 hours. Replace the jet if in doubt. Check jets for alignment, if bent or damaged renew. Fit a new jet if in doubt, as a failed jet will wreck the engine.

## REFITTING PISTON COOLING JETS

Fit new 'O' rings to the jet and lubricate it with clean engine oil.

Push the jet into its aperture in the crankcase until its shoulder is flush with the crankcase, then refit and tighten the retaining screw to the required torque (see **Torque Settings pages 38-40**). Refer to **Fig. 12S**.

WARNING ⚠ DO NOT USE JOINTING COMPOUNDS ON CIRCUITS SUPPLYING OIL TO THE PISTON COOLING JETS.

## CRANKCASE INSPECTION COVERS

Check that the openings in the side of the crankcase are thoroughly clean. Place a new joint around each opening, holding it in position with Loctite 518. Fit the inspection cover, making sure that the joint remains in position whilst tightening the securing screws.

## REMOVAL OF THE GEARCASE

Drain the coolant from the system using the drain taps fitted in the end of the oil coolers (see **Section L2**) and the radiator (if fitted).

Before removing the gearcase, it is necessary to slightly lower the sump (on later engines there is fitted a stiffening plate situated between the crankcase and the sump), by undoing all the sump bolts and the oil pipes connected to the sump. The sump or stiffening plate can then be gently lowered carefully detaching the joint from the lower machined face of the gearcase so the joint lies on the sump or stiffening plate and will not be damaged when the gearcase is removed. It will be necessary to remove the wire mesh guard, belts and fan assembly from the radiator (**Operators Handbook page 44**), also the alternator, its guard, belt and the alternator drive pulley, see **Section B1**. The drive pulley fitted to a parallel extension of the oil pump shaft is of the taperlock variety and can be removed by taking out the locking grubscrews in the front face of the pulley and screwing one into the extracting hole until the grip on the shaft is released. The pulley will then slide off the shaft. **Fig. 1U**.

When re-fitting it ensure that all components are free from oil and grease and that the drive pulley is aligned with the alternator pulley before tightening the taperlock bush (also see **Section B2**).

**WARNING** ⚠ TAKE CARE WHEN PULLING A COOLANT PUMP OUT OF THE GEARCASE AS IT IS A HEAVY UNIT. USE THE CORRECT LIFTING EQUIPMENT.

Remove a water pump by taking out the four bolts fixing the water pump casing to the gearcase and the suspension plate (see **Section D1**).

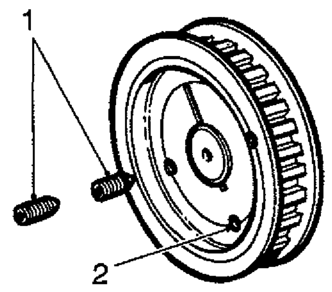


**Fig. 1U**

**Key**
**(Fig. 1U)**
**1** Locking grubscrews
**2** Extracting hole

**WARNING** ⚠ TAKE EXTREME CARE DURING THIS OPERATION AS THE TV DAMPER IS EASILY DAMAGED AND IS VERY HEAVY. USE THE CORRECT LIFTING EQUIPMENT.

**REMOVING THE CRANKSHAFT PULLEY, TV DAMPER, TUNING PLATE AND PULLEY ADAPTOR (SEE SECTION HH1) AS FITTED ON EARLIER 4012 AND 4016 ENGINES**

Remove the three bolts and the pulley retaining plate from the nose of the crankshaft. Attach a grease gun flexible pipe to the grease nipple in the crankshaft pulley adaptor **Fig. 2U** and apply pressure, this will force grease through a drilling in the tapered nose and will help release the grip of the pulley adaptor on the taper. By using crankshaft pulley extractor tool **T6253/209**, the crankshaft adaptor and TV damper can be removed from the crankshaft with a lifting sling fitted to long bolts in the crankshaft adaptor (see **Section HH1**).

**NOTE:** On the later 4012 and 4016 engines there is no provision for fitting a grease gun. The crankshaft pulley adaptor is to be removed by using the pulley extractor tool **T6253/209** only, as experience has shown there to be little advantage in using the grease gun system.

**Key**
**(Fig. 2U)**
**1** Crankshaft adaptor
**2** Grease gun
**3** Retaining plate
**4** Pulley extractor T6253/209

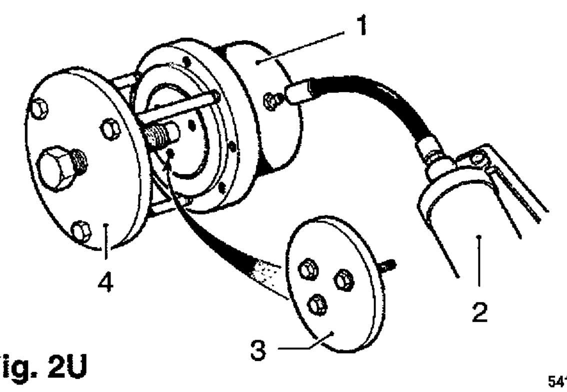


**Fig. 2U**

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT
TAKE EXTREME CARE WHEN REMOVING GEARCASE AS THIS IS A VERY HEAVY UNIT.

## REMOVING THE GEARCASE

Disconnect the connecting links from the actuator/governor to the fuel control shafts and remove the stop levers. Remove the governor and support bracket. Remove the water pipes from the pump inlet elbows and the thermostat housings. Remove the alternator (see **Section B1**) and the front halves of the engine mountings.

Remove all the bolts from around the edge of the gearcase, which can then be lifted away using the lifting eye **T6253/236** (see **Fig. 3U**). The engine suspension plate can remain in place as this only needs to be removed for a major overhaul or cleaning of the oil galleries, etc.

## REFITTING THE GEARCASE, ETC.

In refitting the gearcase, crankshaft pulley, TV damper (see **Section HH1**), and water pumps (see **Section D1**), apply the reverse procedure to that for the removal of the above items. Fit a new joint between the gearcase and suspension plate making sure that both mating faces are clean and that all old jointing has been removed. Lift the gearcase back into position and carefully locate it on the two dowels in the suspension plate, refit all the securing bolts, tightening them down so that the gearcase is pulled squarely up to the suspension plate.

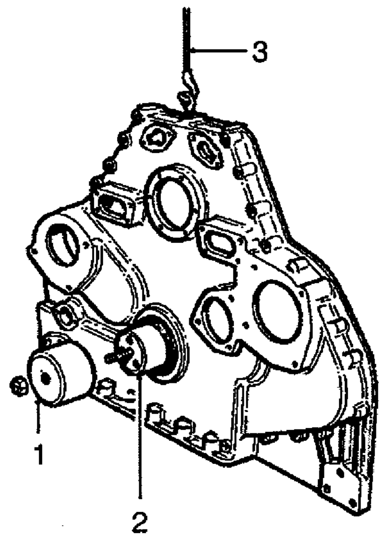



**Fig. 3U** 542.2

## FITTING THE GEARCASE OIL SEAL

Before a front oil seal can be fitted it will be necessary to remove the TV damper (see **Section HH1**) and the crankshaft pulley adaptor (see **Fig. 2U**). To fit the oil seal in the gearcase, a special tool **T6253/141 for 4012 engines or T6253/141A for 4016 engines** must be used. Bolt the oil seal locator to the crankshaft (see **Fig. 3U**), slide the seal up the locator seating it squarely in the gearcase (the seal with lip side to the engine). Push the outer sleeve of the fitting tool up to the seal, steadily tightening the nut until the outer sleeve bottoms. The seal is now in its correct position. Remove the seal fitting tool.

**Key**
**(Fig. 3U)**
**1** Outer sleeve T6253/141
**2** Oil seal locator T6253/141
**3** Lifting eye T6253/236

With the gearcase removed and the gears exposed, visually inspect all of the gears for cracked or broken teeth. Check the backlash on all gears using feeler gauges, **Fig. 4U** with reference to the **Wear and Renewal Limits**. (See **pages 41-42**).

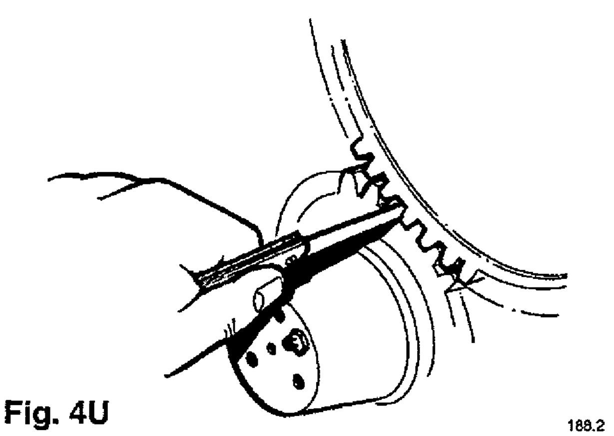



Fig. 4U

### IDLER GEAR END FLOAT

Check the end float of the idler gear by inserting feeler gauges between the retaining plate and the gear at 180° to each other (see **Fig. 5U**). Check with the limits in the **Wear and Renewal Limits on pages 41-42. If the end float is in excess of 0.3 mm (0.012") the gear and stub shaft must be replaced.**

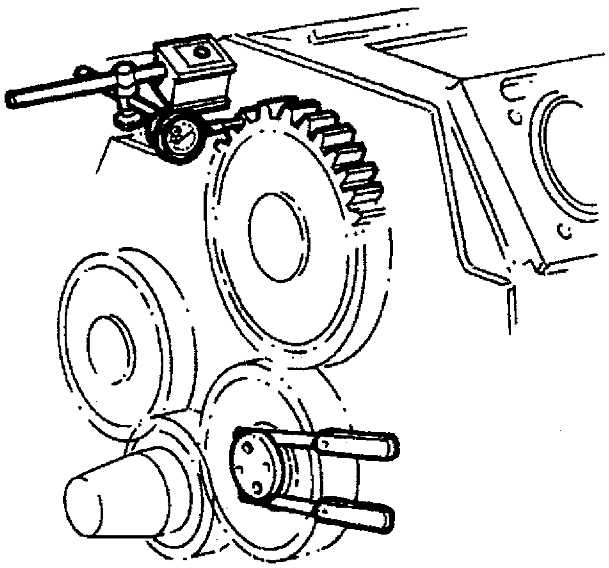



Fig. 5U

### IDLER GEAR BEARING

Remove the two bolts and the idler gear retaining plate and pull off the idler gear. Check the stub shaft and the bush in the gear for score marks and that the general wear is within the recommended limits, **Fig. 6U**, see **Wear and Renewal Limits** (see **pages 41-42**).

If the bush has to be replaced, it may be pressed out of the gear by using a suitably sized stepped mandrel, which should also be used to press in the new bush. This is prefinished and **DOES NOT** require to be bored out to give the design clearance shown in Column IV of the **Wear and Renewal Limits** on **pages 41-42.**

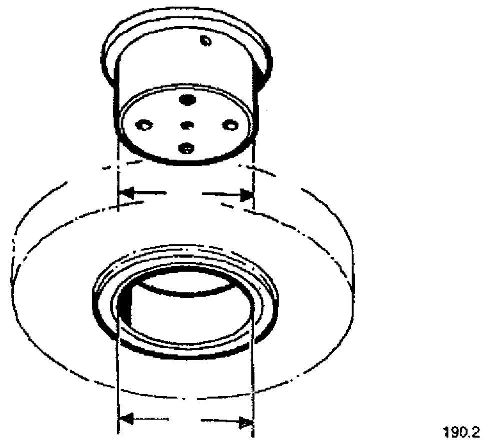



Fig. 6U

## CAMSHAFT GEAR OR IDLER GEAR REPLACEMENT

Should new gears be required, they are supplied complete with timing marks, and it is only necessary to assemble the idler gear to its hub and bolt the camshaft to its gear in the preset position. Then by aligning the timing marks as shown in **Fig. 9U**, the correct crankshaft to camshaft relationship is restored.

## CAMSHAFT END FLOAT

Check the camshaft end float using a dial test indicator, **Fig. 5U**. If the push rods and rockers are still fitted it will be necessary to use a suitable lever behind the gear to move the camshaft (**DO NOT** damage the gears, this is better done without the cam followers fitted). Refer to the **Wear and Renewal Limits** (see **pages 41-42**). If the clearance is in excess of that stated, then the thrust plate will need replacing. Remove the four gear retaining bolts and using hand pressure, ease the gear off the end of the camshaft to expose the camshaft thrust plate, which is held in position by two cap screws. Fit the new thrust plate, refit the gear and check the end float again. If the end float is still excessive, the camshaft gear must also be replaced.

To remove the crankshaft gear, the idler gear and camshaft gear must be first removed. Set the crankshaft gear with its timing mark at 12 o'clock, then using a universally available two leg puller, carefully withdraw the gear from the crankshaft. **Fig. 7U**.

Should the gear be too difficult to remove, grind away the hard surface in the region of the timing mark. Then drill into the gear as large a hole as possible, and split it with a cold chisel to remove it from the crankshaft. Clean away any debris.

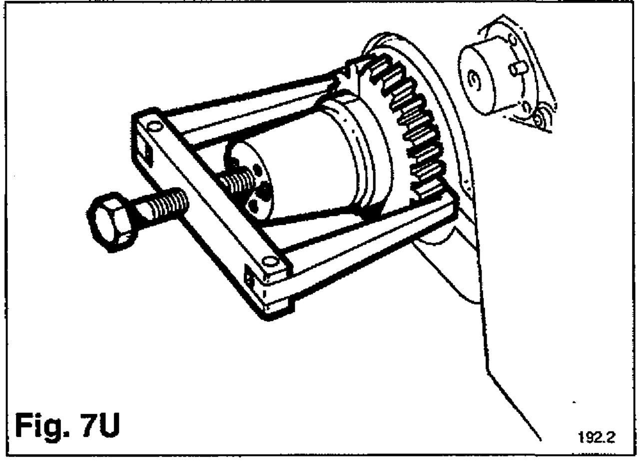



**Fig. 7U**

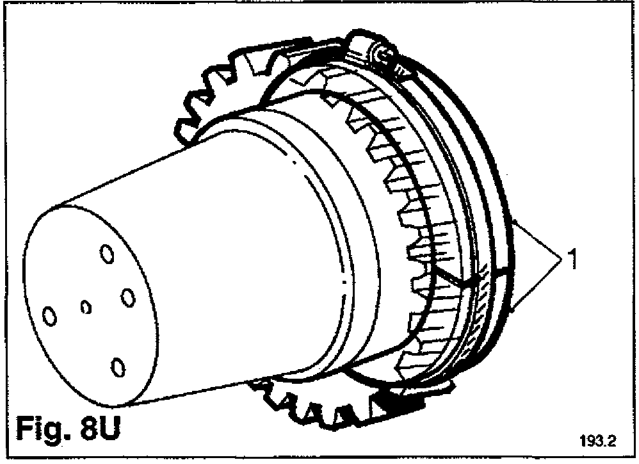



**Fig. 8U**

**WARNING** ⚠ IT IS ESSENTIAL WHEN HANDLING THE HEATED GEAR RING THAT PROTECTIVE EQUIPMENT IS USED. i.e. HEAT RESISTANT GLOVES.

The crankshaft gear is an interference fit and must be heated to 250°C to give sufficient expansion for fitting. This must be accurately monitored or damage to the hardened surface will occur. Place the two halves of the gear spacing tool, Part No. **T85001/33** (1) on the crankshaft, retaining them with a hose clip. **Fig. 8U**. Holding the heated gear with an insulated glove or using a suitable pair of tongs, push the gear onto the crankshaft up to the spacing tool, at the same time lining up the timing mark on the gear with the timing mark on the crankshaft. Allow the gear to cool down before removing the tool.

## CHECKING THE VALVE TIMING

The crankshaft gear Top Dead Centre mark is set 57.8° past the vertical when No. 1 piston on 'A' bank is at its uppermost point, and in this position the two dots on the crankshaft gear coincide with the one dot on the idler gear. At the same time the two other dots on the idler gear must coincide with the single dot on the camshaft gear for the correct valve timing position. See **Figs. 9U & 10U.**

However, when the engine is fully assembled, it is only necessary to look for the TDC No. A1 mark on the flywheel, which can be seen through a hole in the flywheel housing with reference to the timing pointer. See **Fig. 10U.**

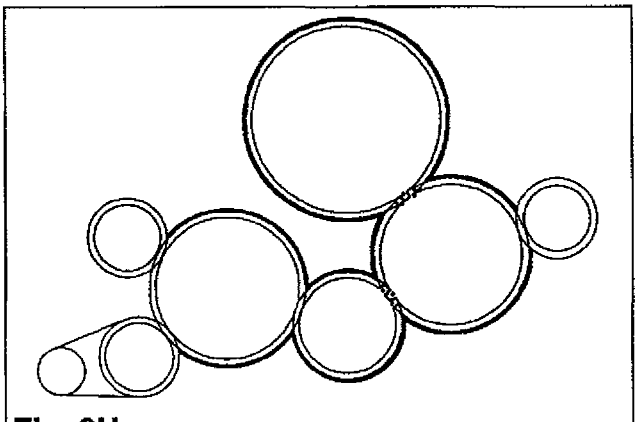


**Fig. 9U** 544.2

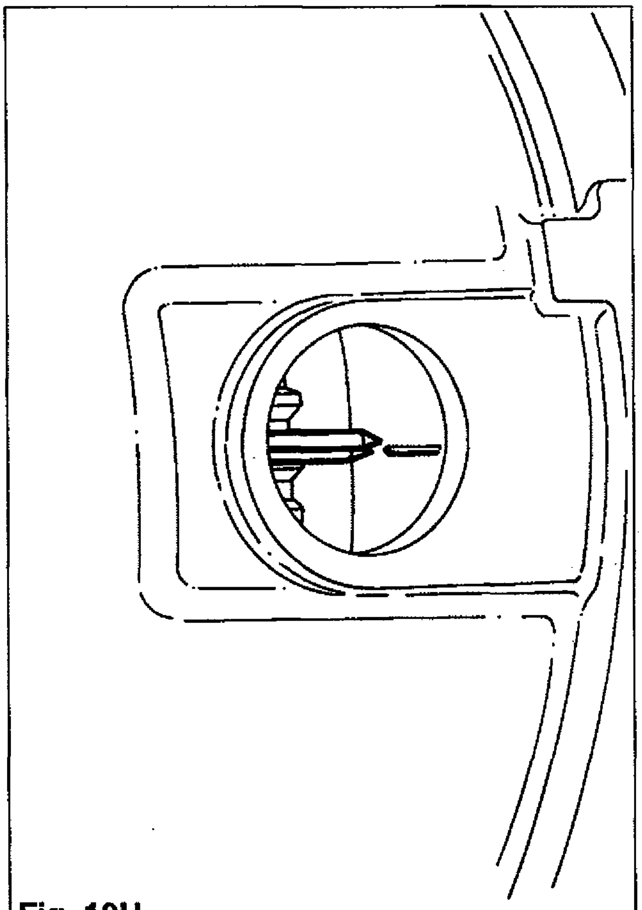


**Fig. 10U** 1074.2

**WARNING** ⚠ THIS IS A VERY HEAVY UNIT.
ALWAYS USE THE RECOMMENDED LIFTING EQUIPMENT.

**NOTE:** Camshaft removal is only undertaken at major overhauls, and therefore the following procedures are based on the assumption that the engine has been removed from its installation and is dismantled in a workshop, with the flywheel, flywheel housing (see **Section X1**), front pulley, damper, water pumps and gearcase (see **Section U1**) having been removed (see **Fig. 1V**).

## CAM FOLLOWER HOUSING ASSEMBLY REMOVAL

Remove the cam follower housing heat shields (if fitted) and the lubricating oil pipes. Remove the rocker covers and rockers (see **Section Q5**) to allow the removal of all valve and injector push rods, marking them for re-assembly to the same rockers.

Remove the seven hole oil feed jets fitted to each cam follower assembly (see **Fig. 1V**), wash them in kerosene (paraffin), prick out any blocked holes with wire and blow them out with compressed air.

**Key**
**(Fig. 1V)**
**1** Heat shields
**2** Lubricating oil pipe
**3** Seven hole oil feed jet
**4** Rocker assembly
**5** Valve and injector push rods
**6** Cam follower assembly
**7** Camshaft gear

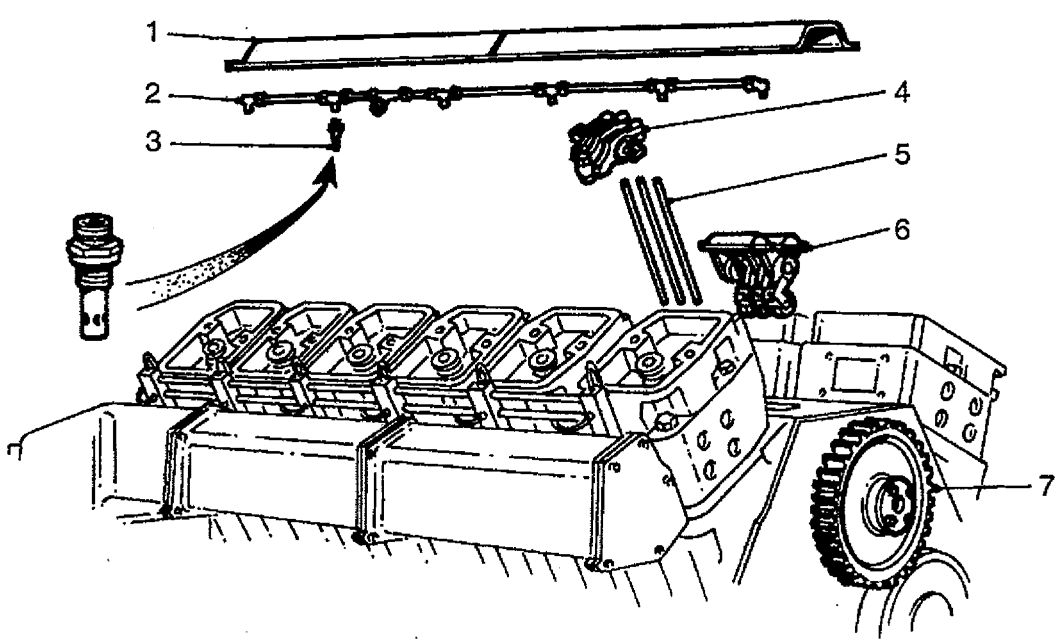



Fig. 1V

**WARNING** ⚠ ALWAYS WEAR EYE PROTECTION WHEN USING COMPRESSED AIR.

Early engines were not fitted with the above oil feed jets and it is recommended that they be fitted at the earliest opportunity to provide improved camshaft lubrication.

Mark each cam follower housing and its location on the cylinder block to ensure that it is refitted in its original position, then remove the four bolts holding each housing to the block and withdraw the complete cam follower assembly. See **Fig. 2V**.

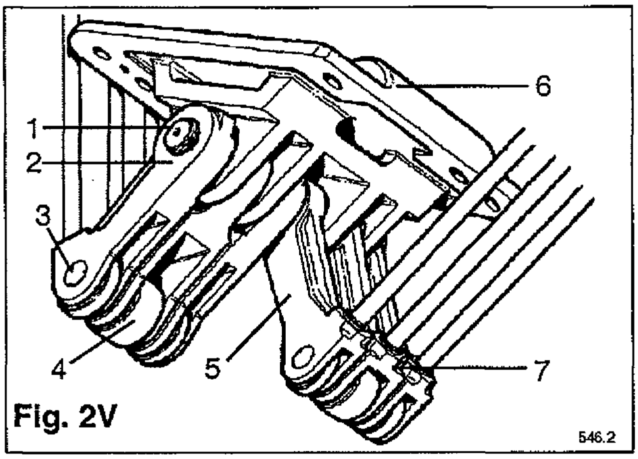


**Fig. 2V**

**Key**
**(Fig. 2V)**
**1** Pivot shaft
**2** Circlip
**3** Pivot
**4** Roller
**5** Cam follower arm
**6** Cam follower housing
**7** Hard socket

**WARNING** ⚠ THIS OPERATION MUST BE CARRIED OUT BY TWO SERVICE ENGINEERS, AS THIS IS A VERY HEAVY UNIT.

**CAMSHAFT REMOVAL**

Release the camshaft drive gear by removing the four screws, drawing it off the camshaft spigot and locating dowel.

Remove the camshaft thrust plate and locate the camshaft guide tube, Tool No. **T6253/142** onto the camshaft spigot, at the gear end of the engine. Using a long wooden drift carefully push the guide tube into the engine, and as the camshaft is withdrawn from the crankcase at the flywheel end of the engine, fit a suitable rope sling to support the weight (see **Fig. 4V**).

Continue pushing the guide tube into the engine until the camshaft is finally withdrawn. Lift the camshaft from the engine and place it in a support cradle, removing the guide tube from the engine.

## CAM FOLLOWER ASSEMBLY INSPECTION

All components should be thoroughly cleaned in a non-caustic cleaning solution, and the oil ways flushed through.

All dimensions should be checked, where possible, against those given in the **Wear and Renewal Limits** (see **pages 41-42**).

**NOTE:** In the case of a defective cam follower, service exchange units are available.

Visually check each cam follower roller for scratch marks, cracks or flats and that it is free to rotate without excessive clearance between the roller and its pivot. If an individual roller is worn excessively, then it must be replaced. Before removing the roller, clearly mark each follower as 'inlet' or 'exhaust', as they are identical but must be fitted onto their original cam. Failure to do this could result in camshaft damage.

Take out the circlips at the ends of the pivot shaft, using Tool No. **T6253/238**, and carefully push out the pivot shaft. Check the pivot shaft and pivot end of the cam follower for wear and that the oil passages in the pivot shaft and the housing are clear.

To remove the worn roller, knock out the pivot frozen in the cam follower arm (using a punch smaller in diameter than the pivot).

**WARNING** ⚠ IT IS ESSENTIAL THAT PROTECTIVE GLOVES ARE WORN WHEN HANDLING FROZEN PARTS.

Fit a new roller into the arm and freeze fit its pivot into place, ensuring that the pivot end is flush with the side of the arm and also that the flat on the pivot is at 90° to the centre line of the arm. Dot punch the pivot and arm, making sure that the dots lie across both the pivot and the arm to ensure that the pivot does not move whilst warming up to a tight fit.

Remove a worn hard socket by knocking it out by means of a punch through the small hole below the socket in the arm. Fit the new socket into the arm using Loctite 270 to retain it.

Liberally coat the components with clean engine oil and reassemble carefully, lining up the oil feed holes.

Check that the end float on the cam followers is between 0.150 and 0.200 mm (0.006 and 0.008").

If the cam follower roller is serviceable, reassemble, making sure that each cam follower arm is fitted in its original position, fit the pivot shaft and secure in position by refitting the circlips, using Tool No. **T6253/238**. Where it is found that the cam follower roller is worn excessively, check the cam lobe on which it ran for wear.

If there is a groove, deep scratch marks, etc., a new camshaft must be fitted together with new followers.

## CAMSHAFT BEARING REPLACEMENT

If a camshaft bearing is worn, badly scratched or damaged in any way, it must be replaced.

Using a special Tool no. **T6253/199** a bearing may be removed and replaced (see **Fig. 3V**). The earlier tool **T6253/151** is suitable for the thin wall bushes previously used, but the new tool may be used for the new thicker bushes or the old ones.

Great care is needed to avoid damaging the new bearing when fitting. The camshaft bearings are pre-finished to size and require no further machining.

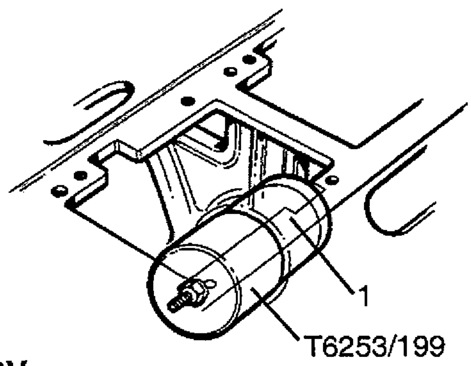



**Fig. 3V**

733.2

## CAMSHAFT OIL WEIRS

The camshaft oil weirs are a design improvement fitted to later engines and it is recommended that they be fitted to earlier engines whenever the opportunity arises. They are rubber inserts fitted to the drain holes beneath the camshaft to maintain a reservoir of oil to provide immediate lubrication when the engine starts (see **Fig. 4V**).

It is a two man operation to fit these oil weirs and a 4.5 mm diameter, 180 cm length, braided cord should be wrapped around the rubber insert, as shown in **Fig. 4V**.

**NOTE:** Only braided cord (e.g. Sash cord) should be used for this operation. Twisted string may fray and leave loose fibres in the oil system and wire may damage the insert.

The free end of the cord is passed through the oil drain hole by the first fitter and he holds the insert in position from above. The second fitter takes up the free end of the cord and wraps this around a bar approximately 1½ cm diameter by 20 cm long.

While the first fitter pushes the insert into the oil drain hole, the second fitter pulls on the cord, which comes off the insert bringing the rubber lip through to the underside of the oil drain hole. It is essential that these weirs are fitted the correct way round (i.e. so that they lie flat on the crankcase wall) and also that they are fitted to all drain holes.

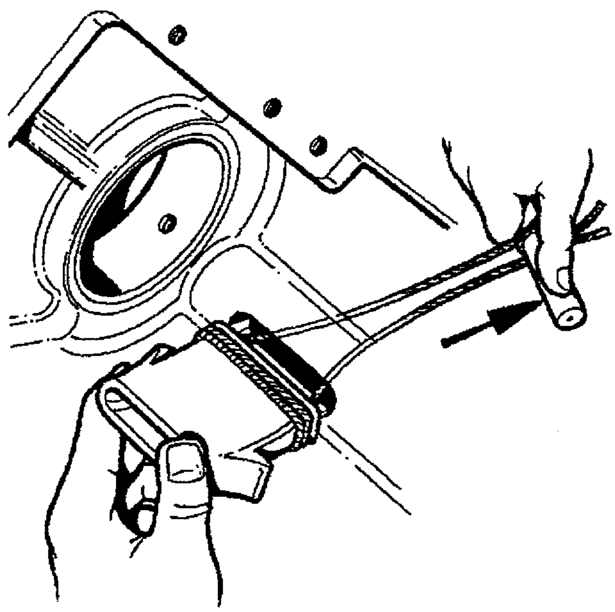


**Fig. 4V**

969.2

**Key**
**(Fig. 3V)**
**1** New bearing

**REFITTING THE CAMSHAFT**

Ensure that the camshaft bearings are clean and undamaged. If the existing bearings are being re-used, ensure that they have not been disturbed from their original locations.

Insert the camshaft guide tube (1) **T6253/142** into the crankcase at the flywheel end (2) of the engine. Using a rope sling, lift the camshaft into position and locate the front end of the camshaft in the guide tube spigot. Whilst supporting the camshaft, push it into the engine, ensuring that the camshaft is not pulled out of the guide tube (see **Fig. 5V**). When the camshaft is in the correct position in the bearings, remove the guide tube from the gear end of the engine.

Fit the camshaft thrust plate and secure with cap screws and spring washers.

Fit the drive gear to the camshaft pigot and locating dowel. If the idler gears are fitted ensure that the timing marks align.

If a Regulateurs Europa or Woodward hydraulic governor is fitted, fit the drive adaptor to the gear and secure it with Durlok bolts.

Using new joints between the cam follower housings and the crankcase, locate the cam follower assemblies, ensuring that the followers are correctly positioned on their respective cams. Fit to the locating dowels and secure the housings in position with bolts and spring washers. On later engines the cam follower housings have blind holes which receive the locating dowels. In this case the dowels should be fitted to the cam follower housing, using Loctite 542 Hydraulic Seal, before the assembly is fitted to the engine. Fit the seven hole oil feed jets (applying Loctite 542 Hydraulic Seal to the threads) and the lubricating oil pipes to each cam follower housing, and connect to the feed pipe from crankcase rail. Refit the heat shields.

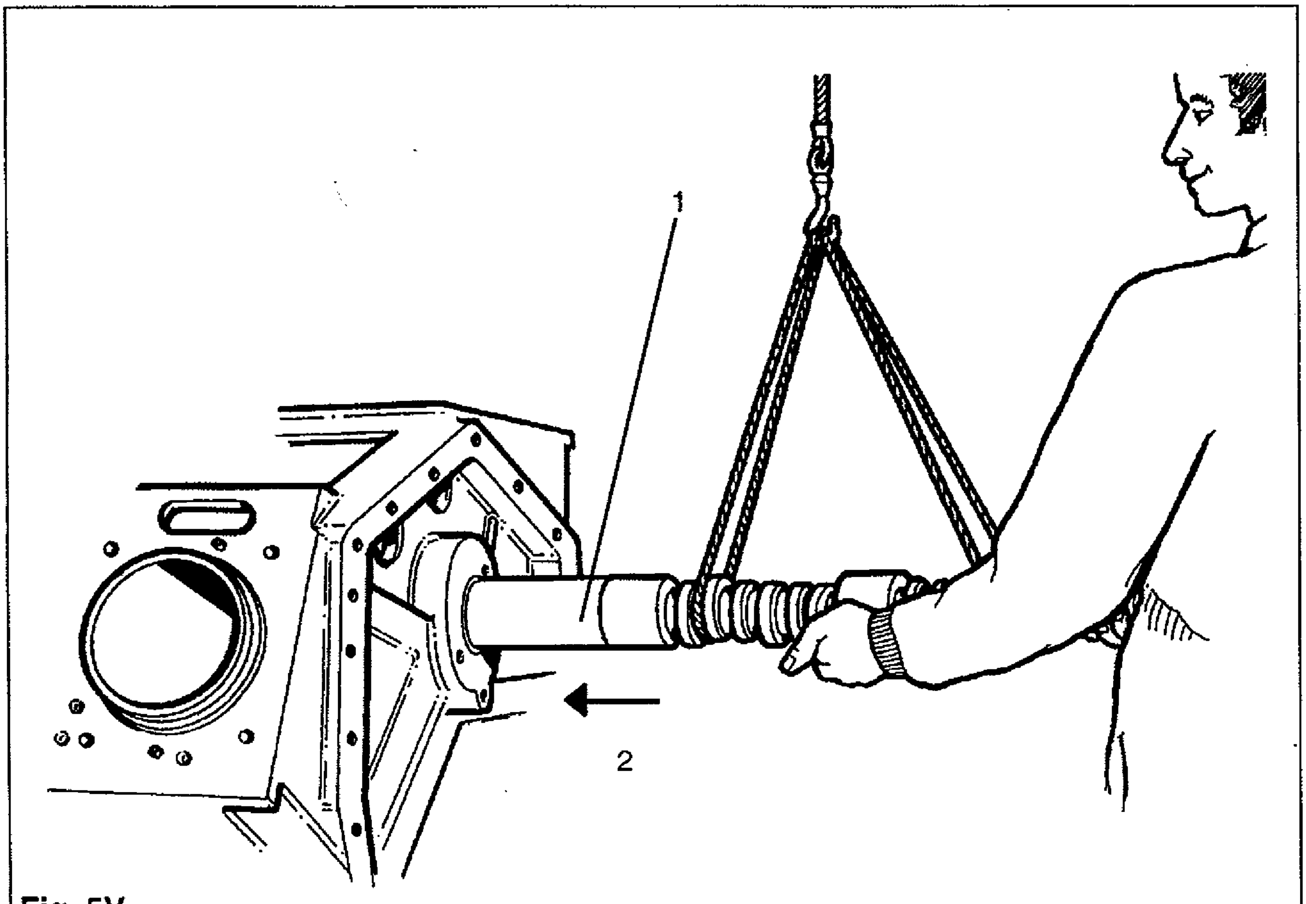



**Fig. 5V**

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT - 342 kg (754 lb) FOR THE 4012 SERIES AND 383 kg (844 lb) FOR THE 4016 SERIES ENGINES.

## REMOVING THE CRANKSHAFT

**NOTE:** Crankshaft removal is only undertaken at a major overhaul, and therefore the following procedures are based on the assumption that the engine has been removed from its installation and is dismantled in a workshop, with the flywheel, flywheel housing (see **Section X1**), front pulley, damper, coolant pumps and gearcase (see **Section U1**) having been removed (see **Fig. 1V**).

Take off the air cleaners, turbochargers, air, exhaust and water manifolds, cam follower housing assemblies, cylinder heads and the sump, then carefully invert the engine and rest it on the top flat surface of the crankcase (be sure that the surface on which the block will be resting cannot scratch or damage the machined face in any way).

Mark with a centre punch and remove the connecting rod bolts and caps see **Section S1**. Withdraw the piston and con rod assemblies from their cylinder bores, refitting the appropriate 'big end' caps and bolts.

Remove the main bearing bolts, side bolts, main bearing caps and shell bearings, noting the identification number stamped on each cap (see **Fig. 1W**). The rear main bearing cap i.e. flywheel end, carries two half thrust washers.

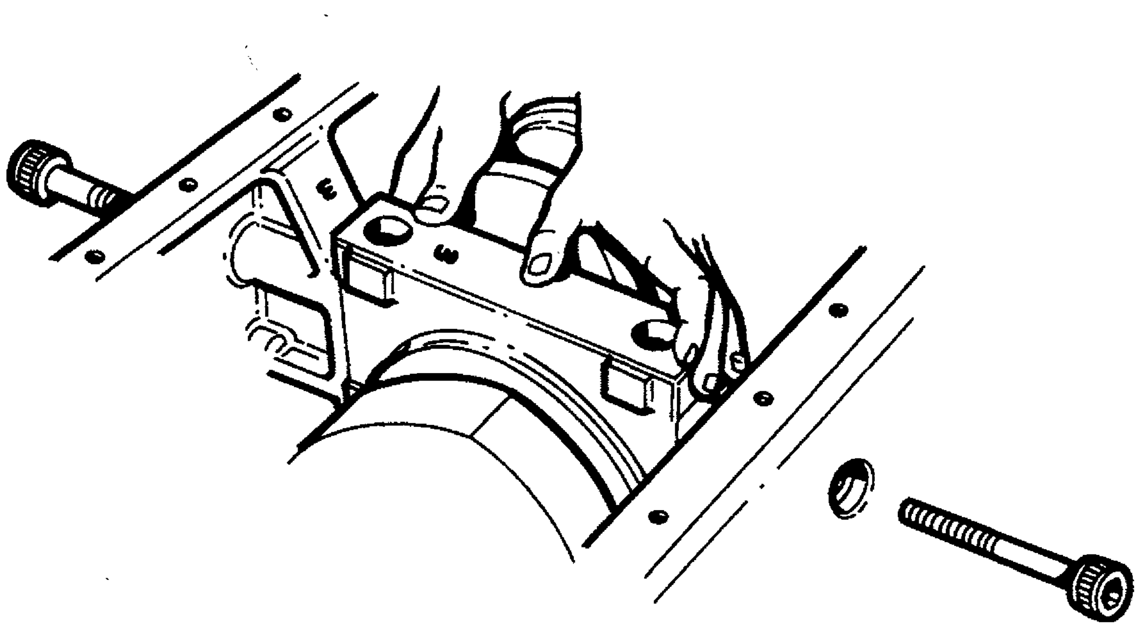


**Fig. 1W**

549.2

Rotate the crankshaft so that the balance weights are vertical (this is the only position the crankshaft can be removed) as the position shown in **Fig. 2W**, then fit a bolt into the flywheel flange (uppermost hole) and pass a rope around this and also the gear at the opposite end. Fit the crankshaft pulley retaining plate to the gear end of the crankshaft (this will stop the sling slipping). Using this with a hoist, remove the crankshaft from the crankcase.

**WARNING** ⚠ ALWAYS WEAR EYE PROTECTION WHEN USING COMPRESSED AIR.

Wash all components, using a brush to ensure that the oilways are clear, then dry off with compressed air, making sure that no cleaning fluid is left in the oilways.

Inspect the bearing shells for pitting and scoring. With reference to the **Wear and Renewal Limits** (see **pages 41-42**) check the bearings for size. If the bearing shells are serviceable, label them indicating their positions in the crankcase. However, it is strongly recommended that a new set of both main and big end bearings is fitted when the engine is dismantled to this extent.

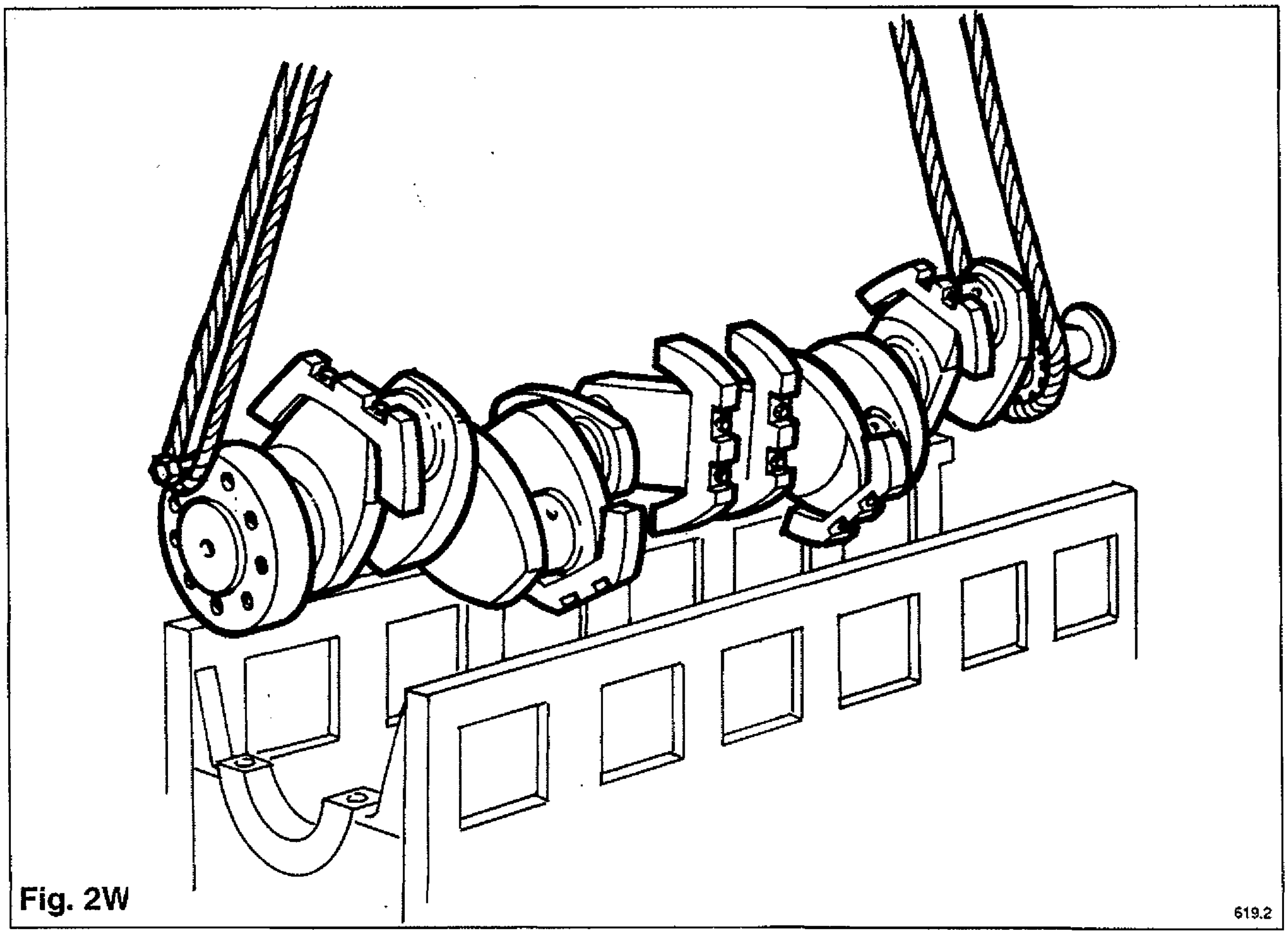



**Fig. 2W**

## INSPECTING THE CRANKSHAFT

With reference to the **Wear and Renewal Limits** (see **pages 41-42**) check the crankshaft journals and pins for wear.
Examine the journal fillet radii, and around the oil holes for cracks.
The balance weights must not be removed. They are suitable only for the crankshaft to which they are fitted. **It is essential that should the balance weights be removed for any reason they must be refitted to the web from which they were removed. The balance weights are suitable only for the crankshaft to which they are fitted. Should a balance weight need to be changed, the complete crankshaft must be returned to Perkins Engines (Stafford) Ltd or their nearest agent for rebalancing.**
If the crankshaft is worn beyond the limits of size, ovality or taper, it should be reground to the nearest standard undersize and new bearings fitted. Consideration should also be given to regrinding the shaft if the dimensions, although not exceeding the limits, are close to them. Bearings are supplied in undersizes (see the **Wear and Renewal Limits pages 41-42**).

## REFITTING THE CRANKSHAFT

Ensure that the main bearing housings and caps are clean and undamaged.
Before fitting the bearings, ensure that the oilways in the crankcase are clean and clear.
Using clean engine oil, liberally lubricate the half bearings in the crankcase. If the original bearings are being re-used, ensure that they have not been disturbed from their original locations. If new bearings are being fitted, under no circumstances should they be scraped, filed or emeried, as all bearings are supplied finish machined.
Using clean engine oil, liberally lubricate the half bearings in the crankcase.

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT.

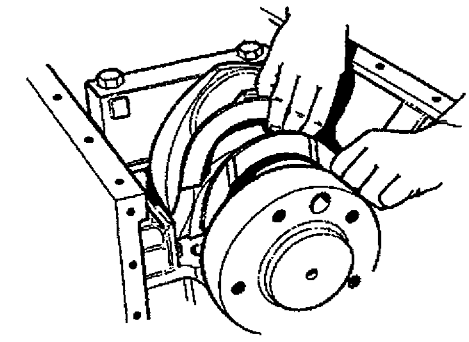


Fig. 3W 551.2

Using a rope and sling hoist, lift the crankshaft into position above the crankcase and gently lower it onto its bearings. Lubricate and fit the main bearing caps starting at the gear end of the crankshaft, ensuring that they are fitted in their correct positions by reference to the identity numbers on the cap and case. The numbers should be on the same side (see **Fig. 1W**).
**NOTE:** If only one or two bearing caps have been removed to assess engine condition, it is possible to re-use the original main bearing bolts, just as it would be if the bearings had required attention in an emergency. However, if all the bearings and the crankshaft are being removed, it is a good policy to renew all the main bearing bolts.
When fitting the rear (flywheel end) main bearing cap, ensure that the bearing side of the thrust washers (the side with the grooves) is in contact with the crankshaft (see **Fig. 3W**) or serious damage will be done to the crankshaft thrust faces.

The following procedures cover the fitting of the main bearing bolts and side bolts.

1 Lubricate the main bearing bolt threads and under the bolt heads using engine oil.
2 Install all the main bearing bolts and side bolts.
3 Tighten all of the side bolts to a snug torque see **sequence Fig. 4W (12 cyl)** and **Fig. 5W (16 cyl)**.

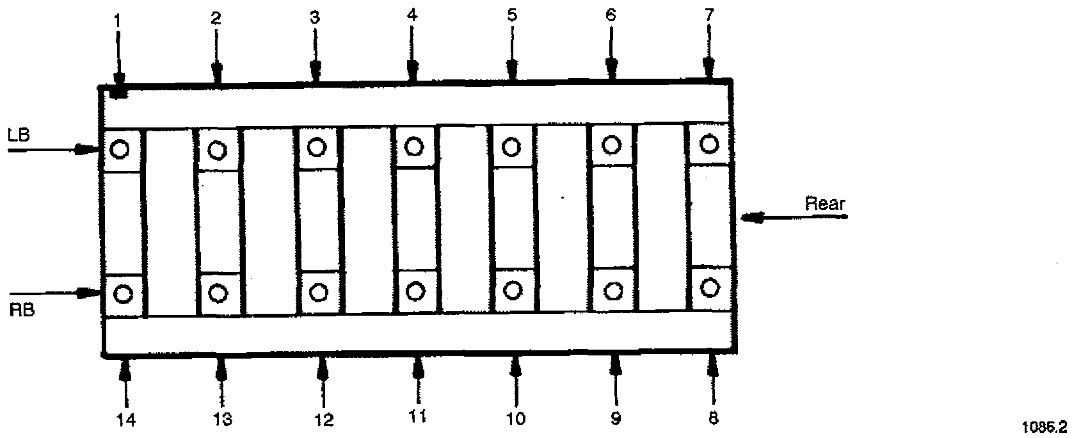



**Fig. 4W**

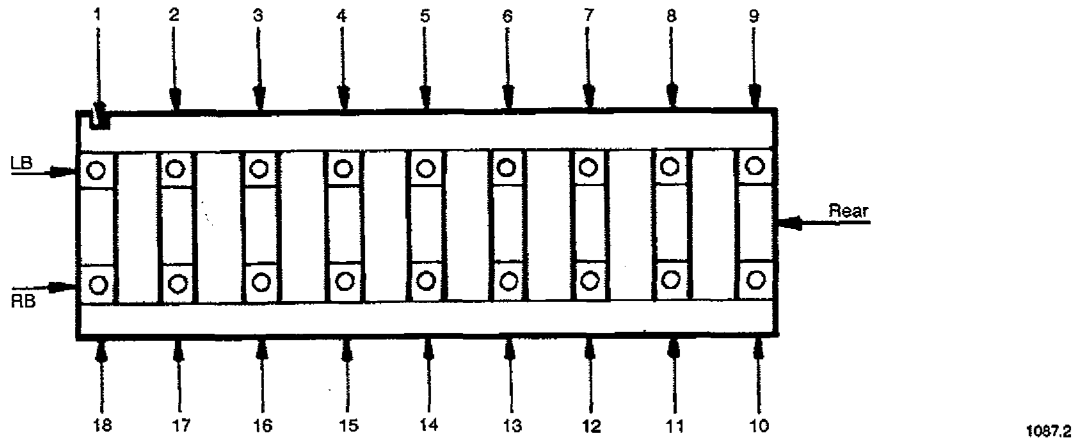



**Fig. 5W**

4 Use the following steps to tighten the main bearing bolts see sequence Fig. 6W (12 cyl) and Fig. 7W (16 cyl).

5 Tighten all main bearing bolts evenly in the stages shown.

| Stage | Torque |
|---|---|
| 1 | Snug |
| 2 | 100 lb.ft (135 Nm) |
| 3 | 200 lb.ft (270 Nm) |
| 4 | 400 lb.ft (540 Nm) |
| 5 | 580 lb.ft (783 Nm) |

6 Tighten all side bolts evenly in the stages shown.

| Stage | Torque |
|---|---|
| 1 | Snug |
| 2 | 124 lb.ft (168 Nm) |

Check that the crankshaft rotates freely and then tighten the main bearing bolts from centre outwards to the required torque and again check that the crankshaft rotates freely.

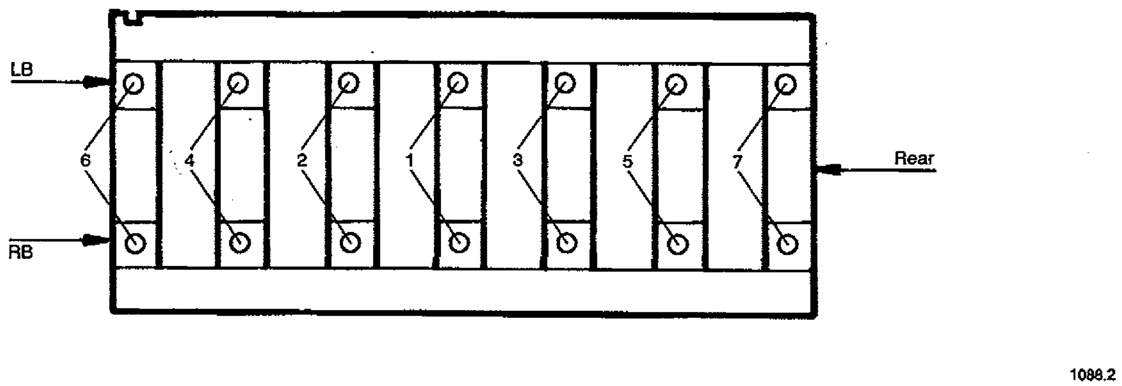



Fig. 6W

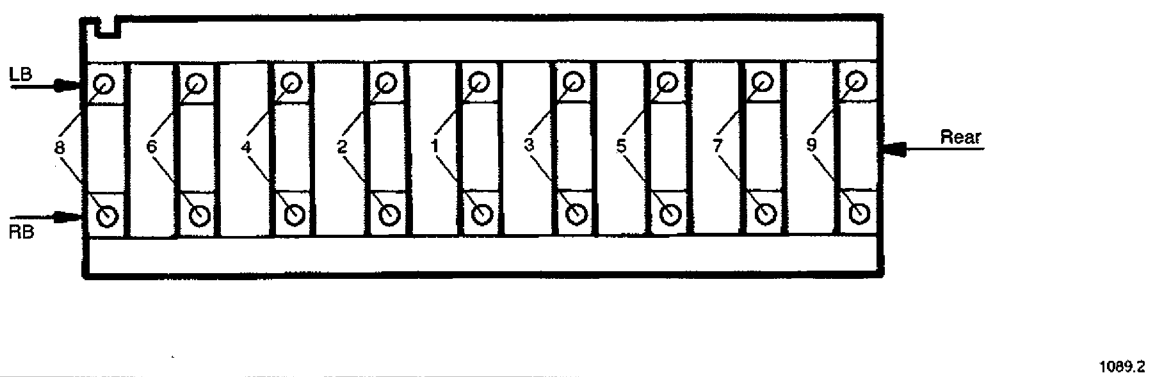



Fig. 7W

Using a dial gauge mounted off the end of the crankcase, with the DTI plunger in contact with the end of the crankshaft, use a lever to move the crankshaft to check its end float (see **Fig. 8W**) with reference to the **Wear and Renewal Limits** (see **pages 41-42**).

Refit the piston and con rod assemblies. Check that the crankshaft rotates easily.

**NOTE:** In addition to the sump on later 16 cylinder engines there is fitted a stiffening plate. This is positioned between the crankcase and sump with a sump joint either side.

Fit a new sump joint and the sump, then carefully lift and turn the engine the right way up.

Refit all the dismantled parts, using the correct procedures and referring to the appropriate sections of this manual.

After connecting any driven equipment up to the engine, e.g. alternator, gearbox, etc., the crankshaft end float should again be checked to ensure that this movement has not been restricted by fitting the driven equipment.

**Caution: Failure to ensure correct end float may result in excessive thrust washer wear or even crankshaft seizure.**

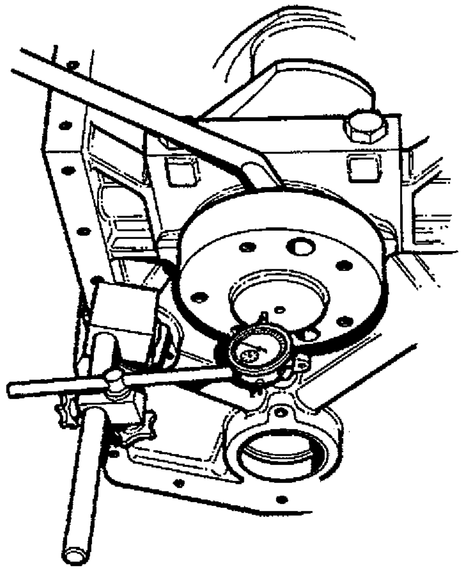


**Fig. 8W**

552.2

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT.

**REMOVING THE FLYWHEEL**

Lock the flywheel to undo the retaining bolts. Do this by putting a bolt in one of the tapped holes in the front face of the flywheel at approximately 10 o'clock then set a piece of wood between the underside of the bolt head and the floor **Fig. 1X**. Slacken all five flywheel retaining bolts then take out two uppermost bolts on the top edge. In their place fit special tool T6253/157 to support the weight of the flywheel and give guidance when extracting the flywheel from the crankshaft **Fig. 2X**. Remove the three remaining flywheel bolts and screw three extractor screws into the holes provided. **Fig. 2X**. The length of these screws will depend on the flywheel fitted, but the threaded portion should be at least 40 mm (1.5") more than the depth of the holes into which they are to be screwed.

Tighten the jacking screws evenly, and push the flywheel off the locating dowels which remain in the crankshaft. Using a rope sling to support the flywheel, carefully slide the flywheel along the pilot studs and lift it clear of the engine. Remove the pilot studs from the crankshaft, and the jacking screws from the flywheel. Clean and check the flywheel, inspect the starter gear ring for wear, broken teeth, etc. If replacement is necessary, drill the ring at the base of the teeth, then place a cold chisel between the teeth and with a few blows from a hammer **Fig. 3X**, the gear ring will split, allowing it to be removed. Check that the ring gear seating is clean and free from burrs.

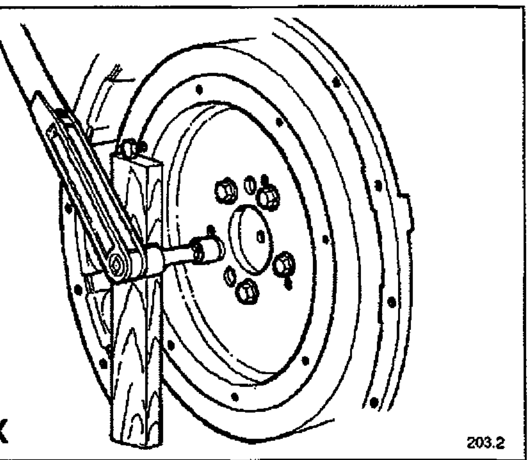



**Fig. 1X**

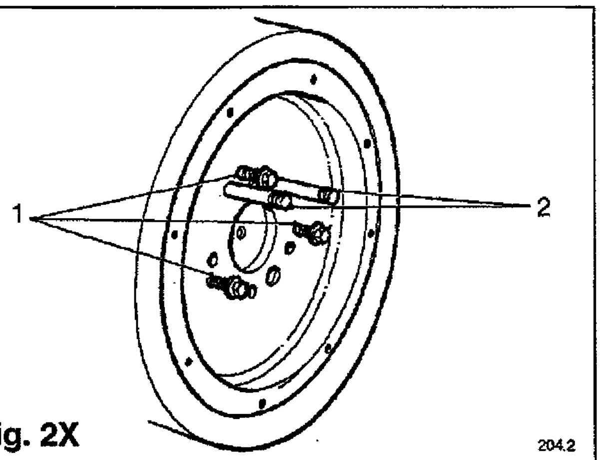



**Fig. 2X**

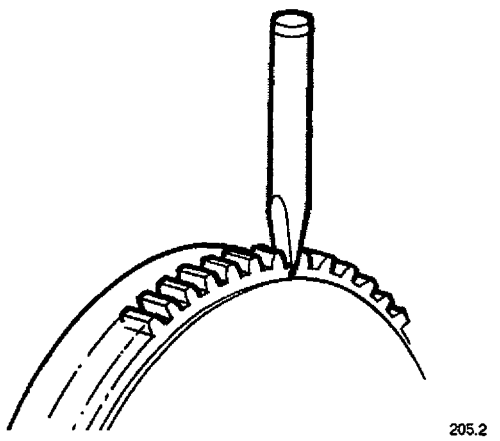



**Fig. 3X**

**Key**
**(Fig. 2X)**
**1** Jacking screws
**2** Pilot studs T6253/157

**WARNING** ⚠ IT IS ESSENTIAL WHEN HANDLING THE HEATED GEAR RING THAT PROTECTIVE EQUIPMENT IS USED i.e. HEAT RESISTANT GLOVES.

### REFITTING

Clean the gear ring of all grease and remove any burrs. Place the flywheel flat with the gear ring spigot upwards. Heat the gear ring to 250°C and place it on the flywheel, checking that the gear ring is hard against the shoulder of the flywheel. Leave it until it is cold.

**NOTE: The ring gear must be fitted with the chamfer on its teeth facing upwards i.e. towards the pinion on the starter motor.**

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT.

### REMOVAL OF THE FLYWHEEL HOUSING

Remove the bolts holding the mounting feet to the engine baseframe. Lift the engine so that the mounting feet are just clear of the engine baseframe and support it. Using a rope sling passed through two starter motor holes in the flywheel housing, set the hoist to a slight tension on the sling, then remove the bolts securing the flywheel housing to the crankcase. Carefully pull the flywheel housing from the dowels locating it to the crankcase. Using the hoist, lower the flywheel housing to the ground. Clean off the flywheel housing and cylinder block, paying particular attention to cleaning the jointing compound left on their mating surfaces. Using a suitable drift, knock out the old crankcase oil seal, without damaging the seating in the housing.

### REFITTING THE FLYWHEEL HOUSING

Lightly coat the flywheel housing mating surface on the cylinder block with Loctite sealing compound 518 (Red), which must be applied on the inner side of any holes, so that oil cannot reach bolts etc. and leak through the threads and under the heads. Hoist the flywheel housing back into position carefully locating it on the dowels set in the cylinder block. Refit all securing bolts, tightening them down to the required torque (see **Torque Settings**) so that the flywheel housing is pulled squarely up to the cylinder block. Lower the engine back onto its baseframe. Refit the bolts through the mounting feet into the baseframe, and tighten them to the required torque.

## FITTING THE CRANKSHAFT REAR OIL SEAL

The oil seal is supplied with its outer diameter already coated with a sealant, and the inner diameter is fitted with a temporary plastic sleeve to protect the sealing lip during fitting.

To fit the oil seal, special tool **T6253/140** must be used. Bolt the oil seal locator to the crankshaft (see **Fig. 4X**). Apply a smear of oil to the outside diameter of the oil seal locator and slide the seal onto it, seating the seal squarely against the flywheel housing (lip side to the engine). Push the outer sleeve of the fitting tool up to the seal, fit the nut and plain washer (see **Fig. 5X**), and steadily tighten the nut until the outer sleeve bottoms. The seal is now in its correct position. Remove the seal fitting tool and discard the temporary plastic sleeve.

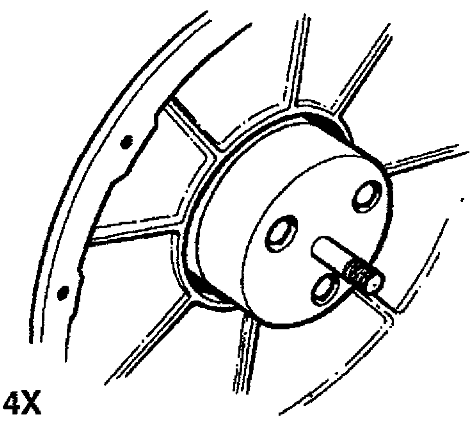


**Fig. 4X** 206.3

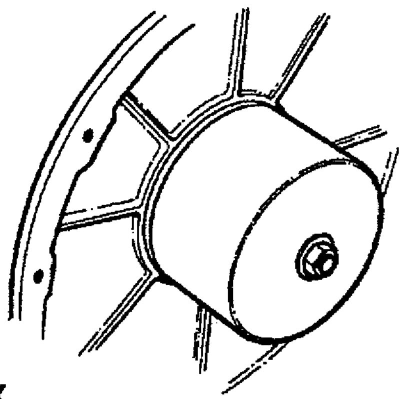


**Fig. 5X** 207.3

| WARNING | USE CORRECT LIFTING EQUIPMENT AS THIS IS A VERY HEAVY UNIT. |
|---|---|

## REFITTING THE FLYWHEEL

Screw the flywheel pilot studs **T6253/157** back into the crankshaft. Using the rope sling and hoist, lift the flywheel back into position, lining the flywheel up with the pilot studs and its locating dowels. Push the flywheel onto the studs as far as the rope sling allows, remove the rope sling and carefully pull the flywheel up to the crankshaft in the recommended tightening sequence see **Fig. 6X Current flywheel and 7X New flywheel.** Remove the pilot studs, and refit the last two retaining bolts. Lock the flywheel as described in **Fig. 1X**, but with the bolt in the front face of the flywheel at approximately 2 o'clock. Tighten the flywheel retaining bolts to the required torque (see **Torque Settings on pages 38-40**).

**NOTE:** The maximum permissible run-out of the flywheel is 0.005" (0.13mm) on the periphery or drive face as measured by a dial test indicator.

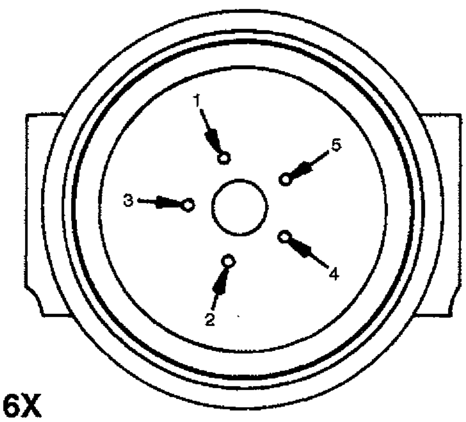



**Fig. 6X** 1081.2

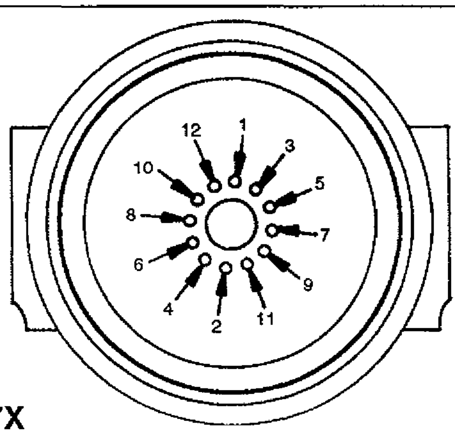



**Fig. 7X** 1082.2

## 'DEEP SEA ELECTRONICS' MODEL 102

### DESCRIPTION

The model 102 two element speed switch has been designed to monitor the speed of the engine, is factory set to operate two independent relays at preset speeds, and does not require resetting in the field. **Fig. 1Y**.

The relays may be arranged to latch, once operated, until an external normally open contact wired between terminals 6 and 2 (supply negative) is operated. Operation of this reset contact will cause the relays to release only if the engine's speed is below the trip level for that relay. The latching is normally done in the control panel, in which case terminal 6 is permanently wired to negative, **Fig. 2Y**.

Provision is made for a 1mA full scale deflection meter for use as a tachometer. (If a tachometer is not used, terminals 4 and 5 are linked).

**Key**
**(Fig. 2Y)**

- **A** Reset
- **B** Meter +ve
- **C** Sensor negative
- **D** Sensor signal
- **E** Supply -ve
- **F** Supply +ve
- **G** Tacho
- **H** Magnetic pick-up
- **I** Engine flywheel

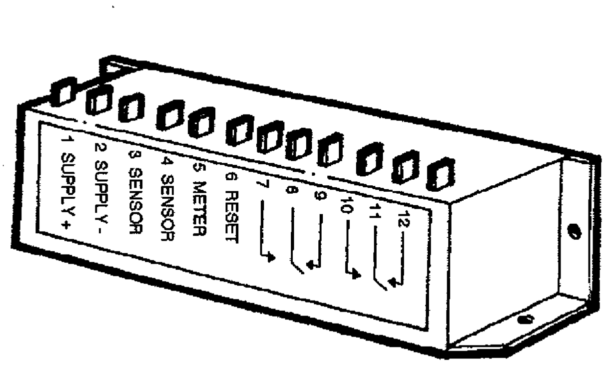



**Fig. 1Y** 210.2

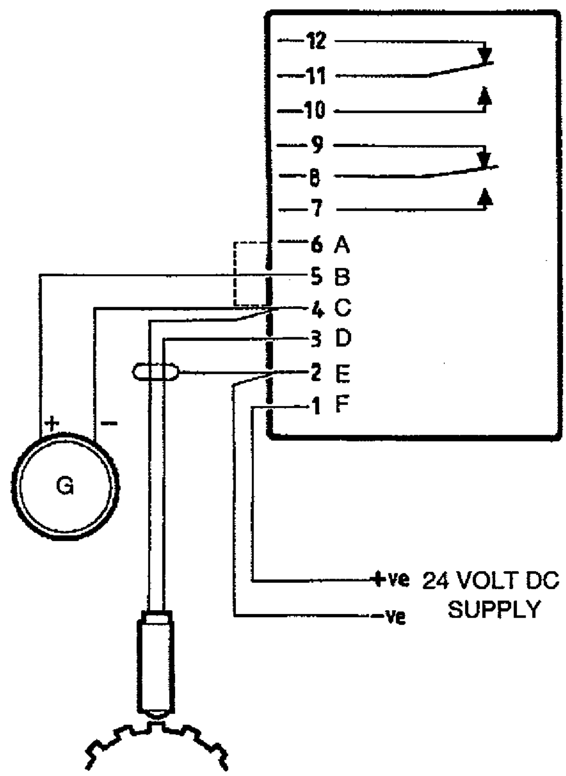



**Fig. 2Y** 211.3

## TESTING THE OVERSPEED SWITCH

The overspeed switch should, if possible, be tested by injecting a signal into the magnetic pickup terminals from a signal generator.

If a signal generator is not available, the overspeed switch can be tested on the engine. **Extreme care must be taken not to excessively overspeed the engine**, since the engine speed cannot be increased to the level required by operating the speed setting control, due to an internal limit.

On the engine governor, the engine throttle control must be pushed **gently** to increase the engine speed, until the trip point speed is reached. On no account must the engine speed be increased beyond 115% of its normal running speed i.e. 1725 r/min. for 1500 r/min. engine, or beyond 107% for engines operating at 1800 r/min. (1926 r/min.)

If the overspeed unit fails to operate on this test, the output voltage from the magnetic pickup should be check with an AC voltmeter. The voltmeter is connected between terminals 3 4 on the overspeed switch, and with the engine running at normal speed, the voltage across terminals 3 and 4 must be at least 0.8 volts. If the magnetic pickup voltage is correct, but the overspeed switch fails to operate, it should be replaced with a factory set unit.

## 'DEEP SEA ELECTRONICS' MODEL 103 LATER ENGINES

The reason for this change by the manufacturer is the revised European Electromagnetic Compatibility requirement now in force, which is covered by the type 103 two element switch.

Although the 103 is a lot smaller than the 102, it operates from the same voltage range of 10 to 32Vdc and detects signals from a magnetic pick-up with an impedance of 10 to 1000 Ohms at a voltage of 1 to 70Vac RMS. It also operates within the same ambient temperature range of -10 to +70°C and either relay can be adjusted to trip at between 10% and 140% of the engines rated speed. Adjustment of the trip points is via two preset screws, turning them clockwise to increase the trip point or anti-clockwise to decrease.

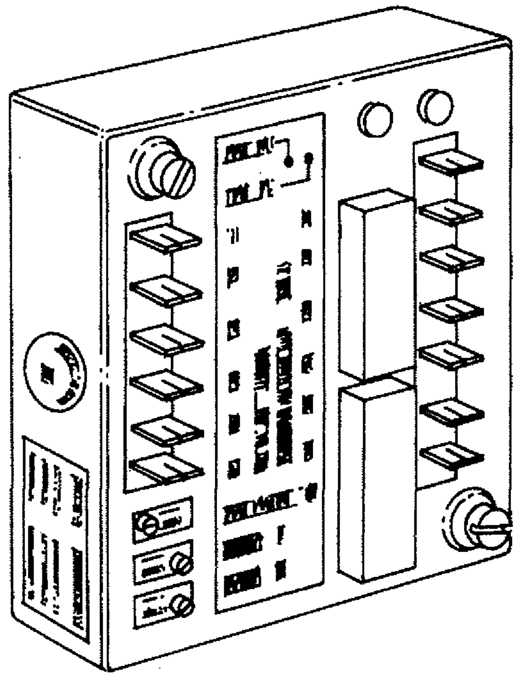


Fig. 3Y

1001.2

The appropriate LED (light emitting diode) illuminates when the trip point has been reached to indicate that it has been activated. However, the unit is preset at the factory and should require no further adjustment on site.

As previously, a latch is provided to inhibit the release of the relays and this can be disabled by applying a continuous negative to the RESET terminal 5. To reset the latch, apply a negative to the RESET terminal 5. Removal of the positive dc power from the unit for a one second period will also reset the latch.

**Key**
**(Fig. 4Y)**

**A** Supply +ve
**B** Supply -ve
**C** Sensor +ve
**D** Sensor -ve
**E** Reset
**F** Meter +ve
**G** Calibrate
**H** Trip 1
**I** Trip 2
**J** Relay 1
**K** Not used
**L** Relay 2
**M** Two switch speed unit Perkins Part No. 655/42
**N** Meter
**O** Magnetic pick-up
**P** Flywheel gear ring
**Q** Overspeed normally set 15% above norminal engine speed 1500/1755 rpm
**R** Speed reference set 600 rpm

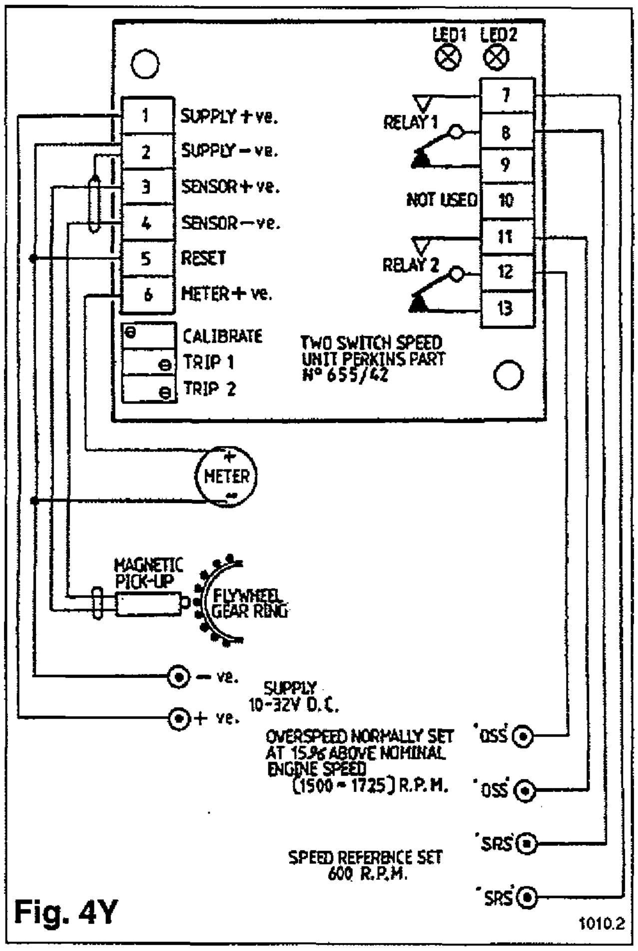


**Fig. 4Y**

## SEM STOP SOLENOID TYPE MD5 (ENERGISED TO RUN) EARLY ENGINES

**WARNING** ⚠ TO PREVENT SOLENOID DAMAGE, PLUNGER MUST BE ALLOWED TO COMPLETE ENERGISED

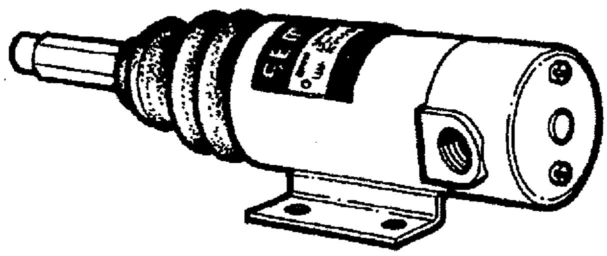


Fig. 1Z

212.2

### GENERAL INFORMATION

The type MD solenoid is designed to stop the engine in the event of high water temperature or low lubricating oil pressure, and is operated by a dual fault switch.

The solenoid magnets feature a dual coil system, which provides a large amount of pulling power on the pull-in winding, and low power consumption in the hold position. The combination of low warm up temperature, together with the coils mechanical build up, allows the magnets to operate in high ambient temperatures.

| TYPE | RATING | VOLTAGE | PULL-IN POWER | | HOLD-IN POWER | |
|---|---|---|---|---|---|---|
| | | | NEWTONS | AMPS | NEWTONS | AMPS |
| MD5 | CONTINUOUS | 24 | 140 | 45 | 210 | 0.75 |

CABLE SIZE minimum C.S.A. (mm2) = L (m) x K (constant)
where C.S.A = Cross Sectional Area of cable ($mm^2$).
K = a constant which varies with voltage (1.5 $mm^2$ per metre length of cable for 24V).
L = length of cable.

EXAMPLE: 4 metres of cable = cable size 6 $mm^2$.
Where the cable size calculated does not equate to a standard cable size, the next larger size of cable must be used.
This formula gives a voltage drop of about 3%, however, to ensure an adequate current carrying capacity for the cable, a minimum size of 4 $mm^2$ should be used.

## OPERATION

Because of the high pull in current and the fact that the solenoid is energised to run (E.T.R.), it is important that the following instructions are adhered to:

1 Starting batteries must be a minimum of 356 Amp/hour capacity at the 20 hour rate.
2 Careful setting of the mechanical linkage is essential, to ensure that the solenoid pull in coil supply is broken when on full stroke. This can be checked by connecting a 24V indicator lamp across the auxiliary terminal and the battery negative, so that the lamp will illuminate when the pull in coil is de-energised.
3 The starting circuit is designed to allow the solenoid to be energised before cranking commences by the use of a relay, as shown on the wiring diagrams in the Operator's Handbook page 53 onwards.

## FITTING INSTRUCTIONS FOR SEM STOP SOLENOID (SEE FIG. 2Z)

1 Align the stop levers to the governor output levers on the actuator output shaft (see **Fig. 1BB**).
2 Set the governor output levers in the maximum fuel position.
3 Bench assemble the solenoid, bracket and plunger to the 130 mm dimension.
4 Fit the solenoid assemblies to the actuator support bracket, leaving the securing screws slack.
5 Hold the solenoid in the energised position (indicated by the white button protruding), and position the assembly so that the plunger just clears the roller in the maximum fuel position.
6 Tighten the securing screws and check the movement of the lever and alignment of the plunger.
7 Wire as shown in the wiring diagram.

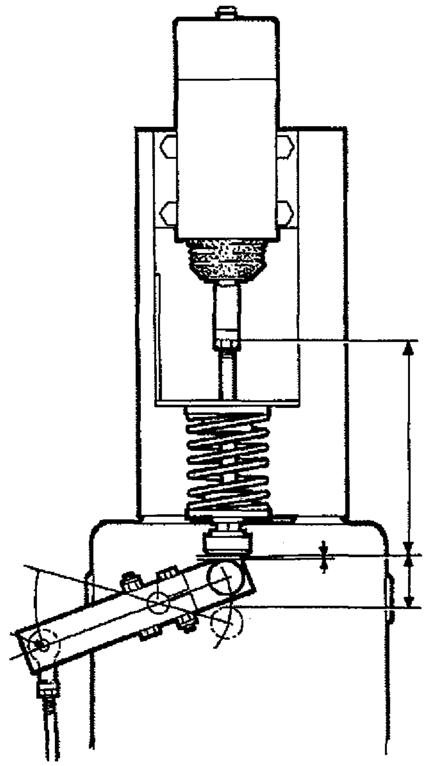


**Fig. 2Z** 553.2

## REPLACING THE SOLENOID

1 Disconnect the wiring, and remove the 4-fixing bolts from the solenoid mounting bracket. Turn the plunger anti-clockwise to remove the plunger from the spindle, whilst sliding the solenoid away from the support bracket, leaving the locknut in its original position, to maintain the 130 mm dimension.
2 Screw the replacement solenoid plunger on to the spindle up to the locknut, and bolt the replacement solenoid to the support bracket.
3 Check that the solenoid assembly still operates as per the above fitting instructions.

## SYNCHRO-START STOP SOLENOID SERIES 2370 (ENERGISED TO RUN) LATER ENGINES

**WARNING** ⚠ TO PREVENT SOLENOID DAMAGE, PLUNGER MUST BE ALLOWED TO COMPLETE ENERGISED

### GENERAL INFORMATION

The series 2370 solenoid is designed to stop the engine in the event of high water temperature or low lubricating oil pressure, and is operated by a dual fault switch. The solenoid is fitted with a dual coil system, which provides a large amount of pulling power on the pull-in winding, and low power consumption in the hold position. The solenoid is suitable for continuous duty and operation in high temperature environments.

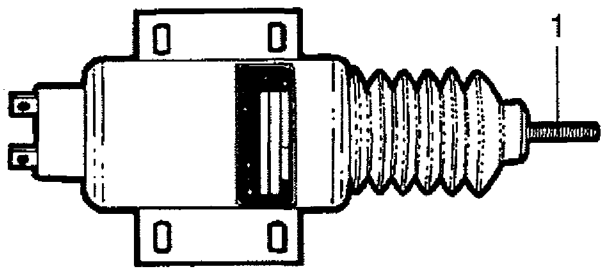



**Fig. 3Z**

| TYPE | RATING | VOLTAGE | PULL-IN POWER | | HOLD-IN POWER | |
|---|---|---|---|---|---|---|
| | | | NEWTONS | AMPS | NEWTONS | AMPS |
| 2370 | CONTINUOUS | 24 | 13 | 31 | 400 | 0.6 |

CABLE SIZE minimum C.S.A. (mm2) = L (m) x K (constant)
where C.S.A = Cross Sectional Area of cable (mm$^2$).
K = a constant which varies with voltage (1.5 mm$^2$ per metre length of cable for 24V).
L = length of cable.

EXAMPLE: 4 metres of cable = cable size 6 mm$^2$.
Where the cable size calculated does not equate to a standard cable size, the next larger size of cable must be used.
This formula gives a voltage drop of about 3%, however, to ensure an adequate current carrying capacity for the cable, a minimum size of 4 mm$^2$ should be used.

**Key**
**(Fig. 3Z)**
**1** Remove stud (if fitted)

## OPERATION

Because of the high pull in current, and the fact that the solenoid is energised to run (E.T.R.), it is important that the following instructions are adhered to:

1 Starting batteries must be a minimum of 286 Amp/hour capacity at 20 hour rate (check with Perkins Engines (Stafford).
2 Careful setting of the mechanical linkage is essential to ensure that the solenoid pull in coil supply is broken when on full stroke. This can be checked by energising the solenoid with a **24V** indicator lamp connected between the auxiliary terminal on the solenoid and the battery positive terminal. When the solenoid is at its full travel the indicator lamp will illuminate see **Fig. 4Z**.
3 The starting circuit is designed to allow the solenoid to be energised before cranking commences by the use of a relay, as shown on the wiring diagrams **in the Operators Handbook page 53 onwards**.

## FITTING INSTRUCTION FOR SYNCHRO-START STOP SOLENOID (SEE FIG. 5Z)

1 Align the stop levers to the governor output levers on the actuator output shaft (see **Fig. 1BB**).
2 Set the governor output levers in the maximum fuel position (with the pointer towards '100') as far as the levers will go, without disturbing the fuel stops. (see **Fig. 5Z**).
3 Bench assemble the solenoid, brackets and plunger assemblies.
4 Fit the solenoid assemblies to the actuator support bracket, leaving the securing screws slack.
5 Hold the solenoid in the energised position, and position the assembly so that the plunger clears the roller in the maximum fuel position by 1 to 3 mm see **Fig. 6Z**.
6 Tighten the securing screws and check the movement of the lever and alignment of the plunger.
7 Wire as shown in the wiring diagram.

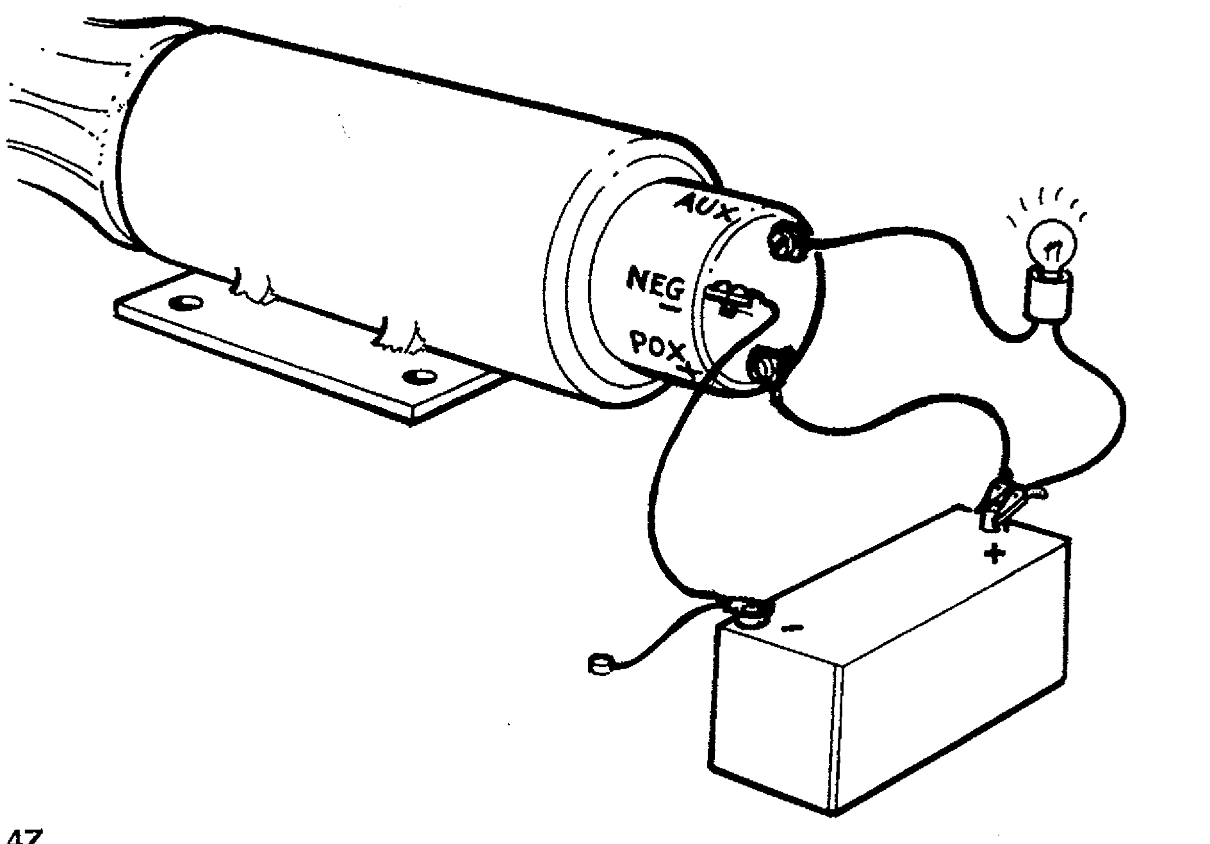



**Fig. 4Z**

## REPLACING THE SOLENOID

1 Disconnect the wiring and remove the 4-fixing bolts from the solenoid mounting bracket.
2 Bolt the replacement solenoid to the support bracket.
3 Check that the solenoid assembly (see **Fig. 4Z**) operates as per the above fitting instructions.

**Key**
**(Fig. 5Z)**
1 No load position
2 Maximum fuel position

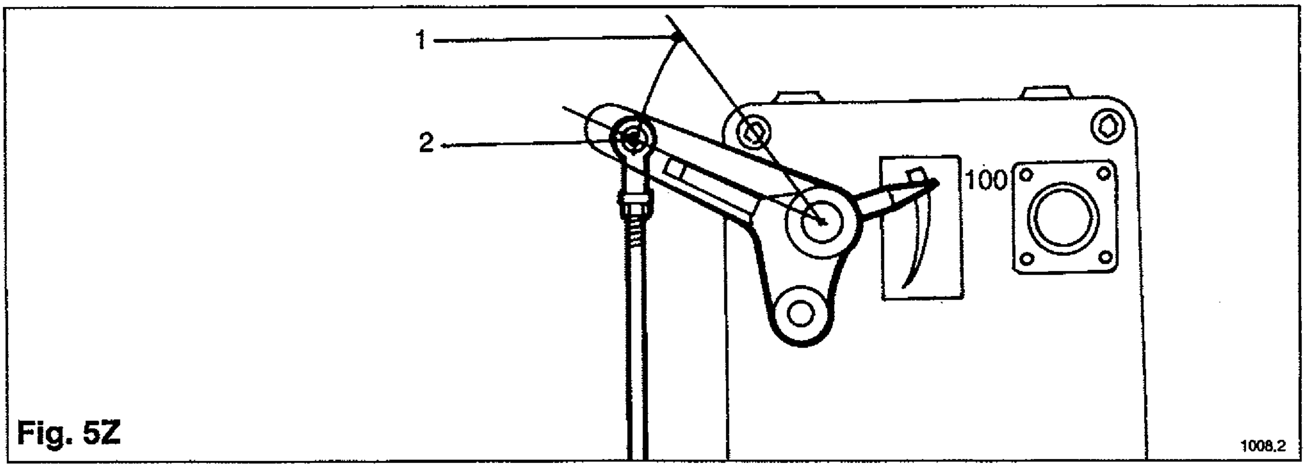



**Fig. 5Z**

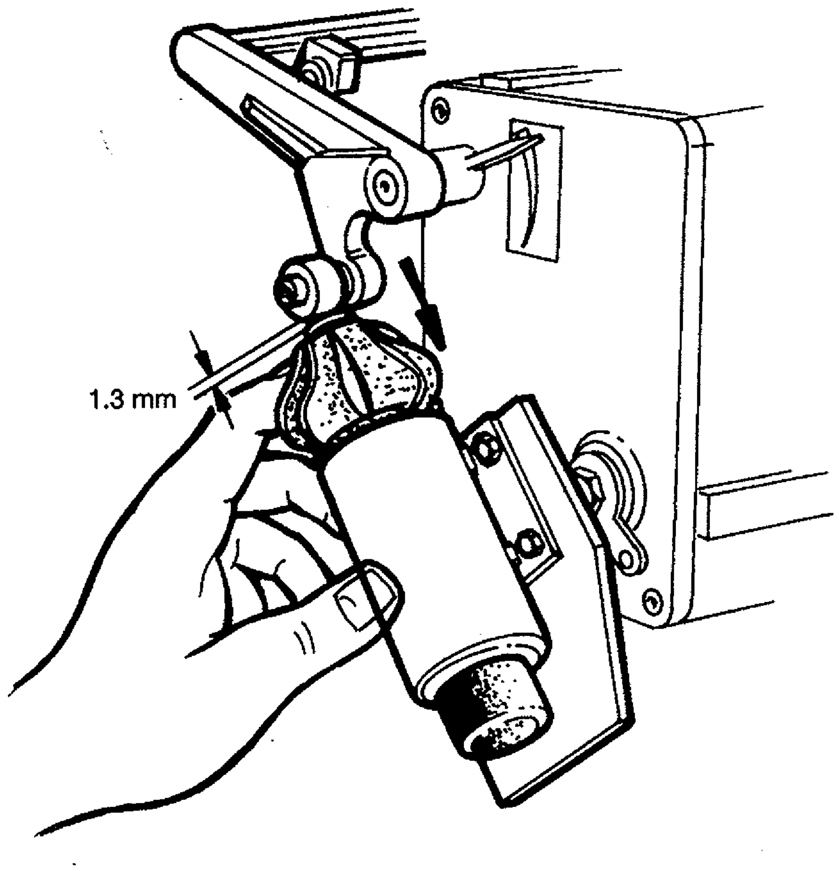



**Fig. 6Z**

## STOP SOLENOID AS FITTED TO WOODWARD UG10 AND 3161 GOVERNORS (ENERGISED TO RUN)

New engines as supplied by the factory have their stop solenoids tested and ajusted before dispatch. However if the solenoid has been stripped for repair or cleaning, then the following sequence of operations should be carried out:

Position the shutdown rod assembly in the solenoid plunger with the end of the plunger friction screw $^1/_8$ inch inside the solenoid plunger nose (see **Fig. 7Z**). Loosen the locknut and, with the solenoid de-energised, turn the solenoid plunger guide clockwise until it is tight against the plunger. The plunger should be seated against the governor cover. Back off the solenoid plunger guide 3 to 4 turns and tighten the lock nut.

Attach the cover assembly (including the shutdown device) to the governor case.

Remove the pipe plug from the hole in the solenoid plunger guide.

With the engine running and the governor in operation controlling the speed de-energise the solenoid and use a screwdriver to turn the shutdown rod assembly clockwise until the governor first starts to shut down, then screw the shutdown rod down one additional turn.

**Key**
**(Fig. 7Z)**

1 Locknut
2 Solenoid plunger guide
3 Solenoid coil
4 Solenoid plunger guide
5 Solenoid plunger
6 Plunger friction screw
7 Governor cover
8 Shutdown spring
9 Shutdown rod
10 Load limit strap (in governor)
11 Pipe plug
12 1/8 inch
13 Solenoid coil
14 Shutdown rod

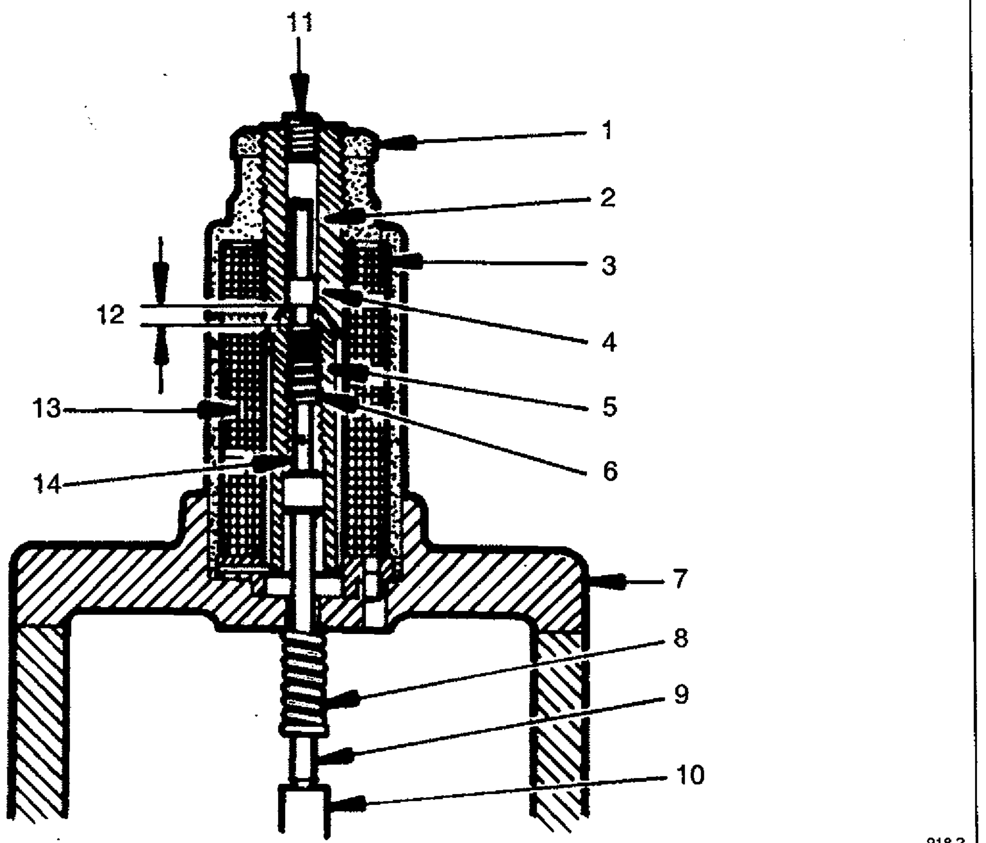


**Fig. 7Z**

## HEINZMANN TYPE E16 ELECTRONIC GOVERNOR

**WARNING** ⚠ THE ENGINE MUST BE EQUIPPED WITH AN INDEPENDENT, SEPARATE OVERSPEED SHUTDOWN DEVICE. WHEN THE ENGINE IS RUNNING THE BATTERY MUST NOT BE DISCONNECTED.

### GENERAL DESCRIPTION

The HEINZMANN governor fitted to the 4012 and 4016 engines is the E16 type and this has been adjusted during engine test. However, depending upon engine applicaiton, further adjustment may be required during commissioning.

Naturally, throughout the life of the engine the governor equipment will require some attention to the magnetic pick-up, controls, control linkage and settings, etc. The following notes describe the procedures that should be followed to fulfil these requirements and are reproduced with the permission of Fritz Heinzmann GmbH & Co.

### OPERATION

1 The speed pick-up measures the actual speed of the engine at the flywheel gear ring and forwards the information to the control unit. In the control box the actual speed is compared with the set-point speed and the resulting discrepancy causes the control circuity to adjust the actuator position, the fuel delivery rate and thus the engine speed

2 If, due to a load change a discrepancy exists between the set-point and speed pick- up figures, the control electronics remove the discrepancy by returning the engine speed to its original setting, i.e. isochronous regulation.

3 If the speed pick-up signal is interrupted, e.g. by a cable breakage or the engine stopping, a safety circuit ensures the shutdown of the actuator drive.

4 The internal governor spring returns the actuator lever to the 'stop' position.

5 Furthermore, if any of the set point potentiometer cables become disconnected, the actuator will move to the 'zero fuel' position until the engine stops.

6 The shutoff devices described above do not replace the usual engine overspeed protection equipment.

## INSTALLATIONS OF THE MAGNETIC PICK-UP

The magnetic pick-up is fitted in the flywheel housing, close to the teeth of the starter ring gear (see **Fig. 0.5AA**), and should be fitted as follows:-

1 Turn the engine until the top or crest of a gear tooth is in the centre of the pick-up head location diameter (see **Fig. 0.5AA**).
2 Screw the pick-up head into the flywheel housing.
3 Screw the pick-up head further into the flywheel housing until it lightly touches the crest of the gear tooth.
4 Unscrew the pick-up head half a turn.
5 Without moving the pick-up, screw the locknut down to the flywheel housing and tighten the locknut (see **Fig. 1AA**).

**NOTE:** The inside of the flywheel housing should be kept clean, since the pick-up head being magnetic will attract and may be affected by particles of ferrous metal.

**WARNING** ⚠ DISCONNECT BATTERIES AND ALL OTHER MEANS OF STARTING THE ENGINE. FOR SAFE OPERATION, PARTICULARLY THE ABILITY TO STOP THE ENGINE, CHECK THAT THE ACTUATOR WILL POSITION THE FUEL INJECTORS IN THE 'NO FUEL' POSITION, i.e. AT ACTUATOR POSITION '10' THE INJECTOR CONTROL ARMS MUST BE IN THE 'NO FUEL' POSITION.

## REMOVING THE ACTUATOR (SEE FIG. 2AA)

1 Disconnect the control links from the governor output levers A, and the multi-pin plug from the electrical socket B.
2 Remove the four capscrews and spring washers C fixing the actuator to the support bracket. Then carefully lift the actuator away from the engine.
3 Remove the existing output levers D for use on the replacement actuator. The lever can be marked with paint dabs to assist reassembly.

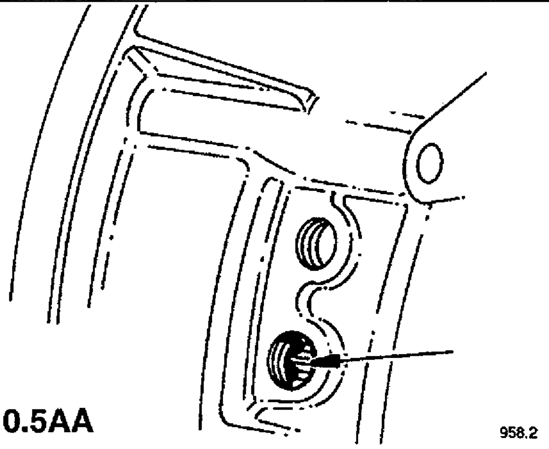


**Fig. 0.5AA** 958.2

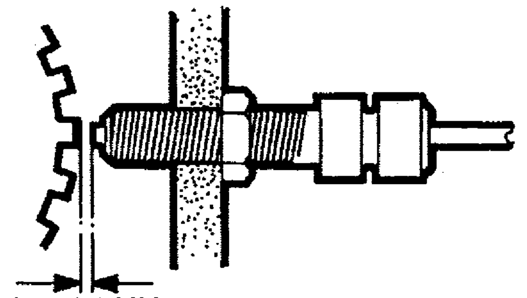



**Fig. 1AA** 225.2

4 To replace the stop solenoid **(see Section Z3)**.

**Key**
**(Fig. 0.5AA)**
1 Crest of gear tooth

## REPLACING THE ACTUATOR

1 With the actuator on the bench, fit the governor output levers onto the actuator output shaft, ensuring that the levers are in line with each other. The left hand bank lever must be on the opposite side to the governor pointer (see **Fig. 2AA**). Tighten the 4 mm clamp bolt and locknut.

2 Fit the actuator on the support bracket. Connect the multi-pin plug into socket. Do not connect the output levers to the control links at this stage. Remove the rollers from the output lever spindles to facilitate their movement if the shutdown solenoids are fitted.

3 With the starter motor(s) isolated, set up the feed back voltage in the control box to suit this actuator (see **Section AA4**).

4 Connect the governor output levers to the control links for each bank of cylinders and refit rollers to output lever spindles and tighten locknuts.

5 Check whether the engine is fitted with the earlier or later injectors and re-set the unit injector control arms according to **Section P** using the appropriate setting tool.
**NOTE:** All 4012TAG2 and 4016 SERIES engines have the latest injectors.

6 Refit shut down solenoids if they have been removed.

7 The shut down solenoids must be fitted in accordance with **Section Z (see Fig. 2Z and 4Z)**
i.e. with the fuel control linkage against the power stops, assuming that these have not been touched and are still sealed. There must be a 1 to 3 mm gap between the solenoid plungers and the rollers on the governor levers when the solenoid is energised (see **Fig. 2AA**).

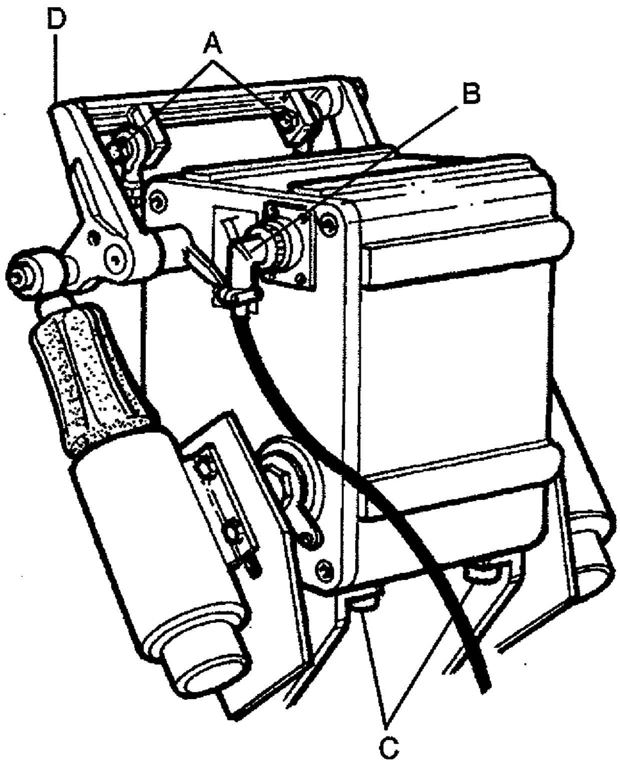


**Fig. 2AA**

## ACTUATOR SPECIFICATION

| | |
|---|---|
| Torque at the governor output shaft 24V | 16 Nm (11.8 lb ft) or 160 cm kp |
| Useful rotation at the governor output shaft | 42° |
| Voltage supply | 24Vdc |
| Current consumption | |
| at steady state about | 1 - 2A |
| at load changes about | 5 - 6A |
| Electric protection | 15A |
| Weight about | 13 kg |
| Temperature range | -55°C to +90°C |

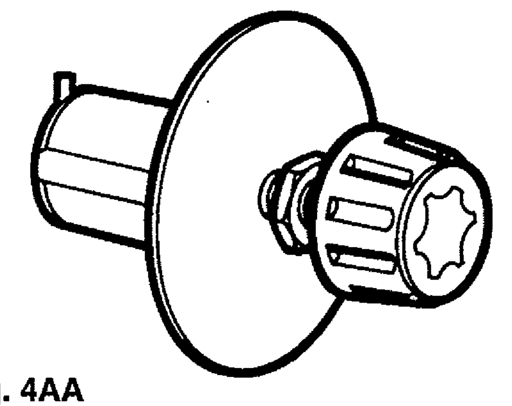



**Fig. 4AA**

## SPEED SET POINT POTENTIOMETER (10 TURN, PART NO. 680/76)

| | |
|---|---|
| Displacement angle | 10 turns |
| Resistance | 5 kOhm |
| Temperature range | -55°C to +105°C |

**NOTE: It is essential that the potentiometer is mounted in a cool position which is free of vibration. It must not be mounted on the engine.**

## CONTROL UNIT KG16-04 (PART NO. 680/84)

**WARNING** INCORRECT ADJUSTMENT OF THIS UNIT MAY CAUSE THE ENGINE TO OVERSPEED, WHICH COULD RESULT IN AN ACCIDENT AND ENGINE DAMAGE.

## SPECIFICATION

| | |
|---|---|
| Working Voltage | 10 - 35V dc |
| Max. ripple Voltage | 10% |
| Max. control current | 15A |
| Current consumption | approximately 60 mA + current for the actuator |
| Ambient temperature | -40°C to +85°C |
| Humidity | up to 100% |
| Control frequency | 200 to 6000 Hz |
| Steady state variation | + 1/4% |
| For frequency greater than 1500 Hz maximum speed variation for a | -40°C to +85°C |
| temperature change from | + 1% |
| Weight | 2.6 kg |

The control unit is installed in an aluminium housing sealed against dust and humidity with an 'O' ring. The control unit can be mounted in any position not subject to vibration, strong magnetic fields, or a temperature greater than 85°C.
For fixing the control unit remove the cover. The fixing points are outside the housing gasket, so the seal is not affected by the installation.
When installation is necessary on the engine or the basic frame, use the anti-vibration units provided.
**NOTE:** For the fuel limit unit built into the control box, see **Section AA12. Fig. 16AA.**

**WARNING** ⚠ ENSURE THAT THE STARTERS CANNOT BE ENGAGED BY DISCONNECTING OR ISOLATING THE FEED TO THE STARTERS AND/OR ISOLATING THE AIR SUPPLY TO THE AIR STARTER MOTOR.

**GOVERNOR SETTING FOR ISOCHRONOUS OR ZERO DROOP RUNNING**

In the event of the control box or actuator being replaced or the original setting being disturbed, the following procedure must be followed to reset the system:

**WARNING** ⚠ THESE ADJUSTMENTS CAN ONLY BE MADE IF A HEINZMANN PG01 TEST UNIT IS AVAILABLE. **TOOL NO. T6253/241**

**ENGINE STATIONARY**

1. Set the pick-up gap (0.5 to 0.8 mm) see **Fig. 1AA.** Set the control box on each bank in turn.

2. **Feedback**
   The feedback setting of the actuator and control box is set as a matched pair and adjusted units are marked with the same serial no. For feedback setting, please note the following:
   a) If the control box and actuator have the same serial number, no resetting of the feedback is normally required. If there is a possibility that the setting has been disturbed, then reset feedback as for (b).
   b) If the control box and actuator have different serial numbers, the feedback voltage has to be set as follows: **(numbers in brackets refer to Fig. 5AA).** Disconnect the linkage from the governor output levers. Connect a dc Voltmeter (0 - 10V range) onto the test points 0V and TP6 (1).
   Remove the rollers from the governor output levers to facilitate the movement of the levers. Switch on the Voltage supply. **DO NOT START.** With the actuator in the 'zero' position (see **Fig. 2AA**), adjust the feedback Voltage to 1.5V with the 'stop' potentiometer (2).
   Put the actuator manually to the maximum position (i.e. 100) and hold, set 5V with maximum fuel potentiometer (3).
   Re-check and re-adjust both values until correct (tolerance + 0.1V).
   c) Re-connect the linkage and refit the rollers and locknuts to the governor output levers.

3. **Frequency Setting**
   The combined unit (actuator/control box) will have been set, and the operating frequency, i.e. the frequency produced by the magnetic pick-up will be recorded on the name plate.
   In the event of a replacement control box being fitted which has not been pre-set, the following procedure should be carried out.

## 4. Setting Procedure

Initial settings (numbers in brackets refer to Fig. 5AA).

| | |
|---|---|
| Gain (5) | 2 (min.) |
| Stability (6) | 3.5 |
| Derivative (7) | 0 |
| Gas gain (8) | 0 |
| Damping (10) | 0 |
| Droop/zero switch (11) | zero position |
| Diesel/ gas switch (12) | Diesel position |
| Fast response (13) | 0 |
| Droop (16) | 0 |
| Speed variation (17) | 0 |

a) The 'minimum or idle speed' potentiometer (15) to be wound fully clockwise to its maximum value.

b) The external speed potentiometer to be set at its maximum value (usually fully clockwise).

**b1) 'Maximum speed' potentiometer (4) to be turned anti-clockwise 10 turns to prevent overspeed on start up.**

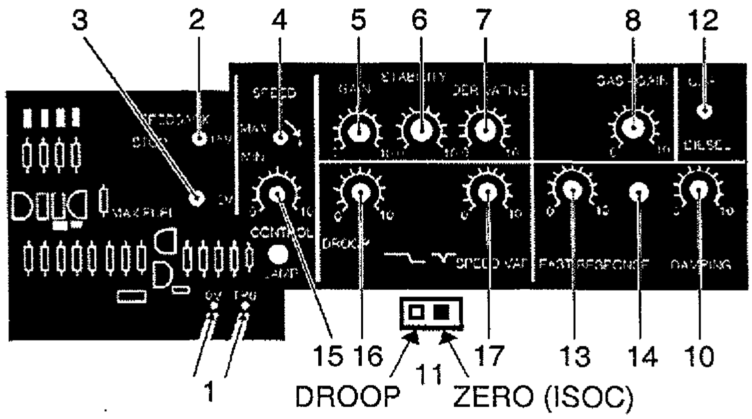



Fig. 5AA

**WARNING** IT MAY BE NECESSARY TO TURN THE 'MAXIMUM SPEED' POTENTIOMETER CLOCKWISE (INCREASING SPEED) TO MAKE THE ENGINE RUN. THIS SHOULD BE DONE SLOWLY TO AVOID OVERSPEED. CHECK FIRST IF ENGINE DOES NOT FIRE, THAT THE GOVERNOR OUTPUT LEVER IS GOING TO 'FULL FUEL' POSITION AND ALSO REFER TO FAULT TRACING **SECTION AA14.**

**ENGINE RUNNING NO LOAD**

c) The 'maximum speed' potentiometer (4) to be adjusted to give rated speed +1%.

d) The external speed potentiometer to be reset (turn down) to give the exact rated speed. At this point the 'gain', 'stability' and 'fast response' potentiometers can be set, providing that the engine is warmed through to normal working temperature.

**NOTE:** The speed setting range of the external speed set point potentiometer **Fig. 4AA**, will be between the speeds set on the 'minimum speed' potentiometer (15) and the 'maximum speed' potentiometer (4).

Turn 'gain' (5) clockwise until unstable and anti-clockwise for stability.

**NOTE:** A 'gain' setting greater than '2' should be achieved. If not, then suspect incorrect voltage settings, sticking injectors or linkage. Similarly the stability setting should be greater than '4'.

**FIXED SPEED GENERATING SET ENGINES WITH HEINZMANN ELECTRONIC GOVERNORS AND NO EXTERNAL SPEED ADJUSTING POTENTIOMETER (FIXED RESISTOR)**

These engines have a control box with a fixed value resistor fitted to take the place of the external potentiometer.

Where a fixed resistor is fitted in place of the external speed setting potentiometer, carry out the above adjustments ignoring any reference to the external potentiometer and set the internal 'maximum speed' potentiometer to the actual rated speed, not rated speed +1% as in (c) above.

If a fast response for transient load changes is required, turn the 'fast response' potentiometer (13) slowly, until the light emitting diode (14) between it and the 'damping' potentiometer just lights. Turn the external speed set potentiometer **Fig. 4AA** fully anti-clockwise and set the lower operational speed with the 'minimum speed' potentiometer (15). Test the engine over the full speed and load range and re-set the governor if necessary **OFF LOAD.**

**WARNING** DO NOT MAKE ADJUSTMENTS ON LOAD AS SHEDDING LOAD MAY CAUSE OVERSPEEDING

**MINIMUM SETTINGS**

| | |
|---|---|
| Gain | 2 (min.) |
| Stability | 4 |

**MANDATORY SETTINGS**

| | |
|---|---|
| Derivative | 0 |
| Fast response | just flashing on 'no load' |
| Damping | 0 |
| Speed variation | 0 |

## DROOP OPERATION

a) Carry out the adjustments as detailed for isochronous above and then with the external speed potentiometer reset to rated speed and the 'droop control' potentiometer turned to minimum, set the 'isochronous/droop' switch to 'droop' **WITH THE ENGINE STATIONARY.**
Restart and set the 'droop' control potentiometer to give the rated speed +5%.
Check that the engine pulls full power (100%) at the rated speed.
Do not adjust the 'maximum speed' potentiometer (4), but if necessary to obtain the correct droop operation, reset the external adjustment potentiometer in conjunction with the 'droop' potentiometer, to give the rated speed at 100% load and the rated speed +5% for no load, i.e. this should be repeated until the correct speed and droop are obtained.

b) Do not reset 'gain', 'stability', or 'fast response' potentiometers.

**WARNING** ⚠ CAUTION MUST BE EXERCISED WHEN RESTARTING AFTER SWITCHING FROM DROOP TO ISOCHRONOUS OPERATION AND BACK. SWITCHING MUST BE DONE WITH ENGINE STATIONARY. UNTIL FINAL SETTINGS HAVE BEEN ACHIEVED, CARE MUST BE TAKEN TO AVOID OVERSPEEDING ON START-UP AND ON ADJUSTMENT. SHOULD THE CURRENT OF THE HEINZMANN ACTUATOR EXCEED 3 AMPS WHEN RUNNING AT FIXED SPEED, THEN THE CAUSE MUST BE INVESTIGATED (e.g. STICKING INJECTORS OR CONTROL SYSTEM). ALL FINAL SETTINGS TO BE OPTIMISED WITH THE ENGINE UP TO FULL WORKING TEMPERATURE (WATER 75°C OUT, OIL TO BEARINGS 85°C), OTHERWISE HUNTING WILL OCCUR AS THE ENGINE WARMS UP.

## FINAL SETTING (Where mode can be either 'droop' or 'zero droop')

a) Set maximum power stop.

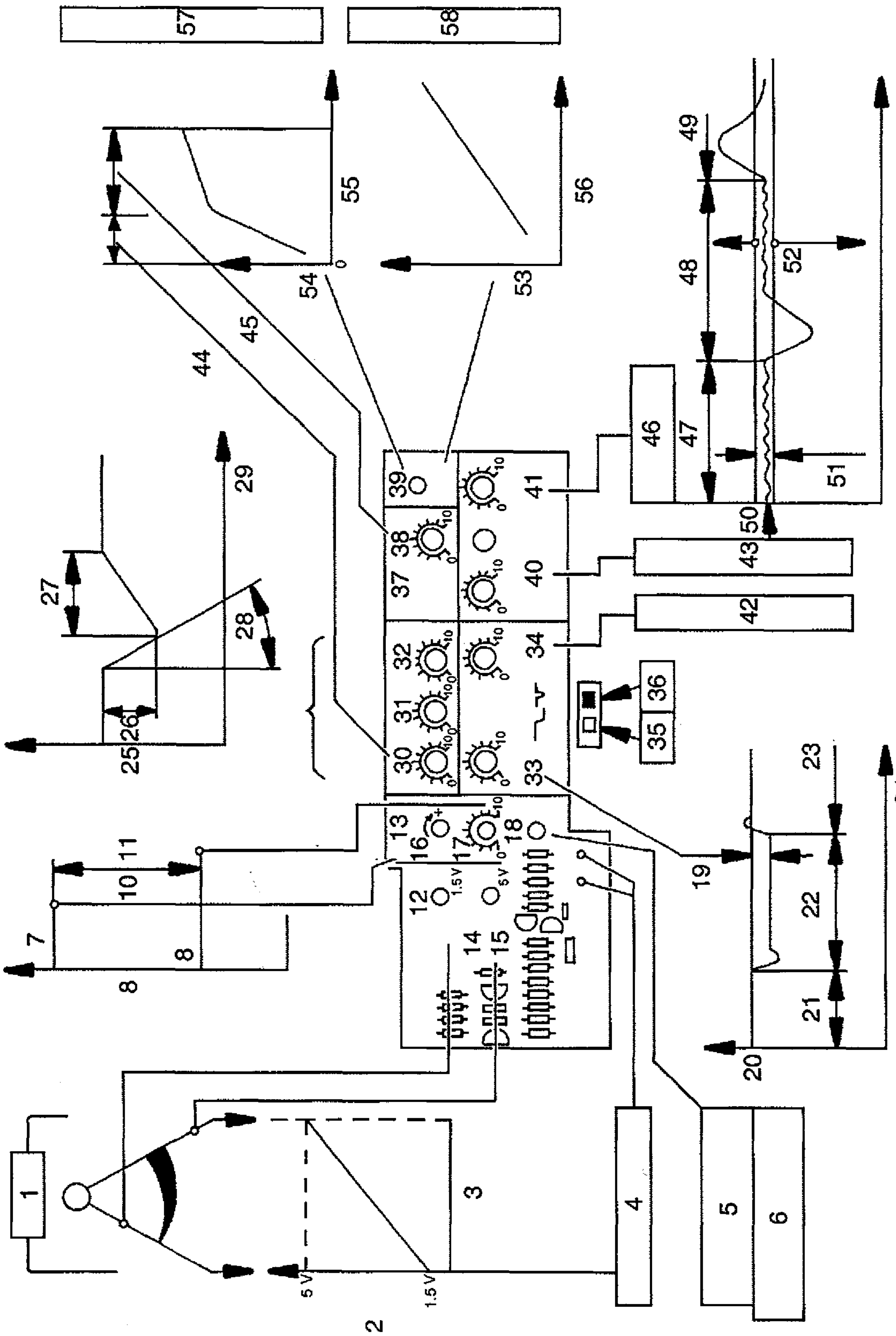
b) Set start-fuel selector switch to appropriate setting i.e. fuel limit on starting excess fuel for starting, standard (see **Sections AA12 and AA14**).
Adjust fuel limit potentiometer to give the desired actuator travel.

**ADJUSTMENT FOR E.6 ... E30 ELECTRONIC GOVERNORS**

**Key**

**(Fig. 6AA)**

**1** Actuator
**2** Feedback voltage
**3** Adjusting angle
**4** Feedback test points
**5** On during stop when voltage exists
**6** Off with starter frequency (about 80 Hz)
**7** Max speed
**8** Speed
**9** Min speed
**10** Speed range
**11** Speed trim potentiometer range
**12** Feedback
**13** Speed
**14** Speed
**15** Max fuel
**16** Max
**17** Min
**18** Control lamp
**19** Droop
**20** Speed
**21** No load
**22** Full load
**23** No load
**24** Time
**25** Speed
**26** Gain
**27** Stability
**28** Derivative (Displacement speed)
**29** Time
**30** Gain
**31** Stability
**32** Derivative
**33** Droop
**34** Speed var
**35** Droop
**36** Zero droop
**37** Gas
**38** Gain
**39** Gas
**40** Fast response
**41** Damping
**42** Only for external droop
**43** Damping range
**44** Gain range
**45** Gas gain range
**46** To eliminate linkage jiggling
**47** No load
**48** Full load
**49** No load
**50** Speed
**51** Damped range
**52** Not damped
**53** Power
**54** Power
**55** Angle of throttle valve 90°
**56** Control rod travel
**57** Not proportional power increase
**58** Proportional power increase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5 V
1.5 V

**Fig. 6AA**

230.4

## ELECTRICAL DETAILS
**Key**
**(Fig. 7AA)**

**1** Engine starter battery or isolated supply battery with charger.
Rating 60 ampere hour for E16 or mains supply unit NG01 respectively battery back-up power supply NG 01 + NSV 01
**2** Supply fuse 15 Amp for E16
**3** Governor on/off switch 20 A
**4** Engine speed potentiometer
**5** Actuator
**6** Magnetic pick-up
**7** **CABLE SIZE**
L1 TO L4 HEINZMANN CABLE
L1 2 X 1.5 $MM^2$ UP TO 7M
OVER 7 M - 12 M USE 2 X 2.5 $MM^2$
OVER 12 M - 20 M USE 2 X 4 $MM^2$
L2 7X15 $MM^2$ UP TO 10 M
OVER 10 M, 20 M USE SEPARATE
2.5 $MM^2$ FOR CABLE 2 AND 3
3 X 1 $MM^2$ FOR 4, 5, 6 WITH SCREEN
L3 3 X 0,5 $MM^2$ WITH SCREEN
L4 2 X 0.5 $MM^2$ WITH SCREEN
ACCESSORY INPUTS: KG - SYG - LT CABLE 1 $MM^2$ SCREEN
**8** Control unit
**9** Generator
**10** Engine
**11** Droop potentiometer
**12** Droop switch
**13** Isochronous
**14** Droop
**15** Yellow/green
**16** Engine stop switch (if required)
**17** Synchronizer
**18** Fuel limit unit
**19** Load anticipation
**20** Load sharing

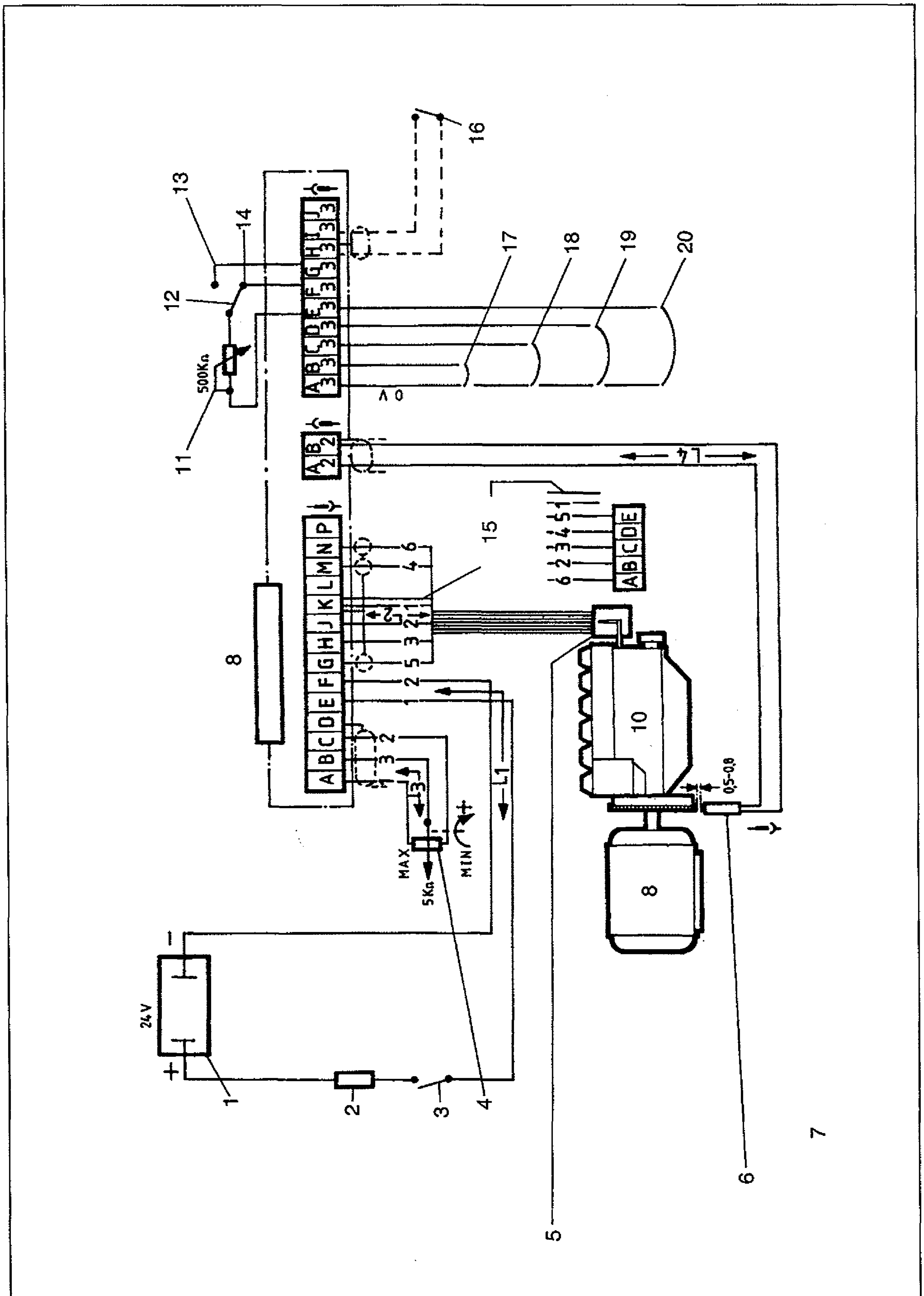


**Fig. 7AA**

557.3

**Key**
**(Fig. 8AA)**
**DETAILS OF BATTERY CONNECTION PROTECTIVE CIRCUIT**

**1** Protective diode
**2** Coils (e.g. stopping solenoid, fuel valve) must be equipped with a protective circuit to eliminate high inductance voltages. Diode type: e.g. IN4007
**3** Charger
**4** Charge is directly connected to the battery
**5** To control box
**6** The governor supply line L1 is directly connected to the battery. Other devices must not be connected to this line.
**7** L1 to the governor. Cable length for the specified cable cross section area must not be exceeded

**Key**
**(Fig. 9AA)**

**1** Screen connected to cable socket at B2, and thus to the battery (-)
**2** Control unit
**3** Magnetic pick-up
**4** Screen must be connected on this side and must not have any connection to the ground

## CABLE SCREENING FOR ELECTRONIC SPEED GOVERNORS

Trouble-free operation of the electronic governor requires a screen for important connecting lines.
The screen must be connected to the control unit or accessories of the governor.
The screen must only be connected on one side; the other side must not be connected, and must not have any connection to ground.

Example: Magnetic pick-up for the governor.

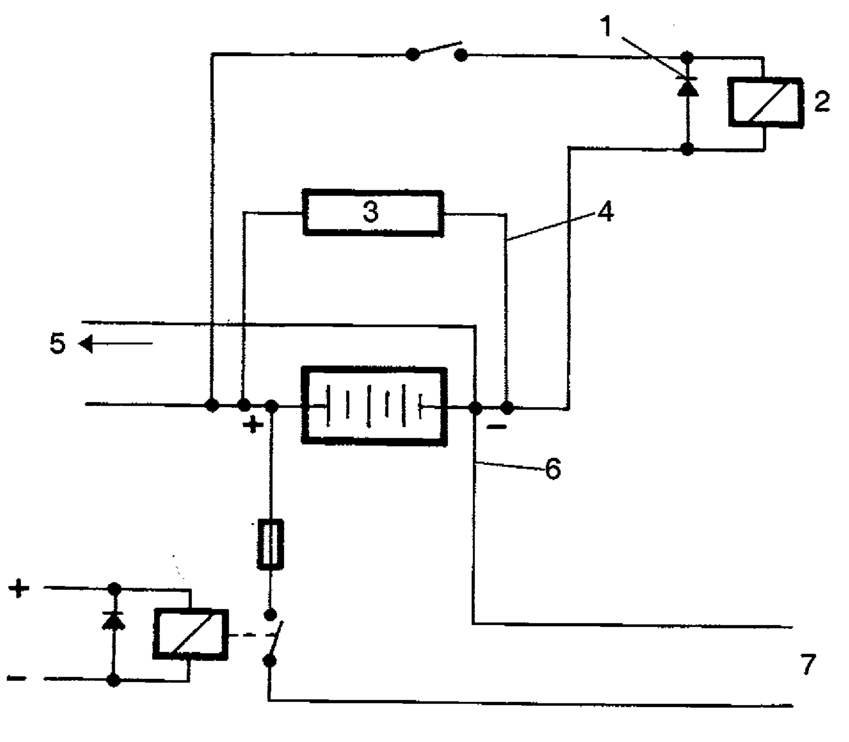



Fig. 8AA

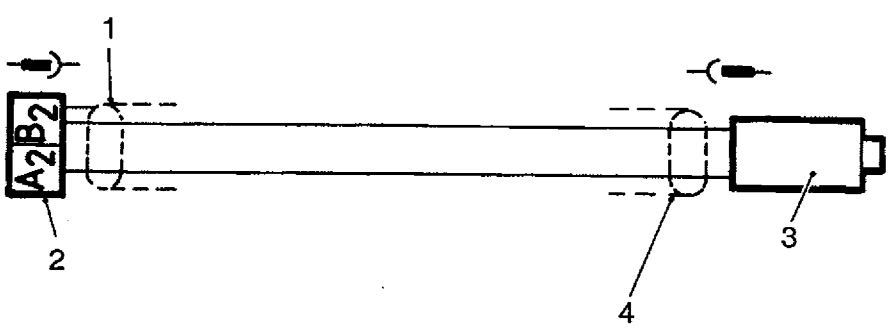



Fig. 9AA

If a line with a screen is wired through a flat connecting block, then the screen must be connected to the flat connecting block without any contact to a negative.
The following arrangements are frequently encountered and they may cause governor disturbances.

**To summarise:**
SCREENS TO GOVERNOR CABLES MUST BE CONNECTED TO THE CONTROL UNIT OR THE GOVERNOR ACCESSORIES (CONNECTED TO THE CONTROL UNIT VIA ZERO V LINE). THE SCREEN MUST IN NO OTHER PLACE BE CONNECTED WITH (-) OR GROUND.

**CHECKING THE SCREEN**

a) Remove the plug at the control unit and check the screen terminals at the cable socket against ground. These are terminals D, F, G, K, B2, A3 and H3 on the governor. No connection may be indicated.

**NOTE:** Earth is ground not governor. Once this has been done, check the shielding for continuity to the governor i.e. if no continuity is found check the cable for faults.

b) Connect the other side of the screen to the negative line via the test instrument. The test instrument must indicate the connection. (See **Fig. 14AA**).

c) If no negative flow is detected in the cable, then for testing purposes a connection with the other line must be established via a link in the cable socket e.g. in case of the governor potentiometer cable on the E16, link BD in the cable socket and check the centre tap to the screen connection.

**Key**
**Fig. 10AA** Correction screen connection
**Fig. 11AA** 1. Battery
**WRONG!** Right & left side of screen connected to different negative terminals
**Fig. 12AA WRONG!** Screen is discontinued
**Fig. 13AA WRONG!** Screen is additionally connected to (-) on the flat connecting block

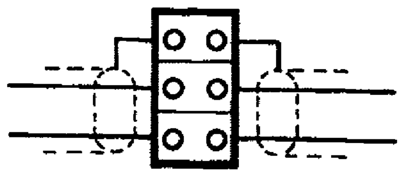


**Fig. 10AA** 234.2

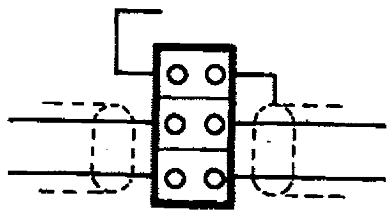


**Fig. 11AA** 235.2

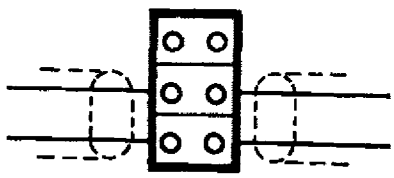


**Fig. 12AA** 236.2

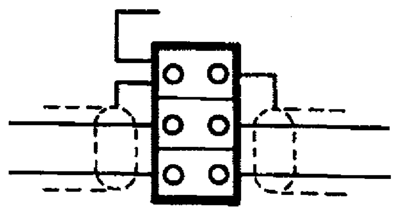


**Fig. 13AA** 237.2

**EXAMPLE: MAGNETIC PICK-UP FOR GOVERNOR**

**NOTE:** Fitted cables have already been checked at the factory.

**Key**
**(Fig. 14AA)**

**1** Instrument <u>MUST NOT</u> indicate connection

**2** Instrument <u>MUST</u> indicate connection

**(Fig. 15AA)**
**DIMENSIONAL DRAWING OF THE CONTROL UNIT**

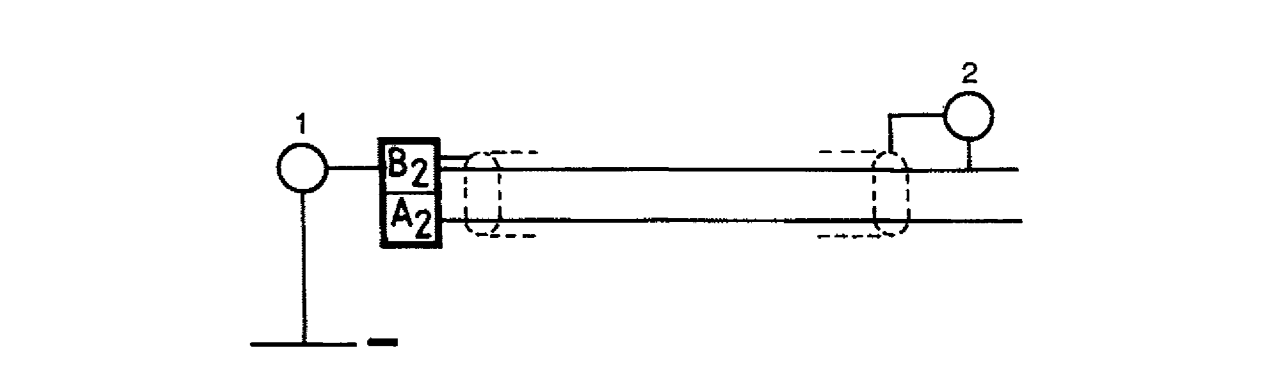



Fig. 14AA

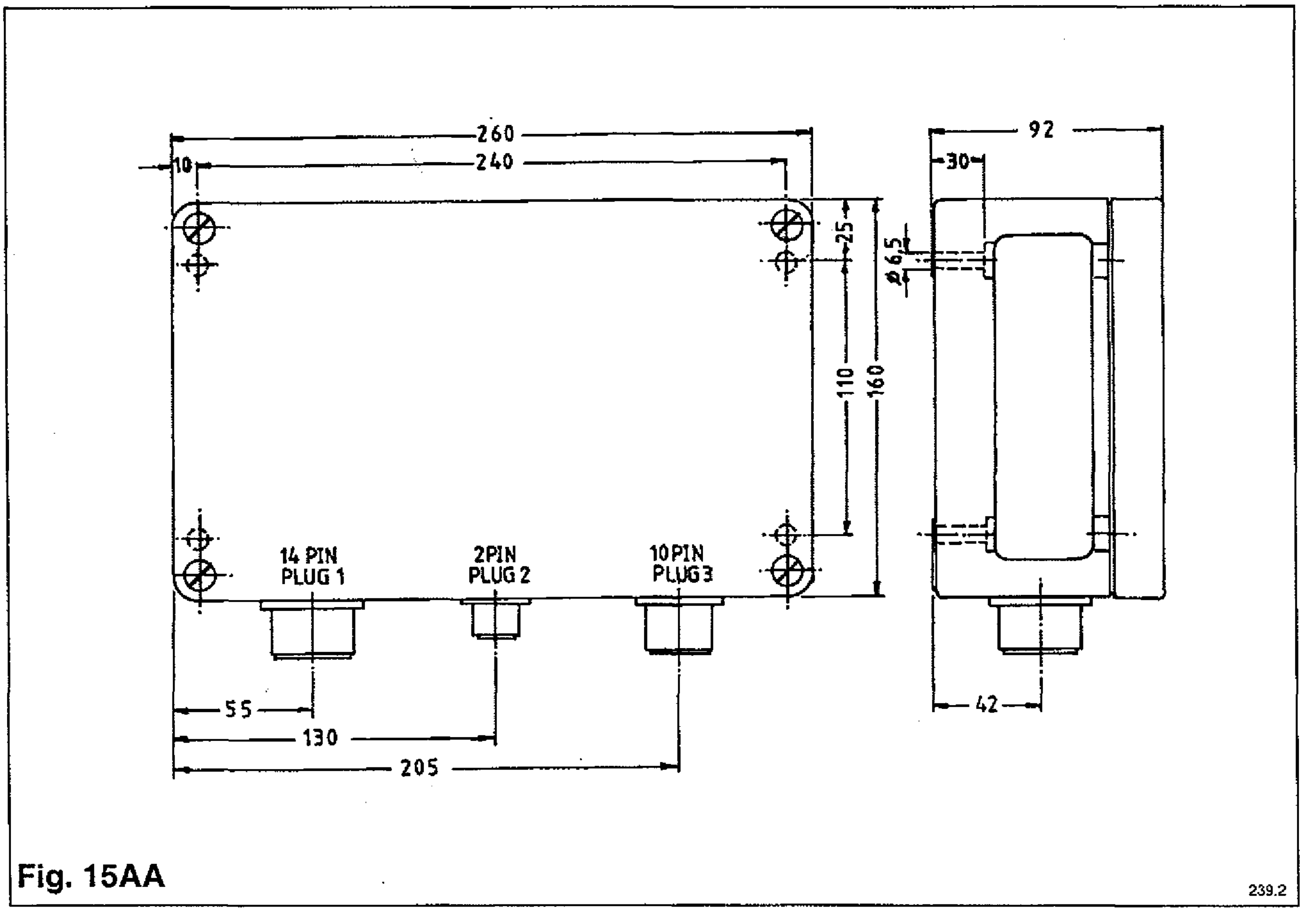



Fig. 15AA

**FUEL LIMIT UNIT SFBG 03 (BUILT INTO THE CONTROL BOX)**
**METHOD OF OPERATION**

The fuel limit unit is basically a clamp that limits the travel of the governor actuator either on engine start or when the engine is running, i.e. load limit.

The unit derives its supply voltage directly from the governor control unit and all connections are made internally.

The start initiation signal is derived from the governor control unit.

When the governor actuator increases fuel due to the engine cranking, the fuel limit is automatically set to either limit fuel level or full fuel depending on the position of the start/overload limit switch.

When the actuator returns from the limit or full position due to the engine being up to set speed, the fuel limit unit is reset and set to no limit or normal running load limit.

Switch position 1 gives normal running load limit.

Switch positions 2 and 3 have no function.

Switch position 4 gives start fuel limiting.

**SPECIFICATION**

| | |
|---|---|
| Voltage supply | Governor supply (24 V) |
| Temperature range | -40°C to +85°C |
| Weight | Mounted in governor control box |

The unit is mounted inside the governor control box and needs no extra connections to it.

**NOTE:** When the 4012 and 4016 engines are fitted with 858/5 pump injectors the fuel limit unit is set to position 4 on the fuel limit selector switch (A) (fuel reduced on cranking) and RV1 potentiometer (B) for fuel limit is adjusted to restrict the travel of the actuator on cranking to 55%.

**Key**
**(Fig. 16AA)**

**1** 0 Volts
**2** Load share point
**3** + 13 Volts DC pin 4
**4** Set point pin 7

**(Fig. 17AA)**
**HEINZMANN GOVERNOR BASIC WIRING DIAGRAM FOR 4012 OR 4016 DIESEL**

**1** Must be fused 15 Amp battery +ve supply
**2** Actuator E16
**3** Control box KG16-04
**4** Auxiliary plug
**5** Engine flywheel
**6** Magnetic pick-up
**7** Speed trim potentiometer
**8** Wiring loom Perkins Supply

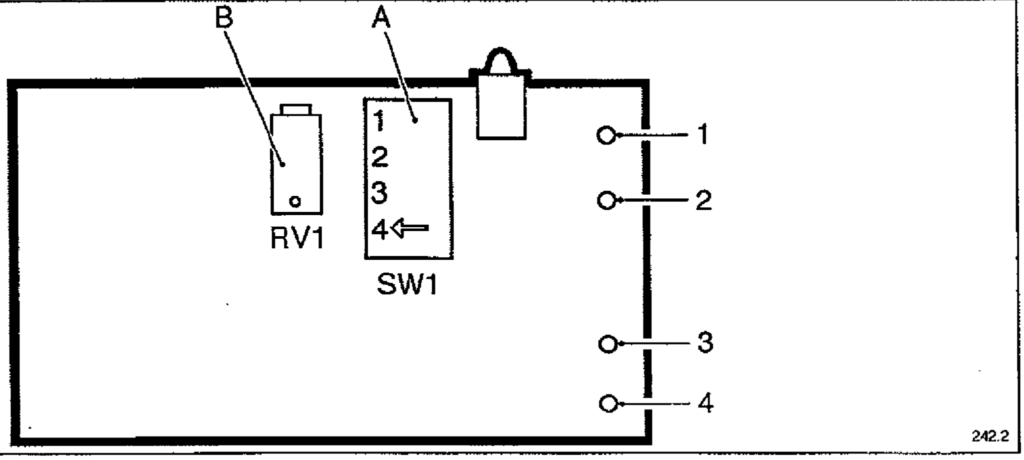


**Fig. 16AA**

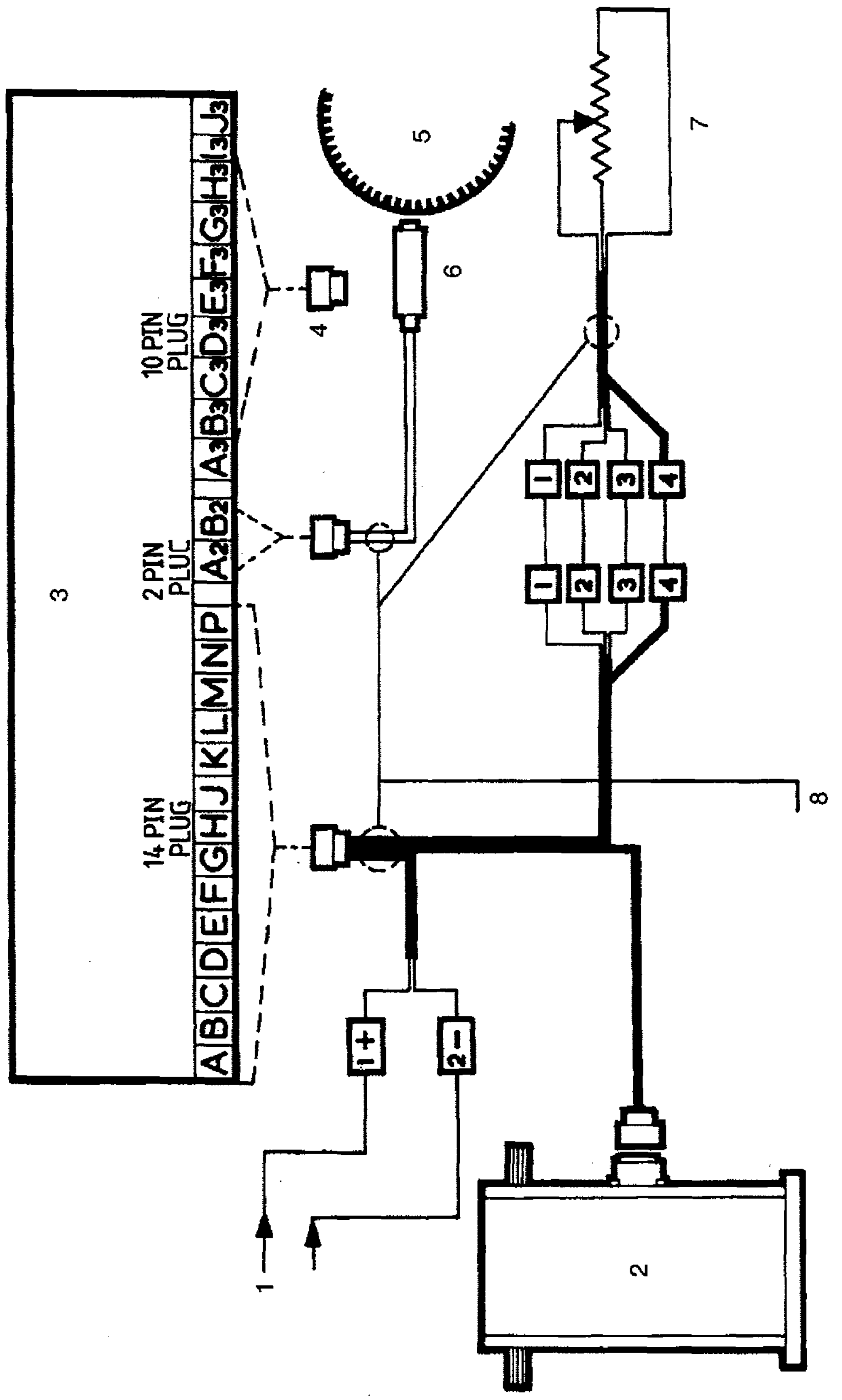



Fig. 17AA

558.3

## FAULT TRACING

| | |
|---|---|
| Governor does not open on start-up | No signal from magnetic pick-up.<br>Excessive magnetic pick-up gap 0.5 - 0.8 mm.<br>Check resistance (approx. 52 ohm) at a control unit A2/B2 cable plug.<br>Check voltage at starter speed (approx. 1.5V ac) at control unit A2/B2 cable plug.<br>Wiring fault - magnetic pick-up defective.<br>Indicator lamp must be lit when voltage supply is switched on and go out from starting frequency upwards.<br>Speed setting potentiometer connection disconnected or incorrect.<br>Check resistance at control unit centre plug A/C up to 5 kOhm; A/B and A/C to 5 kOhm.<br>Speed setting potentiometer or potentiometers for maximum or low speeds set at too low values.<br>Wiring fault in wiring system.<br>Shutdown switch closed.<br>Supply voltage inadequate or polarity reversed.<br>No dc voltage at control unit.<br>Actuator blocked or linkage incorrectly adjusted.<br>Actuator defective.<br>Check resistance at actuator terminals B/C (approx. 2 Ohm).<br>Control unit defective. |
| Governor moves to maximum fuel delivery when power supply is switched on | Wiring fault in wiring system.<br>Faults in pick-up cable -<br>Check shielding<br>Control unit defective. |
| Engine goes to overspeed after start-up | Maximum speed potentiometer set at too high value.<br>Excessive pick-up gap; only a proportion of teeth counted.<br>Bad contact by pick-up lead.<br>Linkage unable to move freely.<br>Feedback voltage incorrectly adjusted.<br>Actuator or control unit defective.<br>If the actuator applies effort on one side only, the fault lies in the control unit. |
| Governor not stable | Faults in pick-up cable -<br>Check shielding.<br>Faults in speed setting potentiometer -<br>Check shielding.<br>Load fluctuations.<br>Faults in speed setting value, e.g. in the output from a motorised potentiometer or as a result of external voltage.<br>Inadequate supply voltage.<br>Poor electrical contact.<br>Play or friction in linkage.<br>Governor incorrectly adjusted |
| Speed droops under load | Droop range switch not in droop range zero setting.<br>Actuator is against 100% fuel delivery stop - engine is overloaded.<br>Stability incorrectly adjusted.<br>Fault in control unit. |

## LOAD SHARING/MEASURING UNIT LMG 03 (PART NO. 680/70)

For generators requiring to be paralleled, a load sharing/measuring unit must be connected to each generator. Refer to **Fig. 20AA** and **Fig. 21AA**

### INTRODUCTION

The Load Sharing Unit measures the output from a generator or the power taken from a grid and will, in conjunction with an electronic speed governor Part No. 680/83 or 680/102, perform the following functions:

Load sharing with zero speed droop.
Load sharing with speed droop.
Load limiting.
Reverse power alarm or trip.

In addition, the load sharing unit may be used in conjunction with the Load Control Unit, LKG01 Part No. 680/73 for control of peak load and zero supply, and with the Load Switching Unit LSCHG 02/2, Part No. 680/81, for switching load dependent relays. When sharing the load between generators operating in parallel, the unit will control the output of each generator proportionally to its rated output. For example, a 50 kW load shared between 40 kW and 60 kW generators in parallel would be split 20 kW and 30 kW respectively.

### METHOD OF OPERATION

Refer to **Fig. 18AA.**

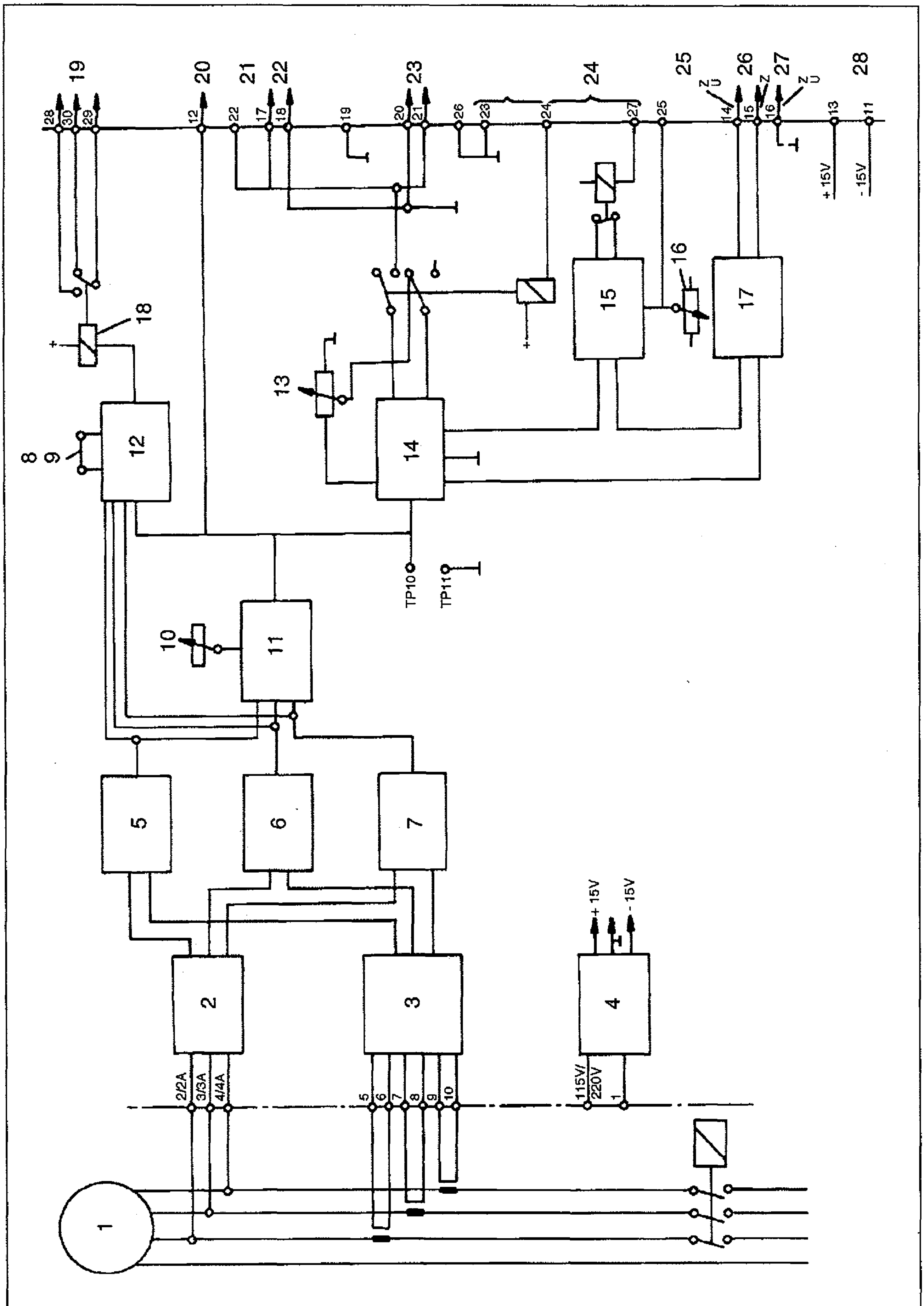
The load sharing unit measures the output power of an ac generator (3 phase voltage and current) and converts this to a dc voltage proportional to the generator load. This voltage is available at terminal strip points 12 and 16 and is also connected to a bridge circuit. Also included are 3 reverse power indicators for each phase to ensure correct wiring.

When generators fitted with load sharing units are running in parallel, these bridge circuits are connected by paralleling leads (17-18+20-21). If a voltage exists between the bridges of the paralleled units, then a small dc current will flow in the paralleling leads. This will cause a change in the speed setting of the connected generators but, as they are all synchronised at the same speed, their outputs will be changed. When the generators are sharing the total load correctly, there will be no current in the paralleling leads.

A change in the gain of the load sharing units or speed settings of the governor will have an affect on the load sharing.

**Key**
**(Fig. 18AA)**
**LOAD SHARING BLOCK DIAGRAM**

**1** Generator
**2** Voltage input
**3** Current input
**4** Power supply
**5** Multiplier
**6** Multiplier
**7** Multiplier
**8** Link for 10% reverse power
**9** Without link 5% reverse power
**10** Gain
**11** Amplifier
**12** Reverse power circuit
**13** Droop
**14** Bridge circuit
**15** Load limit circuit
**16** Load limiting
**17** Output amplifier
**18** Reverse power relay
**19** Reverse power relay
**20** Power signal
**21** Synchronisation group
**22** Connection leads
**23** Connection leads
**24** Auxiliary contactor, Mains contactor
**25** External load limiting and load ramp
**26** To governor and synchroniser
**27** To governor
**28** To governor and synchroniser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23
24
25
26
27
28
TP10
TP11
+15V
-15V
115V/220V
2/2A
3/3A
4/4A
244.3

Fig. 18AA

## TECHNICAL DATA OF LMG 03 LOAD SHARING/MEASURING UNIT (680/70)

| | |
|---|---|
| Voltage input | 220/380V ac +15% ~ or 115/200V ac +15% ~<br>3VA for each phase |
| Current input | 2,5 to 5 A each phase at 100% generator power |
| Power supply | 115/220V ac +15% ~ 20VA |
| Output signal | 6V at 100% generator power, adjustable |
| Maximum voltage of load share line | 3V |
| Accuracy | + 2% at 100% generator power |
| Load limiting | adjustable 50% to 100% |
| Speed droop | 0 - 10% |
| Contact load of the reverse power relay | Maximum 8A at 250V ac ~ |
| Reverse power switching | after 3 secs |
| with link | at 10% reverse power — only when current input equals 5 A for full load |
| without link | at 5% reverse power — only when current input equals 5 A for full load |
| Temperature range | -40°C to +70°C |
| Weight | about 3,8 kg |

### SPEED SETTING FOR GOVERNOR

**Ten turn Potentiometer and Minimum Speed Adjuster (Refer to Section AA3)**

Paralleling lines only one side screened.
Refer to wiring diagram **Fig. 20AA.**
Governor controlling cables 14, 15, 16 screened at the governor only.
Connections for

| | | |
|---|---|---|
| 200V ac | phase/phase | use terminals 2A, 3A +4A |
| 380V ac | phase/phase | use terminals 2, 3 + 4 |
| Power supply | | terminal 1 and 115V ac or 220V ac |

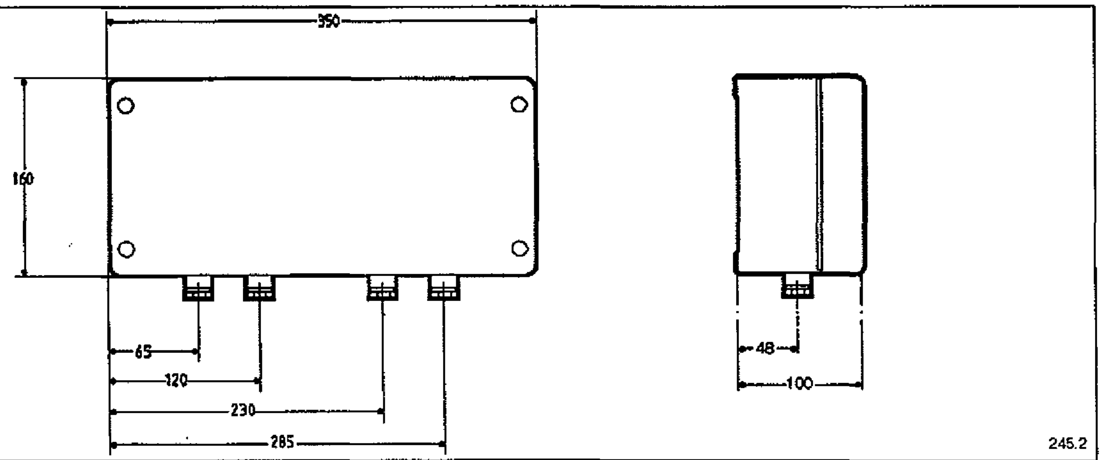



Fig. 19AA

**Key**
**(Fig. 20AA)**
**WIRING DIAGRAM OF LOAD SHARING/ MEASURING UNIT LMG 03 (PART NO. 680/70)**

1 Control unit
2 Connection to governor
3 Speed potentiometer
4 Connection synchronizer
5 Load sharing unit
6 To further load sharing units
7 Load sharing unit
8 Load sharing unit
9 Generator
10 Connection at 380 V AC phase to phase
11 Connection at 200 V AC phase to phase
12 Reverse power relay

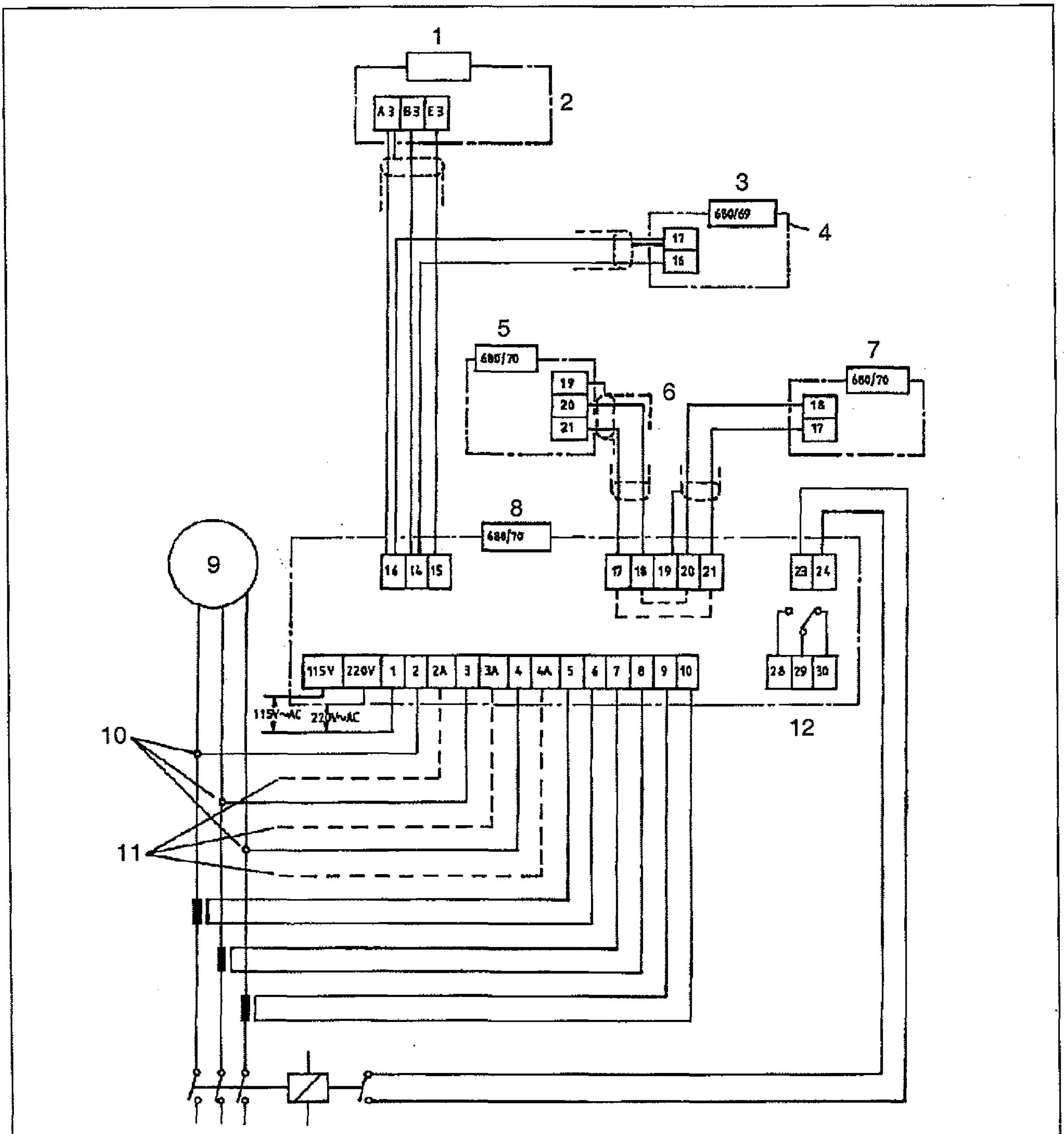



**Fig. 20AA**

## SETTING OF LOAD SHARING WITH ZERO SPEED DROOP (FIG. 21AA)

Before the load sharing unit is adjusted, the speed governors of each installation must be set correctly. Set the 'speed droop' switch to position zero. Using the speed set point potentiometer, the no load speed must be set as precisely as possible, i.e. 50 Hz.

With 'gain' set in the maximum position, turn the 'speed droop' potentiometer (P-Bereich) fully anti-clockwise, and turn the 'maximum load limit' potentiometer (max. Last) 15 turns clockwise.

Start the generator set, and load with 100% generator load in island operation, i.e. not in parallel. By using the light emitting diodes LD 5/6 to LD 9/10, the correct connection of the current transformer will be indicated. If one of the diodes lights, the corresponding links must be changed (e.g. BR 7/8 for LD 7/8). The lighting of a diode indicates reverse power, therefore reversing the current direction with BR links will correct the light emitting diode to 'off'.

On the test points TP 10 and TP 11 (0 Volt) a high impedance voltmeter (20,000 Ohm/ Volt - 10V range) is connected, and with 100% generator load a voltage of 6V is set with the gain adjustment.

Now short circuit the current transformer momentarily, for each phase in turn, on terminals 5/6, 7/8, 9/10. The output voltage of 6V must decrease to 2/3 of its value, (i.e. 4V). Check the current transformer connection if this does not occur. For each engine, test its load sharing unit separately.

After the above setting and tests the installation may be connected together, proceeding as follows:

a) Load generator 1 with 50% load.
b) Switch on generator 2, which will then take half of the load.
c) Increase load slowly to 100%. If there is a different load sharing, correct with 'gain' setting.
   Turning anti-clockwise results in higher load.
d) Check at no load. If there are load differences, speed differences exist in the governor adjustment. Correct these differences (with the speed setpoint potentiometer) before paralleling.
e) Proceed with installation 1 to 3, 1 to 4, etc., in the same way, thereby adjustments of the 'gain' setting or the setpoint value may only be made on the new added installation.

If load hunting occurs between the generators, the output voltage value must be lowered to 5 or 4 Volts.

With mains operation no further setting should be necessary. Also: differences at no load are to be corrected with the speed trim potentiometer of the governor and differences at full load are to be corrected with the 'gain' adjustment of the load sharing unit.

**Key**
**(Fig. 21AA)**

**1** Link for 10% reverse power
**2** LD for reverse power

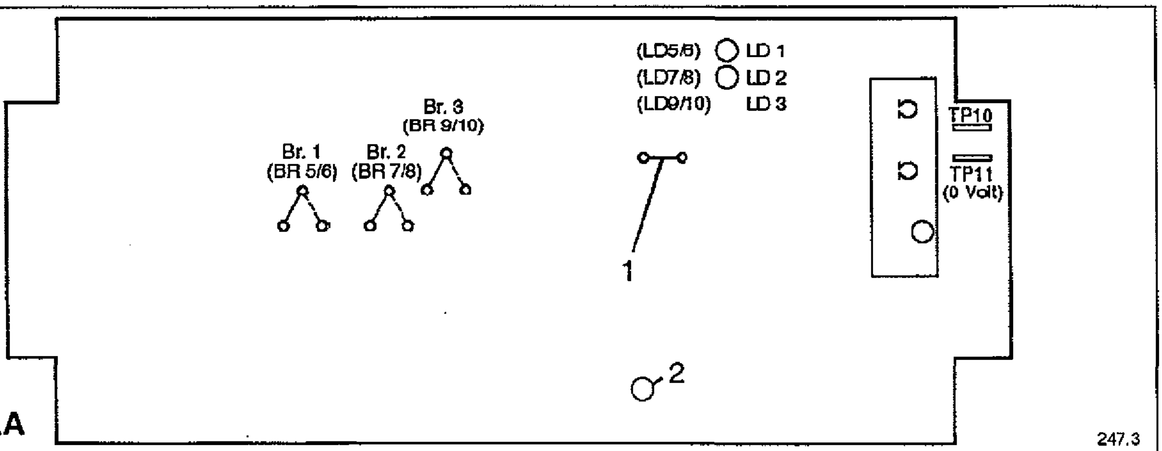



Fig. 21AA

## LOAD SETTINGS FOR PARALLEL MAINS OPERATION

Controlled mains supply with Load Control Unit LKG01 **Part No. 680/73**.

## BASIC LOAD OPERATION

If one or more generators are on the mains, the basic load adjustment is made with the load setting potentiometer (**Part No. 680/76**) connected as follows in **Fig. 22AA**.

The load sharing units must be set up as described (see **Section AA19**).

When a motor potentiometer of 120 sec., (**Part No. 680/54**) is used, instead of the standard set point potentiometer, in conjunction with a separate load control system, the load from the mains can be set i.e. to zero load.

**Key**
**(Fig. 22AA)**

1. To further LMG
2. Load sharing unit
3. Mains
4. Installations

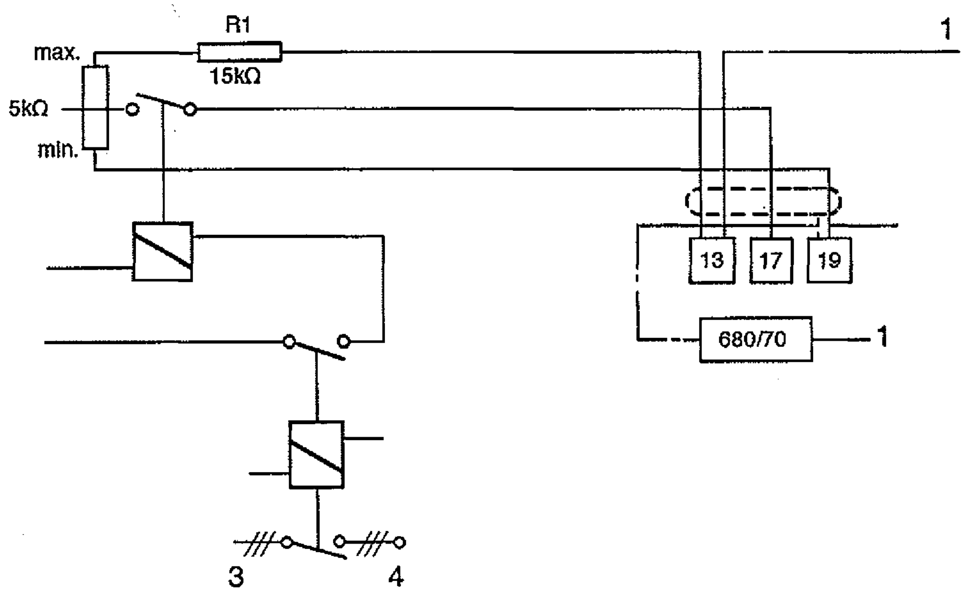



**Fig. 22AA**

## SETTING OF INTERNAL LOAD LIMIT FACILITY LB

To protect a generator against overloading when in parallel with an infinite bus, the maximum load may be limited by using the load limiting option.

Load limiting may only be used during mains operation. Therefore it is necessary to connect the terminals 24 and 27 of the load sharing unit with auxiliary contacts of the mains contactor.

Before setting the load limiting the load sharing must be set as described (see **Section AA19**). With the load setting potentiometer a load is set about 3 to 5% over the full load.

**NOTE:** The actuator must not be on the full fuel stop.

With the load limit potentiometer of the load sharing unit, adjust to the required level by slowly turning the control anti-clockwise.

The setting can be tested by turning up and down the load setting potentiometer.

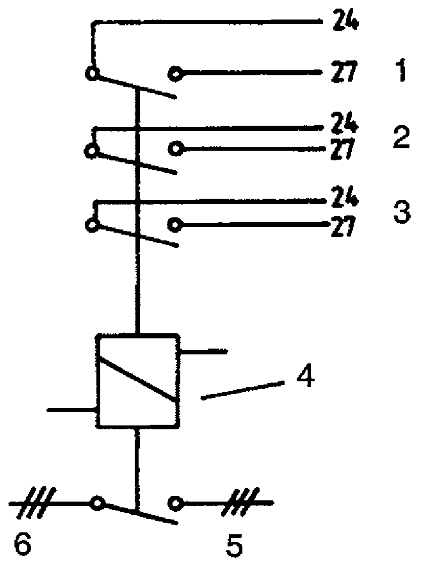



**Fig. 23AA** 249.3

**Key**
**(Fig. 23AA)**

**1** Installation 1
**2** Installation 2
**3** Installation 3 etc
**4** Main contactor for island connecting to mains
**5** Installations
**6** Mains

## REVERSE POWER RELAY

Reverse power switches the reverse power relay after 3 seconds. With the link in, the switching occurs at 10% reverse power and without the link at 5% reverse power. Furthermore, reverse power will be indicated by a light emitting diode, **Fig. 21AA**. Switching and indication will occur if any one phase goes to reverse power.

## SETTING UP FOR LOADING SHARING WITH DROOP.

Check that no interconnecting leads are connected to terminals 17/18, 20/21 and 23/24. Then start up each generator in turn and carry out the adjustments as described in **Section AA19**.

Turn the 'speed droop' potentiometer clockwise and the speed under load will drop. Set the desired droop at 100% rated output.

**NOTE:** The droop must be the same for all the generators, and should be about 4%. When each generator has been set, they may be run up in parallel and their operation checked.

## SETTING THE EXTERNAL LOAD LIMIT FACILITY

With this option, it is possible to adjust the output from a generator connected to an infinite bus by means of an external potentiometer. This applies to both single and multiple installations.

Connect a potentiometer according to **Fig. 24AA** below and increase the internal load limit to maximum, i.e. clockwise.

For single generators carry out adjustments as described in **Section AA19** and for multiple installations see both **Sections AA19** and **AA20**.

Set the load limiting potentiometer as described in **Section AA20**.

Now, for isochronous parallel operation with an infinite bus, the output of the generators may be adjusted by the load setting potentiometer, and limited with the external load limit potentiometer.

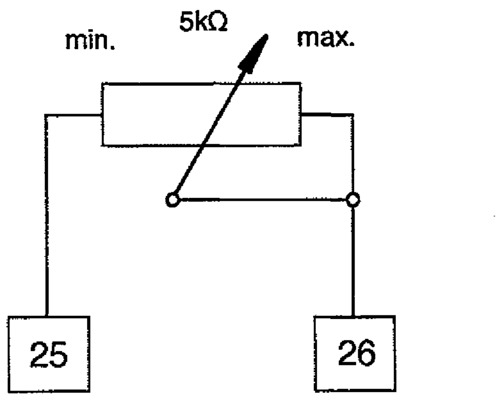



**Fig. 24AA**

## LOAD RAMP FACILITY FOR MAINS OPERATION

During normal operation with the mains, when the generator is synchronized and the main circuit breaker closes, the load setting potentiometer immediately brings a load on the generator to the set valve. If the load setting is above 60% of full load, then the generator engine coupling can be subjected to a great deal of strain due to the infinite mains load.

If a more gentle increase or decrease in load is desirable, then the option of using the **'Load ramp generator' 680/120 (panel) or 680/121 (engine mounted)** would be recommended.

## WIRING DIAGRAM

A typical wiring diagram showing a generating set with automatic synchronizing, power measuring and sharing units are shown in **Fig. 25AA**.

## FAULT TRACING

| SYMPTOM | PROBABLE CAUSE |
|---|---|
| Generator set does not share load with others or trips on reverse power | wrong connections on paralleling lines terminals 17-21<br>'gain' adjustment wrong; wiring, current transformers or voltage input wrong, see **AA19**<br>engine speed wrong, adjusted at no load condition?<br>load limit is 'on' in island operation,<br>no ac power to unit or one phase missing |
| Generator set speed drops when loaded | actuator at maximum position<br>paralleling relay not working,<br>system operates then in 'droop'<br>short circuit in paralleling lines<br>speed governor adjusted for 'droop' |
| Load sharing not correct | maximum load sharing not correct, check gain setting of load sharing unit<br>minimum load sharing not correct, check governor speed for no load operation |
| Generator set does not take up load when in parallel with the mains | see under: 'Generator set does not share load with others' for probable cause<br>load limit setting at zero<br>check actuator position for free movement<br>check voltage between 23-11-14V dc<br>23-13+14V dc<br>23 = ground connection |
| Generator set overloaded when in parallel with the mains | see under: 'Generator set does not share load with others' for probable cause<br>'gain' setting on load sharing/measuring unit too low<br>check voltage between 23-11-14V dc<br>23-13+14V dc<br>23 = ground connection |

**FAULT TRACING SYSTEM FOR MAINS OPERATION**

In a system with load sharing units operating in parallel with the mains, it is important to observe the actuator position before re-adjusting.

Engine failure can make a difference in load sharing. This can also have an effect on the load sharing of units without any failure.

The first check must be:-

Check that the actuator is free from the maximum stop.

Check the engine speed on no load.

Check load sharing with minimum and maximum load to the generator.

Check the load limit.

If re-adjusting is necessary then check:-

That the speed setting is correct, see **Section AA19.**

'Gain' on load sharing unit, see **Section AA19 a,b,c,d and e.**

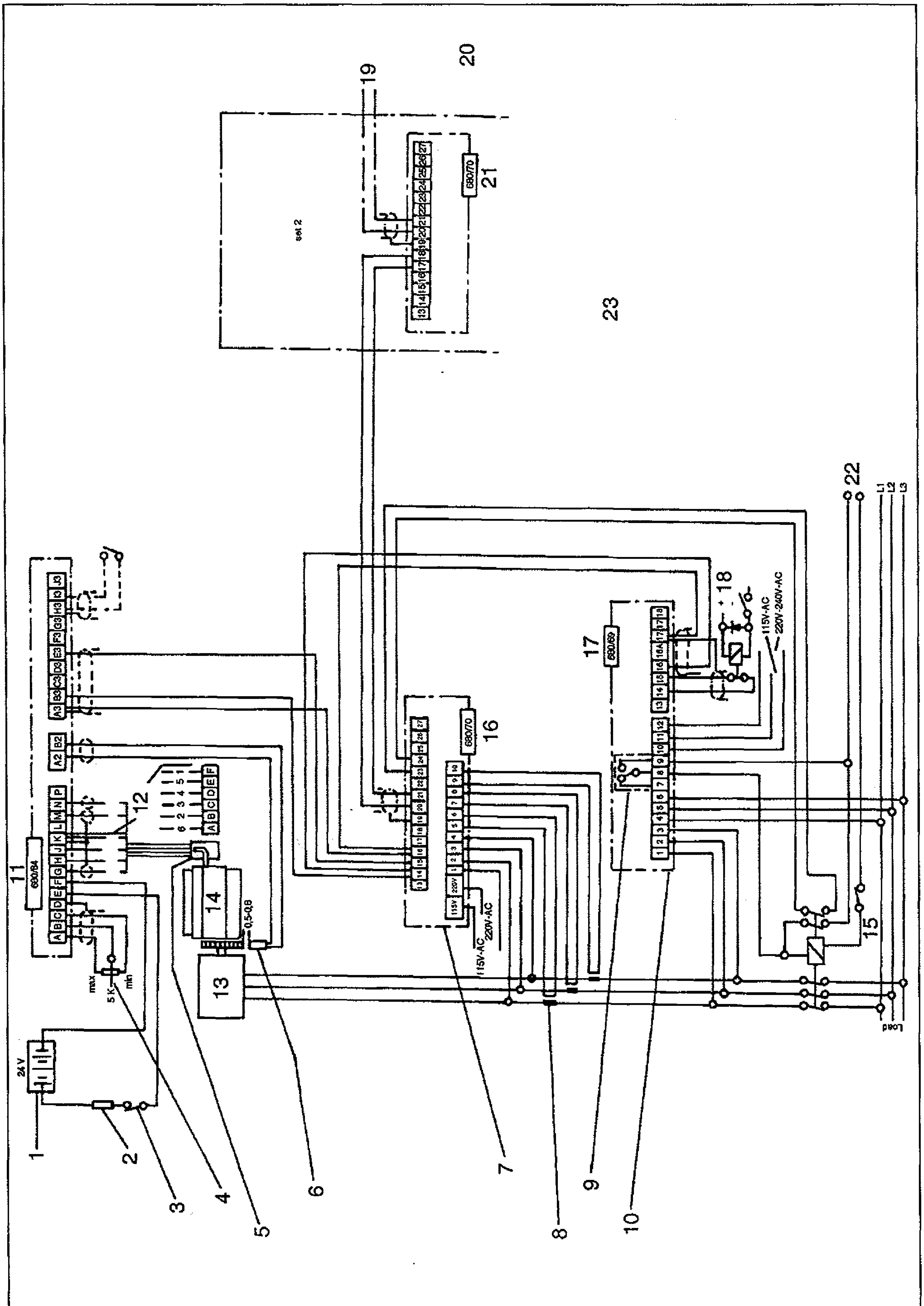
The load limit adjustment, see **Section AA20.**

**Key**
**(Fig. 25AA)**
**TYPICAL WIRING DIAGRAM FOR GENERATING SET WITH AUTOMATIC SYNCHRONIZING, POWER MEASURING AND SHARING UNIT.**

1 Engine starter battery or isolated supply. Battery with charger rating 60 ampere hour for E16
2 Supply fuse 15A for E16
3 Governor on/off switch 20A
4 Engine speed potentiometer
5 Actuator
6 Magnetic pick-up
7 Power measuring unit
8 Current transformer 5A 4VA
9 Synchronizer relay max 8A 250V-AC
10 Synchronizer
11 Control unit
12 Yellow/green
13 Generator
14 Engine
15 Generator on/off
16 Load sharing unit
17 Synchronizing unit
18 + Synchronizer
   - on
19 To further sets
20 The connections not shown as for set 1
21 Load sharing unit
22 Contactor supply
23 Cable size:

L1 to L4 standard
L1 2 x 1,5 mm² up to 7 m
   over 7 m-12 m use 2 x 2,5 mm²
   over 12 m-20 m use 2 x 4 mm²
L2 7 x 1,5 mm² up to 10 m
   over 10 m-20 m use separate
   2,5 mm² for cable 2 and 3
   3 x 1 mm² for 4, 5, 6, with screen
L3 3 x 0,5 mm² with screen
L4 2 x 0,5 mm² with screen

Accessory inputs: cable 1 mm² with screen
SyG, LMG High voltage cables 1,5 mm²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22
23
24 V
5 K
max
min
0,5-0,8
680/84
680/70
680/69
set 2
115V-AC
220V-AC
220V-240V-AC
Load
L1
L2
L3
670.2

Fig. 25AA

## INTRODUCTION

The synchroniser unit was designed to be used with any of the electronic governors produced by the Heinzmann company.
It is used for the synchronisation of a single generator set to island sets, or the whole island to the mains. The frequency, phase and voltage are compared between two generators and brought to the same value. When equal, synchronisation is achieved and a synchronisation switch is operated.
With the closing of the synchronisation switch, the main contactor is closed either directly or by an auxiliary power relay. With the contactor closed, the engine will be paralleled to the load.
In all instances when synchronization is used, some form of load sharing must also be used either by 'speed droop' or 'zero speed droop'. For the latter refer to **Section AA19**.

## METHOD OF OPERATION

The synchronizer measures the frequency, phase angle and voltage between two generators, or a generator and the mains. The frequency error is firstly integrated and reduced to zero and the resulting phase error is modified by an integral/proportional controller. Both frequency and phase errors are then connected to the synchronising input of the governor and a closed loop is formed. Refer to **Fig. 26AA**.
The voltage comparison is used to ensure that all three phases have been connected correctly.
When the frequency, phase and voltage errors have been reduced to zero the contactor relay is energised with an adjustable time delay of between 0.5 and 5 seconds, which ensures bumpless loading of the generator. When the relay closes there is an automatic reset function which will operate with a 0.5 - 1 second delay, and the synchroniser is then disconnected from the governor. However, the supply voltage to the synchroniser must not be switched off, as this would cause a speed change.

**Important note concerning the cabling of the synchroniser:**
The voltage of the synchroniser has to be taken from the generator bus bar for synchronisation of a single aggregate.
The voltage supply of the synchroniser has to be taken from the middle bus bar (consumer bar) when synchronising with several aggregates.
The first generating set to be started must have its synchroniser output switch by-passed to enable the first set to be connected to the bus bars.

## TECHNICAL DATA

| | |
|---|---|
| Supply voltage | 115 or 230 V + 10% ~ 50/60 Hz |
| Power input | about 10 VA |
| Generator voltage range | 115 - 440 V ~ phase to phase |
| Generator frequency range | 50/60 Hz (special type up to 400 Hz) |
| Contact load of the synchronisation switch | maximum 8 A at 250 V ~ |
| Phase angle adjustable | +2° to +15° |
| Voltage detection range | ≤ 80V ac |
| Synchronisation time | about 3-15 seconds dependent upon installation |
| Output signal | ± 4 V dc |
| Maximum frequency correction | ± 2 Hz |
| Switching delay adjustable | 0.5 to 5 seconds |
| Temperature range | -40°C to +80°C |
| Weight | about 2.6 kg |

**Key**
**(Fig. 26AA)**
**SYNCHONISER BLOCK DIAGRAM**

**1** Generator
**2** Mains
**3** Isolation transformer
**4** Isolation transformer
**5** Isolation transformer
**6** Power supply
**7** Angle
**8** Delay
**9** Frequency comparison
**10** Phase angle comparison
**11** Voltage comparison
**12** Gain
**13** Synchronizing time
**14** Integrator
**15** Output Amplifier
**16** Reset circuit
**17** Synchronizer relay
**18** To governor

**Key**
**(Fig. 27AA)**
**SYNCHRONISER PLUS CONTROL CIRCUIT**

**1** Synchronizer relay max 8A 250 V AC
**2** Incoming generator (slave)
**3** Synchronizer unit
**4** Generator on/off
**5** Bus (master)
**6** Control unit
**7** Connection for governor E16
**8** ATTENTION!
Supply voltage has to be connected all the time during operation. This voltage has to come from the generator for generator synchronizer and from bus bar when used for synchronising to the mains.
**9** Contactor
**10** Cable size:
Accessory inputs: SYG-KG cable 1mm²
with screen
High voltage cables 1.5 mm²

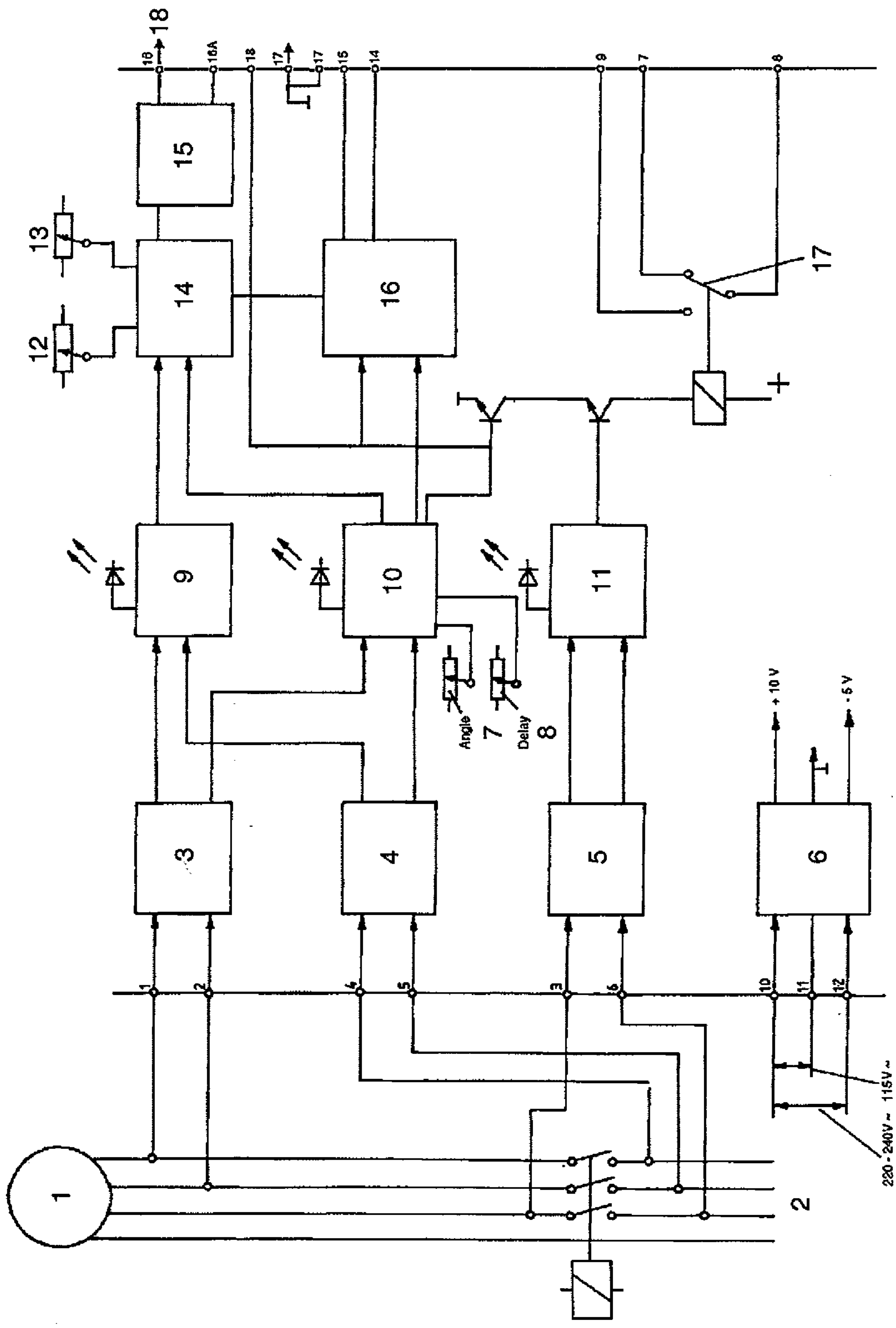



Fig. 26AA

252.3

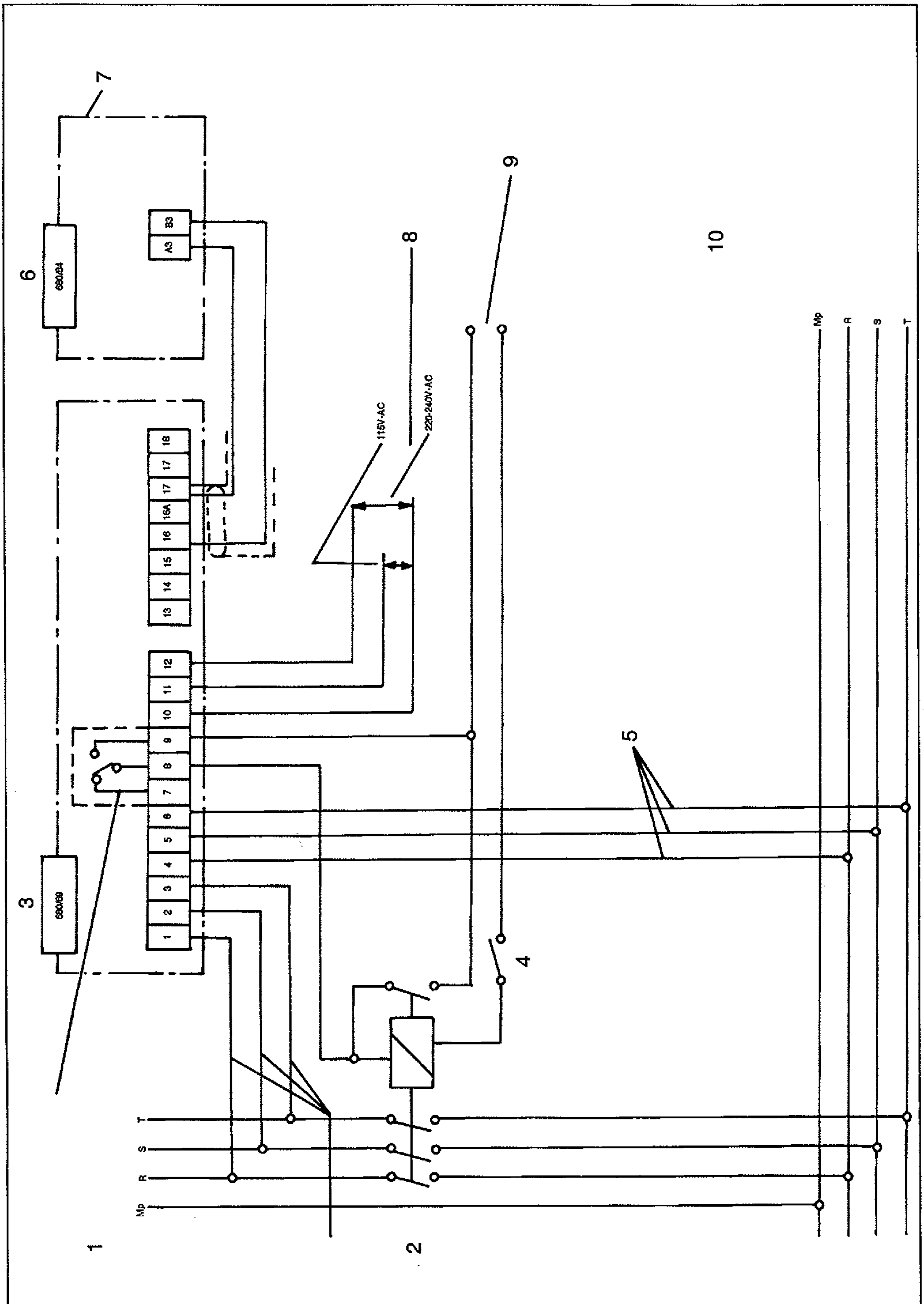



Fig. 27AA

671.2

## ELECTRICAL DETAILS
### SPECIFICATION

Wiring diagram as shown on **Fig. 27AA**.

The synchronizer voltage inputs required for frequency, phase and voltage detection appear in order from generator 1, 2, 3, (RST) to master mains or generator 4, 5, 6, (RST).

The synchronizer power supply is delivered from a 115 V AC or 230 V ac supply, pins 10 - 11 - 12 respectively.

A possible connection for the power supply is between generator 'T' phase and Neutral Mp.

The contactor relay rating can be 250 V ac 8 A or 115 V ac 8A, resistive load, or 24 V dc 1A, resistive load. Contacts can be used either normally open or normally closed, terminals 8 and 9 or 7 and 8.

For governor connections use 16 and 17 (17 = zero V, 16 = signal). Terminal 16A is described later with 14, 15, 17 and 18 under **Special Applications** in **Section AA28**.

## SETTING UP PROCEDURE

### INITIAL STEPS

Before adjusting the synchroniser, ensure that the voltage amplitude of each generator set is equal. If necessary ask the generator manufacturer.

With the links connected between 14 + 15 and 17 + 18 on the synchroniser, start the generators and supply voltage to synchroniser (refer to **Fig. 27AA**). Set and adjust engine to the synchronous speed, i.e. 50 Hz. Refer to **Section AA5.** Then remove the link 14 + 15. Stop the generator sets.

**FIG. 28AA DIMENSIONAL DRAWING OF AUTOMATIC SYNCHRONISER SYG 02 (680/69)**

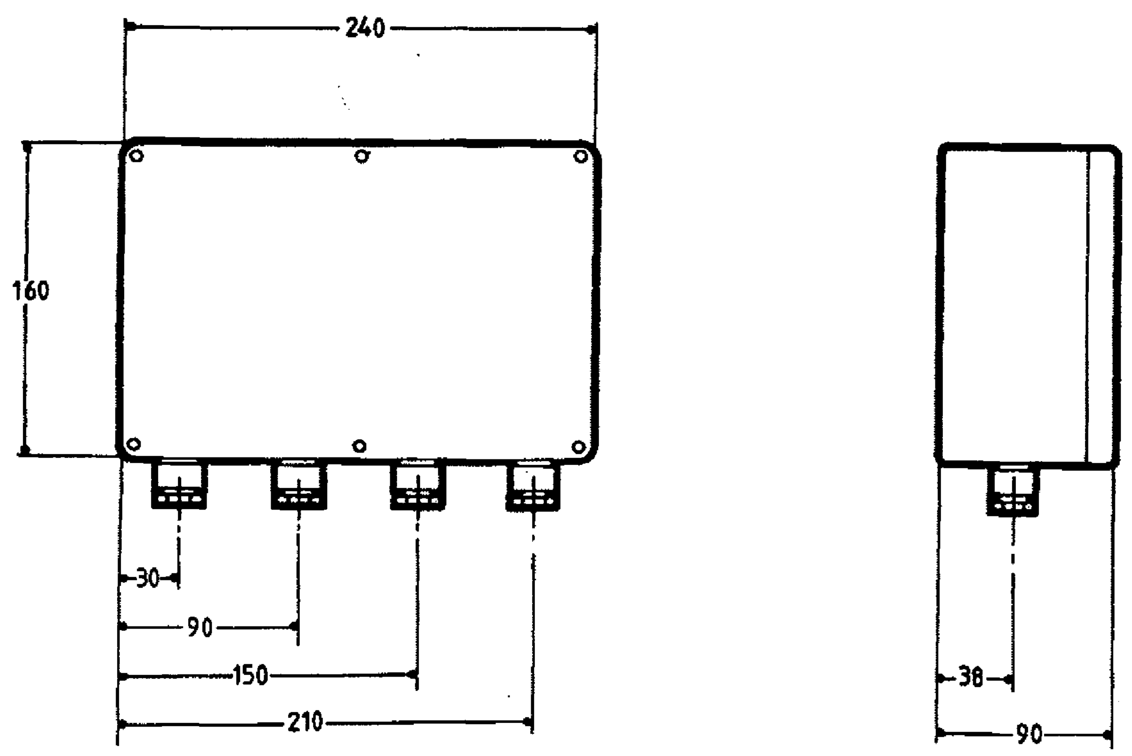



Fig. 28AA

## ADJUSTING THE SYNCHRONISER

When the frequency, phase and voltage of both generators are equal, the synchroniser relay will close with an adjustable delay time from 0.5 to 5 seconds. For all adjustments, the link between pins 17 + 18 must remain to inhibit the above synchronising relay. However, the frequency, phase and voltage indicators will remain working to assist with adjustment. Further, after synchronisation the automatic reset 0.5 to 1 second will operate and all three synchronisation LEDs will operate.

a) Set the required 'phase angle'. The smaller the phase angle the longer the synchronisation time.
b) Set the required synchroniser relay switching 'delay' (usually 0.5 to 1.5 seconds).
c) Turn 'synchronisation time' and 'gain' anti-clockwise.
d) Start the generator sets.
e) Turn 'gain' clockwise until engine instability anti-clockwise for stability.
f) Turn 'synchronisation time' clockwise until unstable anti-clockwise for stability.
g) Once the above settings have been made, check that the generator synchronises correctly by either disturbing the actuator fuel lever or by linking 14 + 15 then remove.

If the generator does not have an acceptable synchronising time then re-adjust (a to f) to obtain the optimum settings. When satisfied with above synchronisation, then remove link 17 + 18 which will allow the main contactor to operate.

**Key**
**(Fig. 29AA)**

1 Phase
2 Angle
3 Syn. time
4 Gain
5 Delay
6 Frequency
7 Phase
8 Voltage

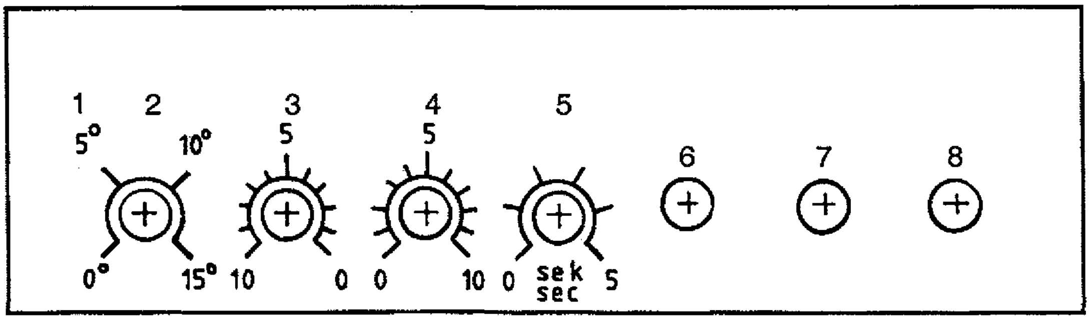



**Fig. 29AA**

255.3

## SPECIAL APPLICATIONS
## SYNCHRONISATIONS OF ISLAND SETS TO THE MAINS

If a group of generators or island system is to be synchronised to the mains, then the mains synchroniser must be connected to the load sharing equipment.
See **Fig. 30AA.**
Only one connection must be made from the mains synchroniser to one of the load sharing units. Instead of 16 use 16A. Refer to **Load Sharing Unit in Section AA15**.

## SWITCHING OFF THE SYNCHRONISER

If it is necessary to inhibit the unit, it is possible with a switch, e.g. automatically disconnect the synchroniser from the governor (i.e. no correction signal or breaker closure). See **Fig. 31AA.**

## STAND-BY SYNCHRONISATION

If synchronisation is required, but no auto reset nor contactor relay operation then link 17 + 18. See **Fig. 32AA.**

**Key**
**(Fig. 30AA)**
1 Synchronizer unit
2 To terminal 23 of 680/70
3 To terminal 22 of 680/70
4 Load sharing

**(Fig. 31AA)**
1 Synchronizer unit
2 Open switch: synchronizer switched on
3 Shut switch: synchronizer switched off

**(Fig. 32AA)**
1 Synchronizer unit
2 Open switch: automatic system
3 Shut switch: no breaker closure

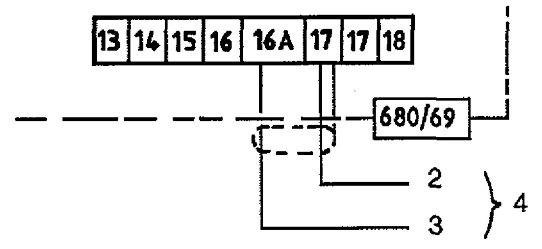



**Fig. 30AA**
256.4

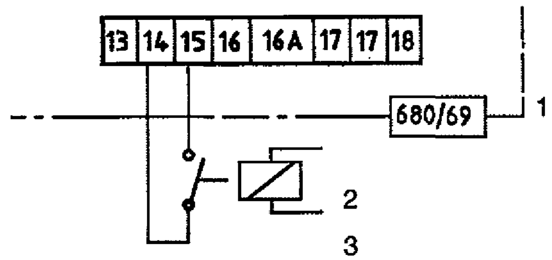



**Fig. 31AA**
267.4

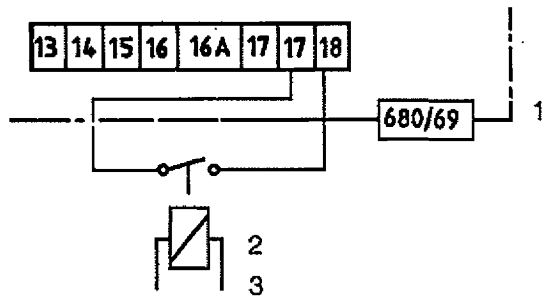



**Fig. 32AA**
258.4

## FAULT TRACING

| SYMPTOM | PROBABLE CAUSE |
|---|---|
| Synchroniser does not correct frequency | no input voltage on terminals 1, 2, 3 or 4, 5, 6.<br>jumper between 14 - 15.<br>input voltage too low.<br>no ac power to terminals<br>10 - 11 (115 V ac) or<br>10 - 12 (220 V ac).<br>engine speed more than + 2 Hz difference with bus **see Section AA27**. |
| During synchronising frequency unstable | 'synchroniser gain' wrongly adjusted **see Section AA27**.<br>engine governor unstable, make jumper between 14 - 15 and observe governor.<br>connection governor/synchroniser, no screened wire used. |
| Synchroniser correct frequency, but no breaker closure occurs | connection between 17 - 18.<br>check if relay on synchronizer works, all<br>3 LEDs must be lit.<br>adjustment 'synchronising time' and 'time delay' far too long.<br>speed governor unstable. |
| Generator frequency runs always high or low | connections 16 and 17 reversed or input phase incorrectly wired<br>connections generator and bus reversed |
| After synchronisation, engine not taking power | speed 'offset' adjustment wrong (see below).<br>engine speed too low **check Section AA27**. |

## 'OFFSET' ADJUSTMENT

'Offset' adjustment is done in the works, but for checking:

a) connect to terminals 1 - 2, 4 - 5, 10 - 12: 220 V ac i.e. master phase and voltage is equal to incoming phase and voltage

b) connect voltmeter to test points 1 and 2 (1 V range), reading must be +25 mV or lower (voltage can be positive or negative). If not, correct with potentiometer. See **Fig. 33AA**.

**Key**
**(Fig. 33AA)**

**1** Offset adjustment
**2** Phase
**3** Angle
**4** Syn. time
**5** Gain
**6** Delay
**7** Frequency
**8** Phase
**9** Voltage

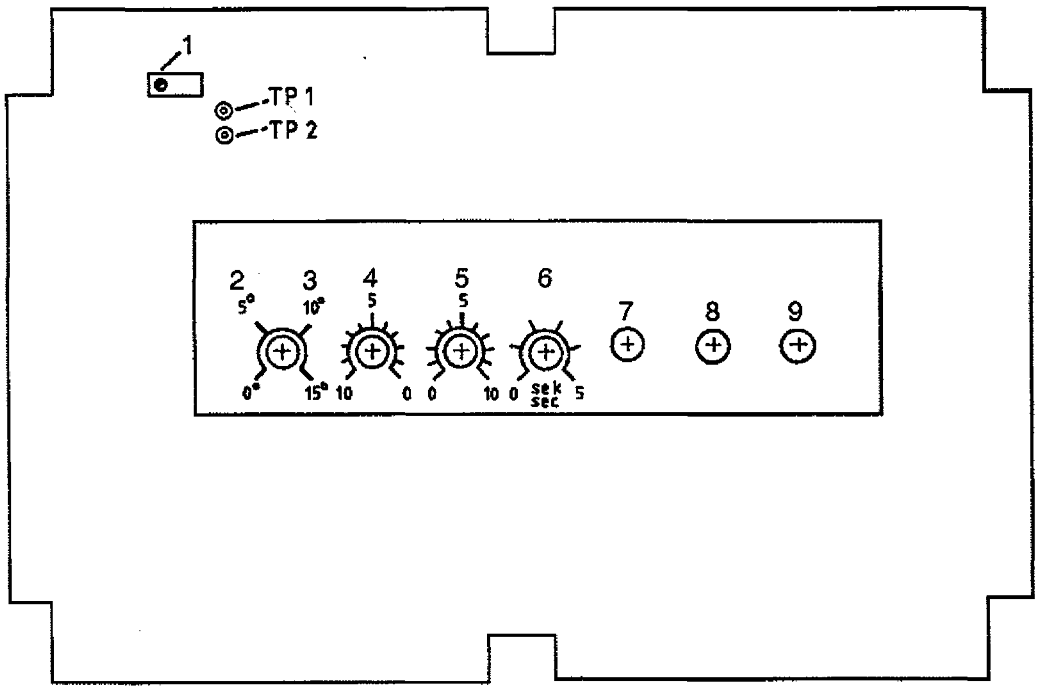



Fig. 33AA

259.3

## FUEL CONTROL BOX SFLAG-01 (PART NO. 680/103)

### DESCRIPTION

The fuel control box aids cold load acceptance on generating sets equipped with the E16 electronic governor, by controlling the amount of fuel delivered to the engine on large load transients.

It has two functions:

'Step' - Limit initial actuator travel

'Time' - Ramp time on remaining travel

### SETTING UP PROCEDURE

These are two potentiometers in the control box.

One labelled 'step' 0 to 100 = 0% to 100% actuator travel.

One labelled 'time' 0 to 100 = 0 to 5 seconds ramp time.

The 'step' and 'time' are adjustable (see **Fig. 34AA**).

e.g. If the desired step is 50% governor travel then the 'step' potentiometer is set to 50%. If the ramp time is to be 4 seconds then the 'time' potentiometer is set to 80.

**NOTE:** There are no standard settings for this unit. It is necessary to try various combinations of 'step' and 'time' to obtain the optimum performance.

If in doubt contact Perkins Engines (Stafford).

The 10 pin plug connector fits into the 10 pin socket in the Heinzmann governor control box.

**Key**
**(Fig. 34AA)**

1. Step
2. Time
3. Green light shows when power is on
4. 24V positive DC feed
5. 10 pin connector

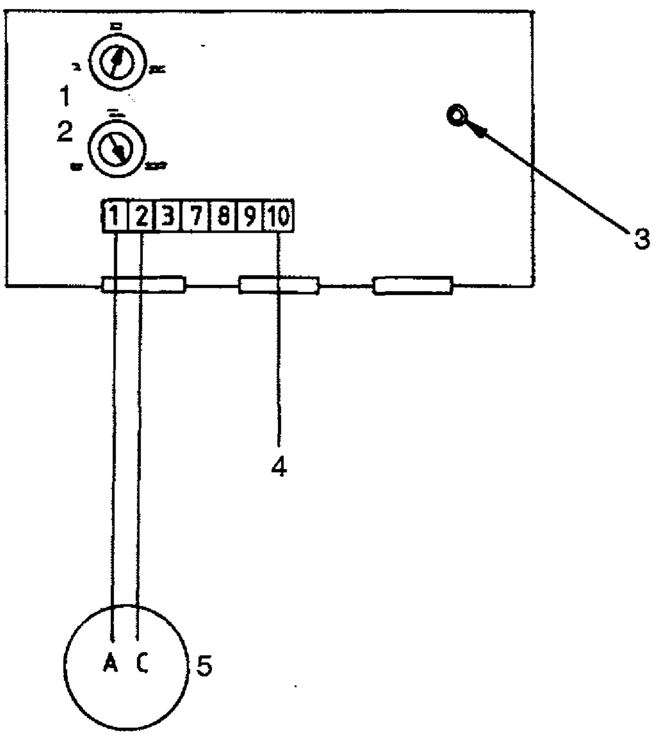



Fig. 34AA

## DUAL SPEED UNIT DSLA 01 (PART NO. 680/109 EARLY, SEE AA32 FOR DSLA 02)

### DESCRIPTION

The dual speed unit for use on generating sets is to aid the initial step load acceptance. It operates only on the initial start of the engine. On starting the engine, the engine speed initially goes to 1740 r/min (58 Hz). When the first load is applied, the dual speed unit senses this load and after an adjustable time delay, switches the engine speed to 1500 r/min (50 Hz).

In addition the dual speed unit contains a load anticipation circuit to improve the response to subsequent load changes (see **Fig. 35AA**).

**Key**
**(Fig. 35AA)**

**1** Gain
**2** Time
**3** Current switching level
**4** High speed
**5** Alternator
**6** 10 pin plug Heinzmann control box socket 3
**7** Shield
**8** Shield
**9** External speed pot
**10** 14 pin plug control box socket 1
**11** Shield
**12** Earth
**13** Neutral
**14** Phase
**15** Any live
**16** AC phase

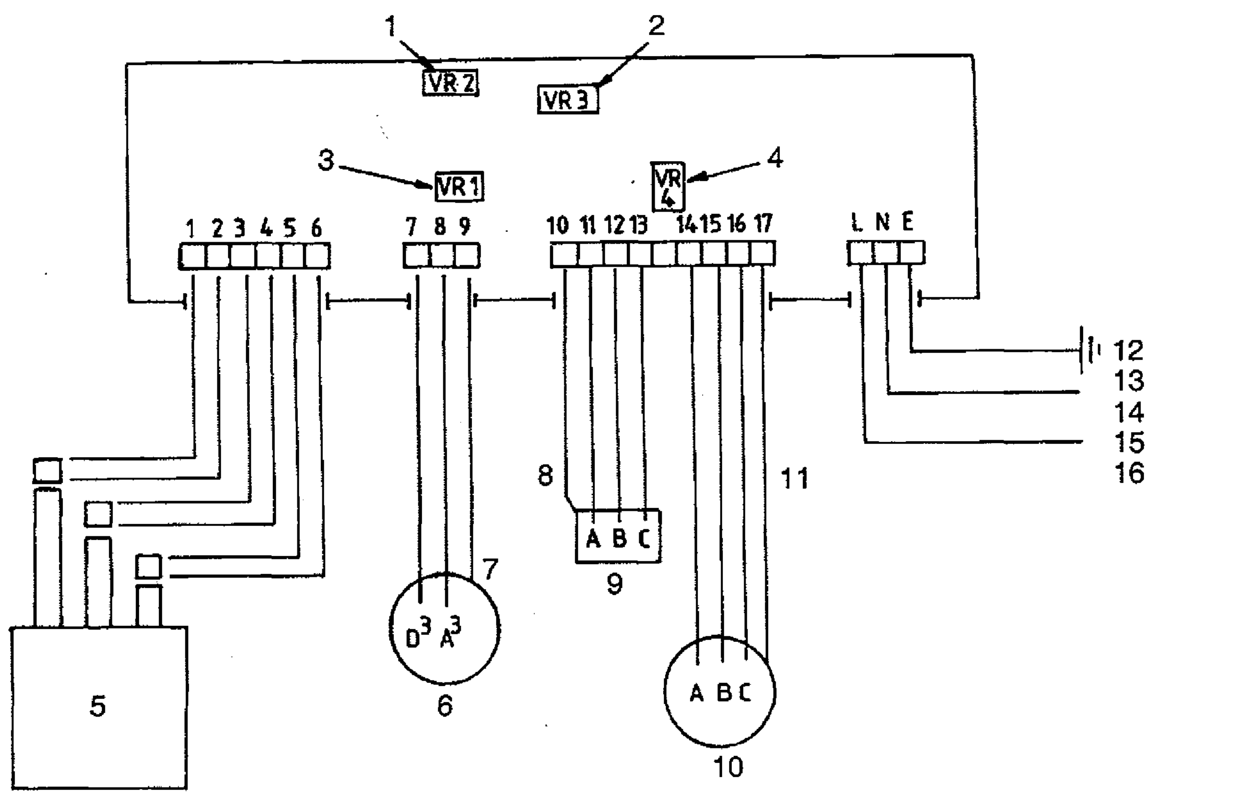



**Fig. 35AA**

## SETTING UP PROCEDURE

(1) Set up the Heinzmann governor control box (see **Sections AA3 to AA5**).
(2) Set the engine speed to 40Hz, using the external speed potentiometer. Stop the engine.
(3) Connect the dual speed unit as shown in **Fig. 35AA.**
(4) Set the potentiometers marked 'VR1' and 'VR2' (current switch 'level' and 'gain') fully anti-clockwise. 'VR3' ('time') should be set to 50% travel and 'VR4' ('high speed') 20 turns anti-clockwise.
(5) Start the engine and set the speed on the normal speed setting potentiometer to 1575 r/min (52.5 Hz). Apply 20% load. The speed will drop approximately 5%. Using the external speed potentiometer, set the engine speed to 1500 r/min (50 Hz).
(6) Load anticipation adjustment.
Apply the load in steps of 20% and adjust the 'gain' potentiometer 'VR2' until the best governor response is found (see **Fig. 36.1AA**). STOP THE ENGINE.
(7) Restart the engine. The engine speed will now be approximately 5% above the isochronous speed. Adjust the high speed potentiometer 'VR4' until 58 Hz is obtained.

**WARNING** ⚠ OVERSPEED PROTECTION SHOULD BE RESET TO AVOID ACCIDENTAL SHUTDOWN.

(8) Adjust pot 'VR1' to approximately 10% of its travel from the minimum position.
(9) Apply approximately 60% load to the engine. The speed will settle to 50 Hz after carrying load.
(10) Adjustments of 'VR1' and 'VR3' should be made to achieve the best results. Past experience has shown the best timer setting to be approximately 2 to 3 seconds.

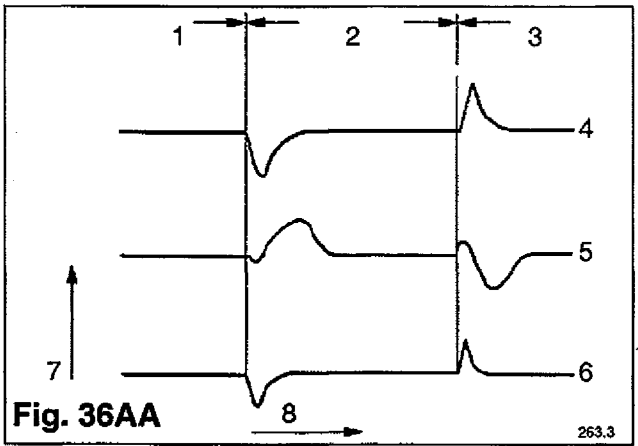


**Fig. 36AA**

## EFFECT OF LOAD ANTICIPATION CIRCUIT (SEE FIG. 36AA)

To obtain performance from the load anticipation unit, adjust the 'gain' control in small steps whilst switching load on and off, in order to obtain the optimum characteristics shown below.

**Key**
**(Fig. 36AA)**
1 No load
2 Full load
3 No load
4 Speed governor without load anticipation unit
5 Too high adjustment of the load anticipation unit
6 Correct adjustment of the load anticipation unit
7 Speed
8 Time

## DUAL SPEED UNIT DSLA 02 (PART NO. 680/111 LATEST TYPE) SUPERSEDE DSLA 01

### INTRODUCTION

The dual speed unit is for use on generating sets to aid initial step load acceptance and can perform several functions:

(1) On starting the engine, the speed initially goes to 1740 r/min (58Hz). When load is applied to the generating set (sensed by a current transformer input to the dual speed unit), the dual speed box, after a time delay (adjustable) switches the engine speed to its normal 1500 r/min (50 Hz).

(2) The dual speed unit has provision for changing the alternator voltage dip characteristic by switching the underfrequency roll off speed on the AVR. Not all alternators can be switched in this way, so no details are given here. Contact the alternator manufacturer if this facility is required.

(3) The dual speed unit also incorporates a load anticipation facility which senses load changes (from the transformer input) and tells the governor to increase the fuel before the engine speed has started to change due to the extra load applied.

**Key**
**(Fig. 36.1AA)**

**1** Power on LED
**2** Load anticipation gain
**3** AVR delay
**4** AVR soft LED
**5** Speed delay pot
**6** Load switch level
**7** Close to inhibit
**8** External speed set pot
**9** Any live AC phase
**10** Neutral
**11** Earth
**12** AVR Relay contacts
**13** Current transformer on alternator
**14** (10 pin control) Box plug
**15** (14 pin control) Box plug

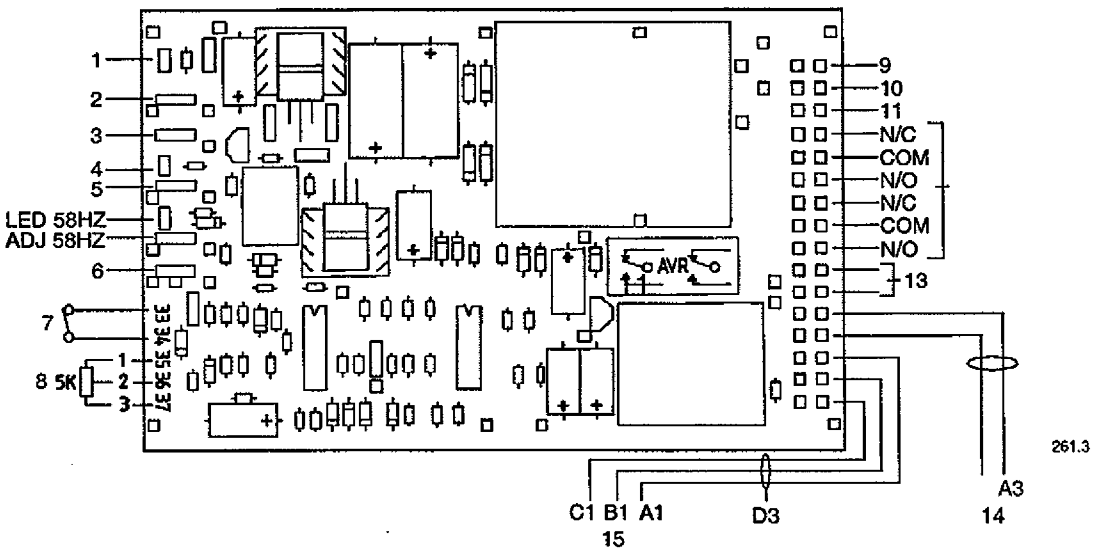



**Fig. 36.1AA**

## SETTING UP PROCEDURE

(1) Set up the Heinzmann governor control box (see **Sections AA3 - AA5**).

(2) Set the engine speed to 45 Hz using the external speed potentiometer (if fitted) or the internal potentiometer in the control box. Stop the engine.

(3) Connect the dual speed unit as shown in **Fig. 36.1AA**.

(4) Using a resistance meter, set the potentiometers in the dual speed unit (see **Fig. 36.2AA**) as follows:

- (a) With the resistance meter connected across the test points 1A and 1B adjust the 'gain' potentiometer to give a resistance of between 95 and 100 kOhms.
- (b) From **Fig. 36.3AA** select a speed delay time and associated resistance, (i.e. time setting to be approximately 2 to 3 seconds). With the resistance meter connected across the test points 3A and 3B adjust the speed delay potentiometer to give the required resistance.
- (c) Turn the 58 Hz adjustment potentiometer 20 turns anti-clockwise.
- (d) With the resistance meter connected across the test points 4A and 4B, adjust the load switching level potentiometer to give a resistance of 1kOhm.

(5) Start the engine, check that both the 'power on' LED (Light Emitting Diode) and '58 Hz' LED are lit.

(6) (a) If the 'power on' LED is not lit, check the wiring and correct it if necessary.

(b) If the '58 Hz' LED is not lit, stop the engine and observe the '58 Hz' LED operation when restarting the engine. If the LED lights and goes out, increase load switching level potentiometer until the LED remains lit when the engine is started.

If the LED does not light, check the wiring.

(7) With the engine at 45 Hz apply 20% load. The speed will drop approximately 5%. Check that the 58 Hz LED switches off. If LED remains lit check wiring and/ or reduce load switching level.

(8) Using the external speed potentiometer (if fitted) or the internal potentiometer, increase the engine speed to 58 Hz.

(9) increase the load to 60%. Load and unload the engine several times, adjusting the dual speed 'gain' potentiometer until the best governor unloading conditions are found (see **Fig. 36AA**). Shut down the engine.

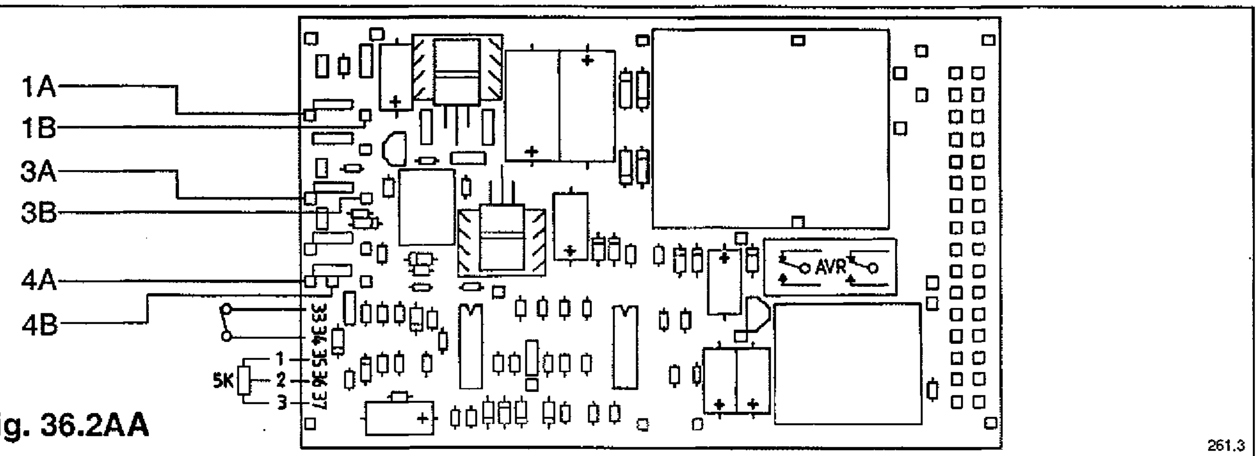



Fig. 36.2AA

**WARNING** ⚠ OVERSPEED PROTECTION SHOULD BE RESET TO AVOID ACCIDENTAL SHUTDOWN.

(10) Restart the engine. The engine speed will now be approximately 5% above the previous speed. Adjust 58 Hz potentiometer until 58 Hz is obtained.

(11) Apply approximately 60% load to the engine. The speed should settle at 50 Hz after carrying the load.

(12) Adjustment of current switching level and speed relay potentiometers should be made to achieve the best results.

**EFFECT OF LOAD ANTICIPATION CIRCUIT**

The engine should be given various step loads of approximately 20% and the load anticipation 'gain' should be adjusted to give best response, see **Fig. 36AA**. Once the optimum setting has been achieved open the circuit breaker and stop the engine.

**Fig. 36.3AA Switching time/potentiometer resistance**

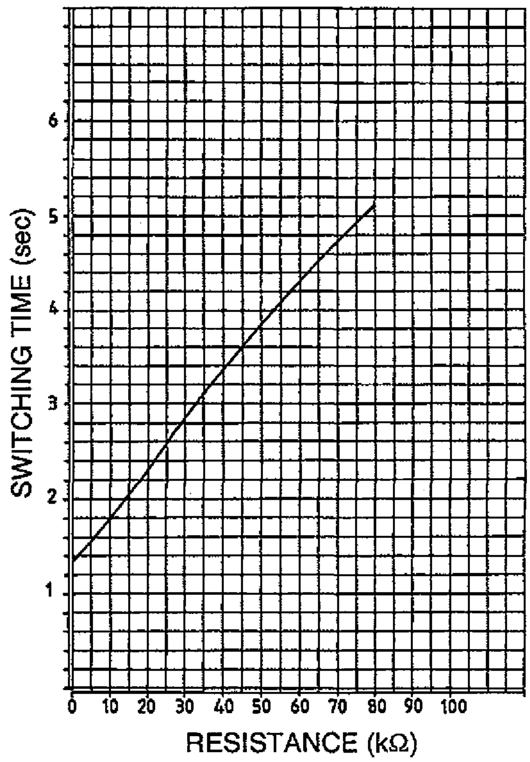



**Fig. 36.3AA**

262.2

**WARNING** ⚠ NEVER START THE ENGINE WITH GOVERNOR LINKAGE OR RELEVANT SUPPLIES DISCONNECTED.

## GENERAL DESCRIPTION

The governor is of the centrifugal flyweight type, comprising a hydraulic servo mechanism which provides adequate work capacity for engines between 200 and 2000 HP and has constant and variable speed ranges.

The unit is completely self contained with its own servo, oil reservoir and an integral oil pump driven directly by the drive shaft. The hydraulic system is self bleeding and maintains oil pressure at a preset rate by means of two spring loaded accumulators - one of which acts as a relief valve.

As the governor is directly driven by the engine, it is able to provide both power input and speed sensing, with the output being mechanically linked to the fuel flow regulating system. A hydraulic feed back system, with an adjustable reset rate and cut-off feature is also included to assist in optimizing the governor response.

Adjustments to most of the main governor features can be made by using the corresponding control knobs located on the governor exterior (the reset rate restrictor screw is accessible after the removal of a blanking plug).

## TO REMOVE THE GOVERNOR

Disconnect the electrical wiring to the shutdown solenoid, mark and disconnect the control links. Do not alter the length of the links. Release and remove the governor output levers from the governor shaft. Remove the four nuts and spring washers securing the governor unit to the bevel gearbox casing. Withdraw the governor unit from the gearbox casing, and remove the bevel gear from the governor drive shaft by unscrewing the securing nut.

## REPLACING THE GOVERNOR UNIT

**WARNING** ⚠ FOR SAFE OPERATION, PARTICULARLY THE ABILITY TO STOP THE ENGINE, CHECK THAT THE GOVERNOR WILL POSITION THE INJECTORS IN THE **'NO FUEL'** POSITION i.e. AT GOVERNOR POSITION '2' THE INJECTOR CONTROL ARMS MUST BE IN THE 'NO LOAD' POSITION.

1. Inspect both the drive shaft and driving member gears to make sure that they are both in good working order and free from chipped or cracked teeth.
2. Ensure that all mating surfaces are clean and free from imperfections before fitting a new joint.
3. Lower the governor unit complete with drive gear onto the bevel gearbox casing, ensuring that the gears mesh correctly and have the specified clearance. See the **Wear and Renewal Limits pages 41-42**. This clearance is of the utmost importance and is adjustable by inserting shims between the mating faces to obtain the correct tooth mesh. A clearance which is too small can result in premature gear or shaft failure, whilst an excessive clearance causes wear and sub-standard governing. Tighten the four nuts to secure unit to the fixing studs, using spring washers.
4. Fit the governor output levers horizontally on the shaft towards the engine and align the levers to each other with the pointer in position '5' (see **Fig. 37AA**). Tighten the clamp bolts and also the locknuts.
5. Connect the governor output levers to the control links for each bank of cylinders.
6. Check whether the engine is fitted with the earlier or later injectors and reset the injector control arms according to **Section P** using the appropriate setting tool.

**Key**
**(Fig. 37AA)**
**1** Shutdown
**2** No fuel
**3** Levers in line with one another
**4** Injector calibration

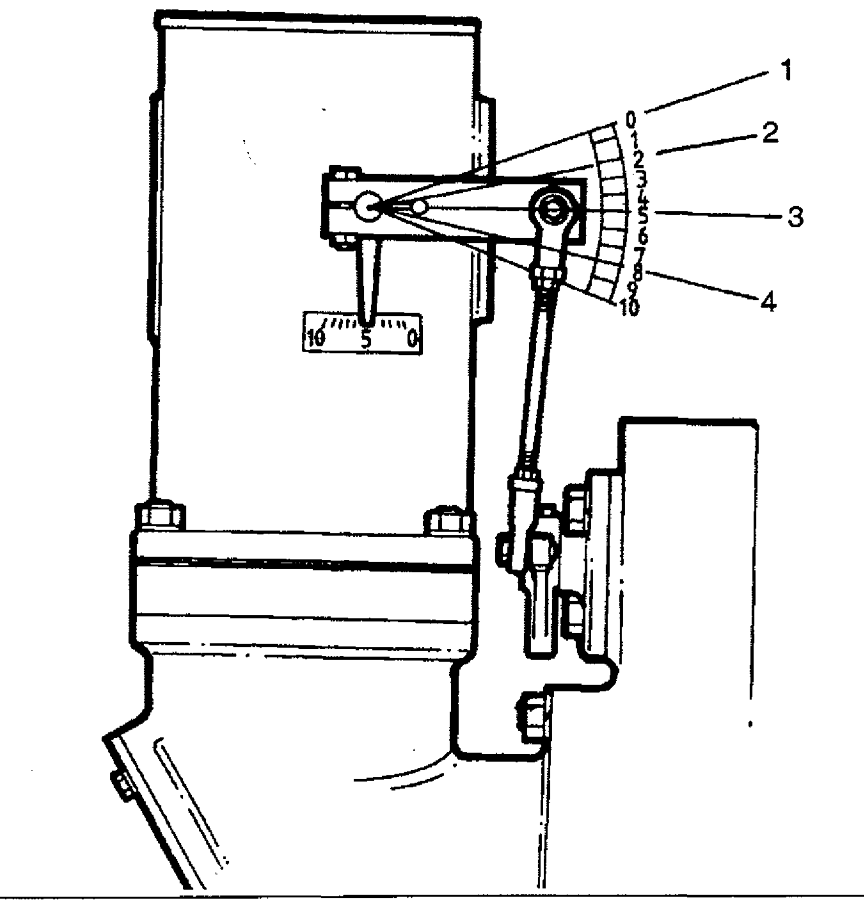


Fig. 37AA

1 Displacer piston
2 Power piston
3 Oil pump driving gear
4 Drive shaft
5 Oil pump inlet check valve
6 Oil pump outlet check valve
7 Oil pump idler gear
8 Accumulator piston
9 Restrictor screw
10 Accumulator spring
11 Boost fuel limit spring
12 Diaphragm
13 Droop lever
14 Minimum speed stop
15 Speed control shaft
16 Maximum speed stop
17 Shutdown shaft
18 Pilot valve extension
19 Fuel limit lever
20 Fulcrum pin fuel limit lever
21 Pilot valve lever
22 Droop link pivot
23 Droop adjusting screw
24 Oil level sight glass
25 Droop link
26 Droop link
27 Feedback link
28 Compensation spring
29 Compensation piston
30 Output shaft
31 Push rod
32 Speeder spring
33 Flyweights
34 Pilot valve spring
35 Rotor drive spring
36 Rotor
37 Pilot valve
38 Fuel limit stop screw
39 Speed setting lever

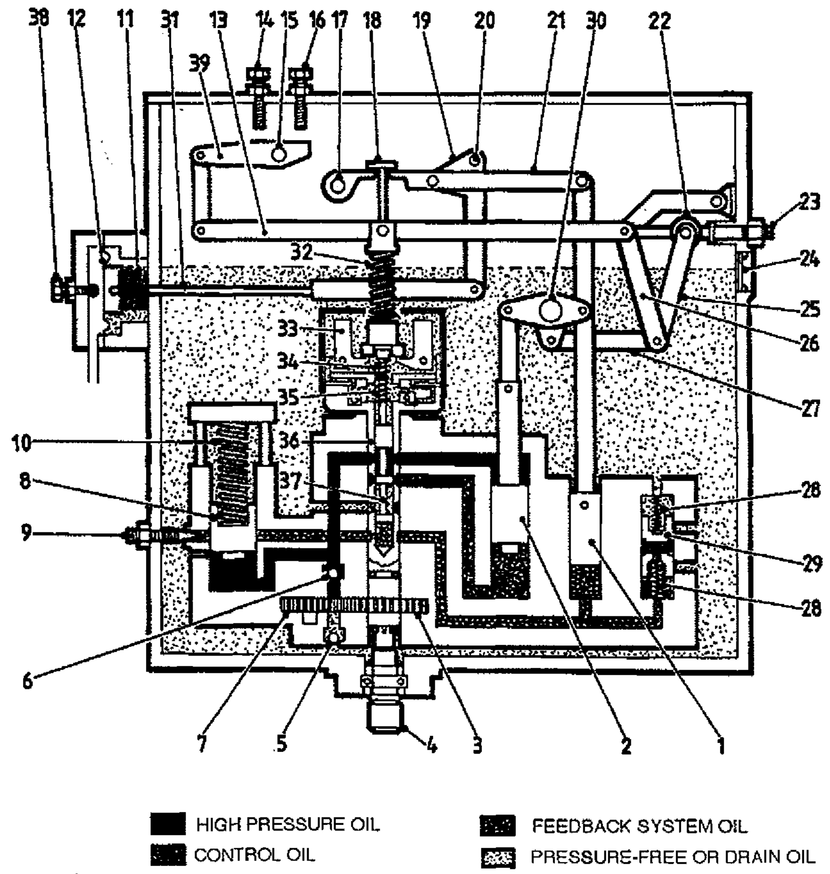



Fig. 38AA

1 **STEADY STATE CONDITION**

When the governor is in a steady state at set speed and constant load level, the centrifugal force of the flyweights (33) and the force of the speeder spring (32) are in a state of equilibrium.

In this situation the pilot valve (37) 'laps' (seals off) the rotor port to the power piston (2), causing the piston and the output shaft (30) to be held in a stationary position.

2 **LOAD INCREASE (ISOCHRONOUS OPERATION)**

When the engine is subjected to an increase in load, it causes a reduction in engine and governor speed. The centrifugal force acting on the governor flyweights (33) will then become less than the speeder spring (32) force causing the pilot valve (37) to move downwards.

Downward movement of the pilot valve allows high pressure oil to pass through the rotor ports to the underside of the power piston (2). The power piston will then rise, overcoming the high pressure oil above it because of the difference in the piston surface areas. As the piston rises, it will rotate the output shaft and therefore increase the fuel supply to the engine.

Rotation of the output shaft causes the displacer piston (1) to be moved downwards. This action will drive oil into the compensation unit, push the compensation piston (29) upwards against the spring force and consequently increase the feedback oil pressure. This increased pressure acts on the bottom of the pivot valve, and by pushing it upwards against the speeder spring, causes a temporary reduction in speed proportional to load increase- thereby producing a stabilising effect.

The upward movement of the pilot valve continues until it reaches the 'lapped' position, at which point the high pressure oil supply to the power piston is cut off. At the same time, the feedback oil is allowed to drain past the adjustable restrictor screw (9) until the system reaches atmospheric pressure. At this point, the forces acting on the pilot valve will be in a state of equilibrium and the engine will have returned to its set speed.

3 **LOAD DECREASE (ISOCHRONOUS OPERATION)**

When the engine is subjected to a decrease in load, there is an increase in engine and governor speed. The centrifugal force acting on the governor flyweights (33) will then overcome the speeder spring (32) force and lift the pilot valve (37).

Upward movement of the pilot valve opens the control port leading to the base of the power piston (2), and allows the oil to drain away. The power piston will then fall, due to the constant high pressure oil on the upper surface, and the output shaft (30) will be rotated to the decrease fuel. At the same time, the displacer piston (1) is lifted upwards, causing the feedback system oil to fall below atmospheric pressure. This has the effect of drawing the pilot valve downwards against the centrifugal force of the flyweights, giving a temporary increase in speed proportional to the load decrease. The lowering of the pilot valve continues until it reaches the 'lapped' position, at which point the control port becomes closed and the power piston ceases to drop.

At the same time, oil is drawn into the feedback system via the adjustable restrictor screw (9) until the pressures equalise.

## 4 LOAD INCREASE (FOR GOVERNORS WITH ADJUSTABLE DROOP)

When the engine is subjected to an increase in load, there is a reduction in engine and governor speed. The centrifugal force acting on the governor flyweights (33) will then become less than the speeder spring (32) force, causing the pilot valve (37) to move downwards.

Downward movement of the pilot valve allows high pressure oil to pass through the rotor ports to the underside of the power piston (2). The power piston will then rise, overcoming the high pressure oil above it because of the difference in the piston surface areas. As the piston rises, it will rotate the output shaft (30) and therefore increase the fuel supply to the engine.

Movement of the output shaft is also transmitted via links (27), (25), (26) and (13) to the top of the speeder spring, reducing its compression and thereby resetting the speed to a lower value (speed drop or 'droop').

The amount of 'droop' applied is set by the droop adjusting screw (23), located on the governor exterior. Rotation of the screw causes links (25) and (26) to move apart, acting effectively as a bell crank lever to alter the amount that the output shaft 'feedback' affects speeder spring force. Isochronous governing (previously described) is achieved when the adjusting screw is turned fully anti-clockwise (zero droop), i.e. when links (26) and (25) coincide.

Upward movement of the power piston also causes the displacer piston (1) to be moved downwards. This action will drive oil into the compensation unit, push the compensation piston (29) upwards against spring force and consequently increase the feedback oil pressure. This increased pressure acts on the bottom of the pilot valve, and by pushing it upwards against the speeder spring causes a temporary reduction in speed proportional to load increase - thereby producing a stabilising effect.

The upward movement of the pilot valve continues until it reaches the 'lapped' position, at which point the high pressure oil supply to the power piston is cut off. At the same time, the feedback oil is allowed to drain past the adjustable restrictor screw (9) until the system reaches atmospheric pressure. At this point, the forces acting on the pilot valve will be in a state of equilibrium and the engine will be running at its new slighly lower speed (due to the 'droop' effect).

5 **LOAD DECREASE (FOR GOVERNORS WITH ADJUSTABLE DROOP)**

When the engine is subjected to a decrease in load, there is an increase in engine and governor speed. The centrifugal force on the governor flyweights (33) will then overcome the speed spring (32) force and lift the pilot valve (37).

Upward movement of the pilot valve opens the control port leading to the base of the power piston (2), and allows the oil to drain away. The power piston will then fall, due to the constant high pressure oil on the upper surface, and the output shaft (30) will be rotated decrease fuel.

Movement of the output shaft is also transmitted via links (27), (25), (26) and (13) to the top of the speeder spring, increasing its compression and thereby resetting the governor speed to a higher value. This operation can be adjusted to meet specific requirements by altering the droop adjusting screw (23), located on the governor exterior.

Rotation of the screw causes links (25) and (26) to move apart, thereby altering the amount that the output shaft 'feedback' affects speeder spring force. Isochronous governing (previously described) is achieved when the adjusting screw is turned fully anti-clockwise (zero droop), i.e. when links (26) and (25) coincide.

Downward movement of the power piston will also lift the displacer piston (1), causing the feedback oil to fall below atmospheric pressure. As a result, the pilot valve and the compensation piston (29) are drawn downwards, giving a temporary increase in speed proportional to the load decrease. The pilot valve continues to be drawn downwards until it reaches the 'lapped' position, at which point it will close off the control port and thereby stop further descent of the power piston. At the same time, oil is drawn into the feedback system via the restrictor screw (9), until it reaches atmospheric pressure.

At this point,the forces acting on the pivot valve will be in a state of equilibrium, with the engine running at a slighly higher speed.

6 **FEEDBACK**

In addition to the simple stabilising action described previously, the hydraulic feedback system has another feature which considerably improves the quality of governing:

**Feedback 'By-pass'** (Non-linear feedback)

By-pass occurs when the feedback pressure exceeds a pre-determined level, and oil is allowed to pass in and out of the compensation piston (29) centre annulus and associated ports, thereby by-passing the restrictor screw (9). This action momentarily cuts the stabilising effect of the feedback, and reduces transient speed overshoots.

7 **SPEED SETTING INCREASE**

Engine speed is raised by moving the speed setting lever (39) downwards, thereby increasing the speeder spring (32) force. This overcomes the flyweight (33) centrifugal force causing the pilot valve (37) to move downwards. The resultant action is the same as for a load increase (previously described), with the governor output returning to a position dependent on the load characteristics.

8 **SPEED SETTING DECREASE**

Engine speed is decreased by moving the speed setting lever (39) upwards, thereby reducing speeder spring (32) force on the flyweights (33), and allowing the pilot valve (37) to move upwards. The result of this movement is the same as for a load decrease (previously described), with the governor output returning to a position dependent on the load characteristics.

**START THE ENGINE**

**1 BEFORE STARTING:**

i) Ensure that the governor contains the correct level of oil (see **Section AA41 Governor Operating Oil**).

ii) Set the speed setting controls to the required position.

iii) If the governor has a solenoid operated shutdown mechanism - energised to run, ensure that the correct voltage is supplied.

**Starting:**

Start and run the engine unit in accordance with the instructions on **page 23** in the **Operators Handbook**. When the engine is being started for the first time since refitting the governor, slightly erratic governing may be experienced. This will be eliminated after a few seconds when the air trapped in the hydraulic system has been automatically purged. Subsequent starting operations should not experience this problem because of the unique 'self bleeding' action.

**2 EXTERNAL LINKAGE ADJUSTMENTS**

The governor output scale is calibrated in divisions marked 0-10 which cover a maximum angle of rotation of 40° (1 division = 4°). The output shaft uses 60% of this 40° movement to travel between NO LOAD and FULL LOAD. Therefore the usable travel is 6 x 4° = 24° (division '2' is FULL SPEED, NO LOAD, division '8' is FULL SPEED, FULL LOAD).

Adjustment of the fuel pump linkage length alters the position of the output datum point, whereas adjusting the output lever length will control the output range.

Before final adjustments of the external governor linkages are made, it is necessary to run the engine for 1 hour in order to achieve normal working temperature. When this condition is reached, the fuel pump link should be adjusted to obtain governor output position '2' (FULL SPEED, NO LOAD).

The engine should then be run at FULL SPEED, FULL LOAD where it must reach this output at position '8'. If the reading is less than '8', the output lever length must be reduced, and conversely if the reading is higher than '8', the lever length must be increased. These reductions or increases in length should be made in small increments at NO LOAD, making sure that the NO LOAD position of '2' is maintained by adjusting the fuel pump linkage length accordingly. These alterations should be repeated until the NO LOAD to FULL LOAD range falls between positions '2' and '8'.

**3 SPEED STOP ADJUSTMENT***

Minimum Speed Setting

With the engine at its normal working temperature, adjust the speed to the required minimum value by using the speed setting control. The minimum speed stopscrew (14) and locknut should then be adjusted until the screw just makes contact with the stop plate. Check the setting by initially raising the speed, and then reducing it until the stopscrew prevents any further decrease. Re-adjust the stopscrew and repeat if necessary.

**Maximum Speed Setting**

This is a similar operation to that described above, except that it is the maximum speed being adjusted. To check the correct operation, reduce the speed first and then increase it until the stop screw (16) prevents any further rise. Check and re-adjust as necessary.

***NOTE:** Speed stops on new or overhauled governors are factory set.

4 **SPEED DROOP**

The speed droop is altered by rotating the droop adjusting screw (23) located at the rear of the governor. This is connected to the internal droop mechanism and is locked in position by a Nyloc nut. Each full turn in the clockwise direction represents an increase of 0.5% droop (approx.), whilst rotating the shaft fully anti-clockwise gives zero droop or isochronous operation.

5 **RESTRICTOR SCREW**

The **R** E series governors have a feedback system incorporated within the hydraulic circuit to give stabilisation by minimising speed transients and limit overshoots. To alter the characteristics of this feedback system, a restrictor screw is installed for the purposes of adjustment.

To obtain access to the restrictor screw the blanking plug at the front of the governor must be removed. It is then possible to adjust the screw with the use of a long bladed screwdriver.

Turning the restrictor screw clockwise will increase the transient speed deviation and stability whereas unscrewing the restrictor will reduce the transient speed deviation and reduce the stability. Adjustment should be made until a restrictor screw setting is found which provides the desired stability and transients for the application of the governor.

**NOTE:** When a governor is operated for the first time since refitting, it may be found that air is trapped within the hydraulic system. Although the governor is 'self-bleeding' it can be useful to unscrew the restrictor for a few moments to assist this action.

**NOTE:** In the case where a new governor has been supplied, the speed stops and droop are pre-set at the factory to suit the required application. However, it may be necessary to adjust the restrictor screw setting in order to obtain optimum stability and transient performance.

**GOVERNOR OPERATING OIL**

**TYPE AND GRADE OF OIL**

The R E governor series has been designed to operate using a standard SAE30 mineral oil for most applications. However, should the ambient temperature be constantly below 10°C, then it is advisable to use oil with an SAE20 value. Likewise, if the ambient temperature is constantly above 40°C, then SAE40 is recommended.

If instability is experienced when the engine has been started from cold but disappears with the increase in temperature, then the use of a multigrade oil is recommended.

As the oil used in the governor directly affects the operation, it is important to remember the following rules:

* Only use the grade of oil suitable for the application.
* Do not use hydraulic oils, or those with a high alkaline value.
* Ensure that the correct level is maintained Do not overfill or underfill.

## OIL LEVEL

In order to prevent any unwanted substances from entering the governor unit, it is essential to clean the area surrounding the filler neck prior to adding oil. The governor should be at its normal working temperature and filled through a fine mesh filter, until the level reaches the centre line of the sightglass located in the side of the casing; **DO NOT OVERFILL OR UNDERFILL** as this will result in poor governor performance.

A governor that is being filled for the first time or one which has just undergone repairs may require to have the level rechecked soon after is has been started up; this is due to the oil passages being filled, hence lowering the level. Should it be necessary to remove excess oil from the governor due to overfilling, the drain plug at the base of the unit can be unscrewed and the surplus oil removed. (See **Section AA42 Routine Maintenance**).

## OIL COOLER

In some cases the governor may be fitted with an oil cooler which is mounted onto the casing. These units are installed where the governor is constantly operating under heavy load and speed in a hot environment, thus giving rise to excessive oil operating temperature. (See also **Section AA42 Routine Maintenance**).

## ROUTINE MAINTENANCE

Under normal working conditions the R E governor series require the minimum of routine maintenance which consists of regular visual checks and the replacement of the operating oil.

### Visual Examination

**Check for:**

1) Correct level of operating oil.
2) Excessive external oil leakage.
3) Drive shaft seal failure.
4) Discoloration of oil level sight glass.
5) Security of governor mounting, clamp bolts on output levers, nuts, bolts, etc.

## OIL CHANGE (SEE ALSO SECTION AA41 - GOVERNOR OPERATING OIL)

The governor operating oil should be changed yearly or after every 5000 hours of usage, whichever occurs first. If the oil becomes contaminated or appears to be excessively dirty it is recommended that it is replaced immediately.

The procedure for draining and refilling is as follows:

1) If possible, run the governor for a short period in order to warm up the oil.
2) Drain the oil from the governor by removing the drain plug located in the flange plate.
3) Should the oil show signs of contamination, it is advisable to flush out the governor with a small amount of fresh oil.
4) Refill to the specified level using the correct grade of oil for the application.

**NOTE:** If the governor has an oil cooler fitted, it is advisable to follow the maintenance instructions supplied by the manufacturer.

## EXTERNAL LINKAGES

In order to minimise friction all linkage pivot points must be suitably lubricated. This is especially the case where fork, blade and pin type pivots are used, as opposed to Unibal Joints which require less maintenance.

It is important that the oil or grease to be used for these purposes meets the operating requirements of the governor with regard to working temperatures, location, etc., (see **Section AA41**).

Finally, it is recommended that only qualified service personnel should be permitted to carry out repair work other than routine maintenance. Assistance and advice regarding this matter can be obtained by contacting Perkins Engines (Stafford).

## SPECIAL TOOLS

A range of special tools which are necessary for certain governor adjustments/repairs can be purchased by contacting Perkins Engines (Stafford).

## FAULT TRACING

The following section deals with a few of the major operating faults which may arise during a period of time and their possible solutions. As previously mentioned, the manufacturer strongly recommend that only qualified service personnel should be permitted to undertake repairs and maintenance on the governor unit.

**FAULT:** 'HUNTING'

'Hunting' is best described as a rhythmic change in speed above and below that of the set speed. The frequency of these changes rarely exceeds 2 Hz.

**CAUSES:**

**Governor related causes**

1) Incorrect feedback restrictor screw setting.
2) Droop setting or governor output travel incorrect.
3) Incorrect oil type or viscosity.
4) Oil contamination or incorrect level.
5) Internal governor faults.

**Engine related causes**

1) Defective fuel injector(s)
2) Governor to fuel injector linkages incorrectly adjusted or worn.
3) Faulty fuel pump(s) (non-linear characteristics at low deliveries).
4) Incorrect fuel boost pressure.
5) Restricted fuel pump supply.
6) Contaminated fuel, i.e. water or air.
7) Engine inertia and coupling characteristics.

**FAULT:** 'JIGGLING' OR 'SNATCHING'

'Jiggling' is the term given to rapid regular movements of the governor output at a frequency in excess of 4 Hz. These movements are relatively small and so therefore have little noticeable effect on speed.

'Snatching' is the term used to describe a similar action to 'jiggling' with the exception that movements occur on an irregular basis. As in the case of 'jiggling' there is a minimum effect on speed.

Both of these conditions are an indication of the quality of drive signal that is being received by the governor rotor flyweights. Although regular cyclic variations are damped out by the integral rotor drive spring, this cannot, however, eliminate those cyclic variations which are excessive and/or irregular. It is therefore necessary to determine which of the following is the cause of the problem.

**CAUSES:**

1) Rough engine drive.
2) Internal governor faults.
3) Governor oil level incorrect or viscosity too low.
4) Excessive backlash between crankshaft and camshaft.
5) Slackness in chain driven mechanisms.
6) Insufficient or excess clearance in governor drive gears.
7) Worn or damaged gears.
8) Mis-aligned governor drive shafts.

**FAULT:** FUEL PUMP INJECTORS SLOW TO OPEN

**CAUSES:**

1) Low governor oil pressure (worn pumps, leaking check valves, worn pistons and valves).
2) Cranking speed too low.
3) Start booster not working correctly.

**FAULT:** NO OUTPUT FROM GOVERNOR

**CAUSES:**

1) No governor oil pressure.
2) Failure of governor drive.
3) Damaged governor internals.
4) Linkage sticking or incorrectly adjusted.

## SHUTDOWN UNIT
## SOLENOID TYPE - ENERGISED TO STOP
## GENERAL DESCRIPTION AND OPERATION

The solenoid operated shutdown mechanism is fitted to governors where a remote shutdown control is required.

The mechanism consists of an electrical solenoid mounted on the top of the governor, with the solenoid core attached to the shutdown lever located within the governor. The shutdown lever is allowed to pivot on a fulcrum pin, and includes a shutdown rod which is positioned beneath the pilot valve stem nuts.

When the solenoid is energised, the solenoid core is pulled upwards thereby raising the shutdown lever/rod assembly. As a result, the shutdown rod will lift the pilot valve to the point where the governor is moved to the zero fuel position (shutdown).

De-energising the solenoid will cause a return spring to move the solenoid core and shutdown lever back to the lower position, thereby removing any influence on the pilot valve to allow normal operation.

## INSTALLATION

The solenoid operated shutdown mechanism is fitted to the governor and adjusted before leaving the factory. Therefore, the only installation requirement is for the correct electrical supply to be connected to the solenoid, as shown on the installation drawing.

## MAINTENANCE

The solenoid type shutdown mechanism does not require regular maintenance other than a visual check to ensure that all electrical connections are secure and properly insulated. Fault rectification and/or overhauling must be carried out by either a qualified engineer who is familiar with the type of unit fitted, or by a Regulateurs Europa approved Service Distributor.

## TECHNICAL DATA

| | |
|---|---|
| Solenoid type | - Dual Coil Solenoid (High current 'pull', low current 'hold') |
| Voltage requirements | - 24 Volts dc |
| 'Pull' current | - 17 Amps |
| 'Hold' current | - 0.25 Amps |

## FUEL LIMIT UNIT

The fuel limit mechanism may be fitted as an optional feature to a governor being used on a turbo-charged engine.

The purpose is to limit the fuel in order to achieve a better fuel/air ratio during acceleration and stating periods. This produces a more complete combustion process which improves acceleration, minimises exhaust smoke and reduces thermal loading.

Fuel limitation also provides a means of protection for the engine in the event of turbocharger failure or restriction of the air supply.

## FUEL LIMITATION - WITH RESPECT TO BOOST PRESSURE

This type of fuel limitation mechanism limits the governor output position in relation to the inlet manifold boost (air pressure derived from the turbocharger).

The mechanism consists of a mechanical link between the governor pilot valve and a pneumatic servo mounted on the governor exterior. The servo receives an air pressure signal from the engine inlet manifold, which deflects the diaphragm against a return spring, causing movement of the pushrod and fuel limit lever to restrict pilot valve travel.

When maximum air pressure is applied to the servo, the pilot valve is able to operate free of any limitation. However, a reduction in air pressure allows the spring force to return the push rod, thereby lifting the pilot valve proportionately. This will continue until the preset lower limit has been reached. The preset limit is adjusted by means of a stop screw on the pneumatic servo, which mechanically stops the travel of the servo pushrod/fuel limit lever. (This also acts as a 'fail-safe' in the event of an air supply or turbocharger failure).

## INSTALLATION AND MAINTENANCE

The fuel limit mechanism (boost pressure) is fitted to the governor and calibrated to customers' specifications before leaving the factory.

When installing the governor, the boost pressure signal pipe must be connected securely, ensuring that all joints, etc., are airtight.

The mechanism requires no regular maintenance apart from a routine inspection of pipes and connections for security and leakage.

**(FOR USE WITH REGULATEURS EUROPA AND WOODWARD HYDRAULIC GOVERNORS)**

**GENERAL DESCRIPTION (SEE FIG. 39AA)**

The governor drive comprises a splined quill shaft (15), driven from an adaptor plate (8) bolted to the camshaft drive gear (9), and a meshing bevel gear (16) and bevel pinion (3) enclosed within a cast and machined gearbox casing (4) mounted to the free-end drive cover (7). The gearbox central casing is bored to form a plain bearing for the bevel drive gear spindle. The governor (28) which is spigot mounted to the upper side of the casing is secured by four studs (26) and M10 nuts. The bevel pinion (3) with key (2) is secured to the governor drive shaft (1) by a castle nut (21) with split pin (20). The bevel gear and pinion backlash adjustment is achieved by a laminated shim (27) between the governor and gearbox casing, and a final adjustment with a laminated washer (25) between the pinion and the shoulder of the governor drive shaft if required.

Lubrication of the gears is provided from a small sump retaining oil (17) in the gearbox casing and a pressure feed to the bevel gear bearing (14).

**Key (Fig. 39AA)**

1. GOVERNOR DRIVE SHAFT
2. KEY - DRIVE SHAFT
3. BEVEL PINION
4. BEVEL GEARBOX
5. M10 NUT
6. JOINT - BEVEL GEARBOX
7. FREE-END COVER
8. ADAPTOR PLATE
9. CAMSHAFT DRIVE GEAR
10. CAMSHAFT
11. M12 'DURLOK' SCREW
12. M10 SCREW
13. OIL FEED UNION
14. OIL SUPPLY TO BEVEL GEAR SPINDLE
15. QUILL SHAFT
16. BEVEL GEAR
17. OIL LEVEL - BEVEL GEARBOX
18. CIRCLIP
19. COVER PLATE
20. 5/32" SPLIT PIN
21. 5/8" UNF CASTLE NUT
22. PLAIN WASHER
23. M6 SCREW
24. JOINT
25. LAMINATED WASHER
26. M10 STUD
27. LAMINATED SHIM
28. GOVERNOR

**NOTE:** The condition of the governor drive is directly linked to governor performance, (see **Sections AA35 and AA55**).

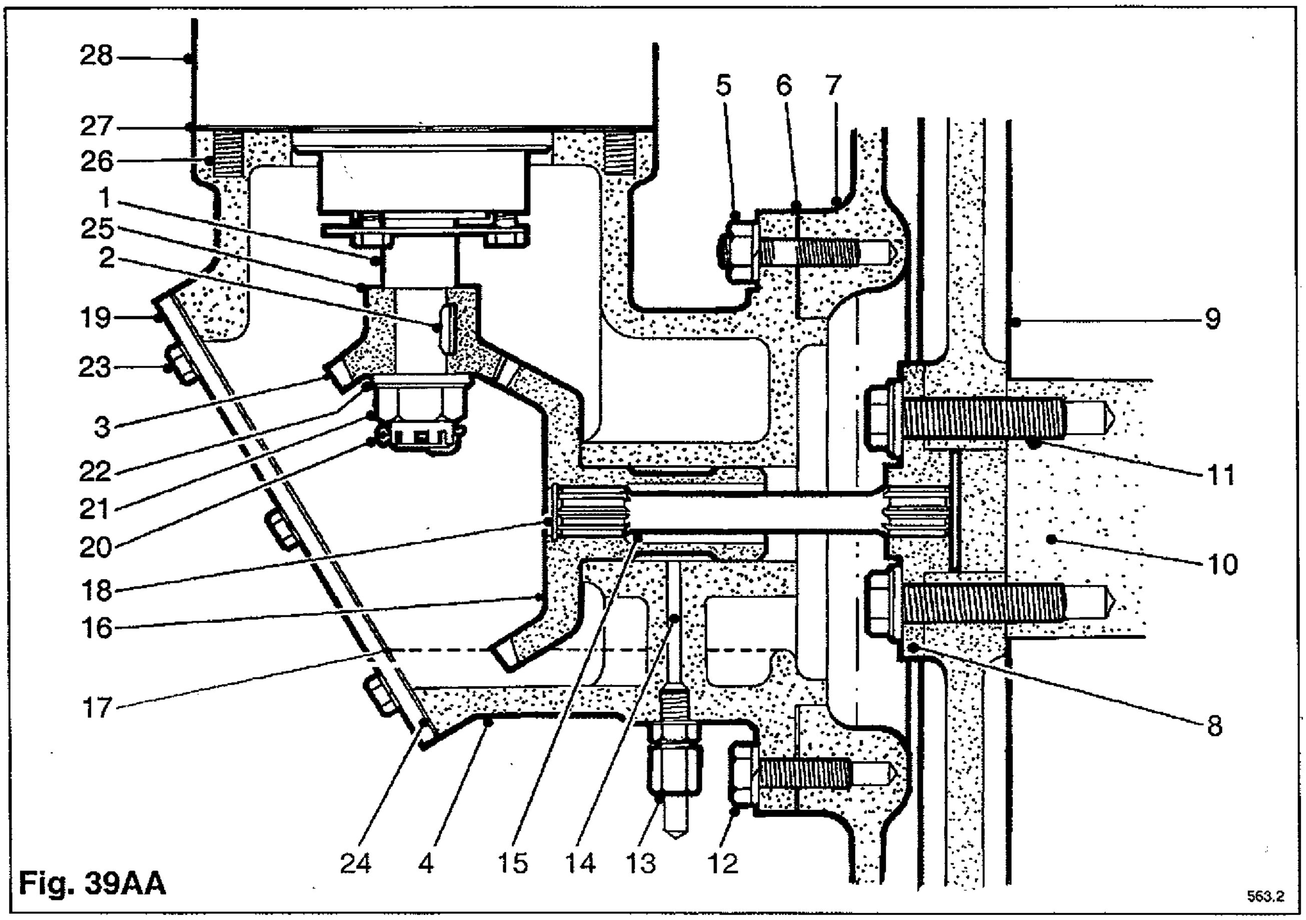



**Fig. 39AA**

## TO REMOVE AND DISMANTLE

Disconnect the electrical connections to the governor shut down solenoid.

Mark and disconnect the governor fuel pump control linkage (see **Section BB1 and Fig. 37AA**).

Release and remove the oil supply pipe (13) from the governor drive gearbox (4).

Release and remove the four bolts (26) securing the governor (28) and remove the governor together with the laminated shim (27).

Release and remove the screws (23) and remove the cover plate (19) and joint (24), first placing a suitable container under the bevel gearcase in which to catch the oil contained in the gearcase sump.

Withdraw the bevel gear (16) together with the quill shaft (15) and withdraw the quill shaft from the bevel gear.

Release and remove the four screws (12) and two nuts (5) all with spring washers securing the bevel gearbox casing (4) to the timing gearcase (7) and remove the casing.

Remove the $^{5}/_{32}$" split pin (20), $^{5}/_{8}$" UNF castle nut (21) and the plain washer (22) from the governor drive shaft (1). Using a suitable puller, remove the bevel pinion (3) and drive key (2).

If the splines of adaptor plate (8) are worn, it may be necessary to remove the adaptor plate by first removing the Durlok screws (11) from the camshaft and camshaft drive gear to allow removal of the adaptor plate only. This may be done without disturbing the camshaft drive gear but the old or new adaptor plate (8) **MUST** be fitted and secured before attempting to bar the engine over.

## INSPECTION

All parts should be cleaned and checked against the dimensions quoted in the **Schedule of Wear and Renewal Limits** (see **pages 41-42**).

Check the drive splines of the quill shaft and bevel gear for fretting and burring; blend out such marks with a fine oil stone.

Check the condition of the adaptor plate splines for fretting and burring.

Check the bevel gear and pinion gear teeth for fretting or burring. Renew if worn.

Check the bore and thrust face of the gearbox casing for scoring or wear and check against the **Wear and Renewal Limits Schedule**. Light score marks may be blended out with a scraper.

Check that the oilways in the gearbox casing are clear. Examine the threads of screws and studs for serviceability.

**TO ASSEMBLE AND REFIT**

The following procedure is based on the assumption that the governor drive has been completely dismantled for the renewal of component parts. Ensure that all mating faces are clean and free from old jointing, burrs, or surface imperfections which may impair sealing or alignment.

Using a new joint (6), fit the bevel drive gearbox (4) to its spigot in the free-end cover (7) and secure with two nuts (5) and four screws (12) with spring washers.

Insert the quill shaft (15) into the adaptor plate (8). Fit a new circlip (18) to its groove in the bevel gear (16). Fit the bevel gear (16) spindle to the bore of the gearbox (4) engaging the splines of the bevel gear with the splines of the quill shaft.

Fit the drive key (2) and bevel pinion (3) to the governor drive shaft (1) and secure using the plain washer (22) and the $^5/_8$" UNF castle nut (21). The split pin (20) is fitted later.

On assembly, or if any new component parts are fitted, the mesh of the gears may have changed and will required checking and adjusting as follows to ensure the specified clearance (0.05 to 0.15 mm):

Using a new laminated shim (27), lower the governor (28) into position on the spigot of the bevel gearbox (4). Using four M10 nuts secure the governor to the bevel gearbox studs (26).

Using feeler gauges, check the mesh of the bevel gear to bevel pinion is within the specified limits above. If not within these limits, remove the governor and adjust the thickness of the laminated shim to suit, reassemble and again check the mesh of the bevel gear and pinion. Fit the $^5/_{32}$" split pin (20) to the $^5/_8$" UNF castle nut (21) on completion of adjustment.

It should only be necessary to fit the laminated washer (25) if, due to machining tolerances, the thickness of the laminated shim (27) when fitted would be less than 0.254 mm (0.010").

Using a new joint (24) fit the cover plate (19) to the bevel gear box (4) and secure with screws (23) with spring washers.

Using a new Dowty seal fit the male stud coupling and oil supply pipe (13) to the bevel gearbox and secure.

Reconnect the fuel pump control linkage to the governor (see **Section BB1 and Fig. 37AA**).

Reconnect the electrical control to the governor shut down solenoid.

**WARNING** ⚠ THE ENGINE MUST BE FITTED WITH AN INDEPENDENT OVERSPEED SHUTDOWN DEVICE. WHEN THE ENGINE IS RUNNING THE BATTERY MUST NOT BE DISCONNECTED.

The UG10 lever and dial mechanical-hydraulic governors are linked directly to the pump injector control shafts. Both types are driven by bevel gears from an extension to the front of the camshaft, and they are mounted vertically between the two thermostat bodies. They have their own oil supply (SAE 30 or SAE15W/40 engine oil) and the level may be observed in a sight glass. The maximum travel of the governor output shaft is 42°, but only approximately 28° of this is used from no load to full load, the rest allowing for over travel for shut-down and excess fuel supply for starting.

They normally operate isochronously regardless of engine load, except during transient load conditions.

The governors are fitted with their own shut-down solenoids, which are energised to run, and operated from the 24 Volt engine starting system. See **Fig. 40AA.**

**TO REMOVE THE GOVERNOR (UG10, WHETHER DIAL OR LEVER TYPE, AND 3161)**

Mark the governor shafts and levers before disturbing them, and disconnect the electrical connections to the solenoid.

Unscrew the 4 nuts securing the governor to the right angle drive adaptor, detach the governor levers from the fuel control shafts by removing the ball joint screws at one end of each control link. This is to maintain the lever to shaft relationship if no exchange or dismantling of the governor is contemplated. Similarly detach the connection to the manual speed control on the front of the governor, and lift the governor off the engine, placing it in an upright position on a wooden block with a hole in it to accomodate the bevel gear and shaft.

## REPLACING THE GOVERNOR (UG10, WHETHER DIAL OR LEVER TYPE, AND 3161)

**WARNING** ⚠ FOR SAFE OPERATION, PARTICULARLY THE ABILITY TO STOP THE ENGINE, CHECK THAT THE GOVERNOR WILL RETURN THE INJECTORS TO THE **NO FUEL** POSITION.

1 Inspect the drive shaft and gears to make sure that there is no excessive wear. (See **Wear and Renewal Limits pages 41-42**).

2 Ensure that both mating surfaces are clean and free from imperfections before fitting a new joint.

3 Lower the governor complete with gear onto the gear box and ensure that the bevel gears mesh properly when tightened down. The backlash should be between 0.05 and 0.15 mm, and this may be adjusted by the addition of shims between the governor and gear box faces. If there is insufficient clearance it will result in excessive wear and ultimately failure of the drive. Fit the cover plate with a new joint.

4 Fit the governor input and output levers, making sure that the latter are correctly aligned with one another, and in accordance with the markings applied before dismantling.

5 Reconnect the links to the fuel control levers on each bank.

6 Re-attach the speed control cable to the input lever, and reconnect the shut-down solenoid wiring.

7 If a new or reconditioned governor is being fitted with no marking on the output shafts, the levers should be positioned as shown in **Fig. 40AA**. Make sure that the governor rotates freely before fitting the bevel gear and $^5/_8$" UNF castle nut and split pin. (See **Fig. 39AA Section AA45**). Set the compensation adjustment to the same setting as that on the displaced governor.

## OPERATION OF THE UG10 GOVERNOR

The governor has been set up and adjusted on engine test before leaving the Perkins Engines (Stafford) works.

**WARNING** ⚠ BE PREPARED TO MAKE AN EMERGENCY SHUTDOWN TO PREVENT THE ENGINE RUNNING AWAY OR OVERSPEEDING WHEN FIRST STARTING THE ENGINE AFTER INSTALLATION.

## ADJUSTMENTS TO UG10 GOVERNOR (LEVER OR DIAL TYPE)

1 Remove the $^1/_8$" NPT socket pipe plug from the base on the left side of the governor and attach a 0-200 lb/in$^2$ pressure gauge. See **Fig. 40AA.**

2 Start the engine and run it until it achieves its normal operating temperature. Remove the load.

3 Check that the governor has 140 to 150 lb/in$^2$ oil pressure at normal operating speed.

4 Remove the hexagon plug from the front of the governor base to gain access to the needle valve. Close the needle valve and then open it just enough to cause a small hunt. Use a Phillips or Pozidriv screwdriver for preference, as a plain screwdriver can damage the thread inside the bore and affect the governor performance. Let the engine hunt for appproximately half a minute to bleed trapped air from the governor passages.

5 Close the needle valve and open it again half a turn. If the governor continues to hunt, repeat step 4.

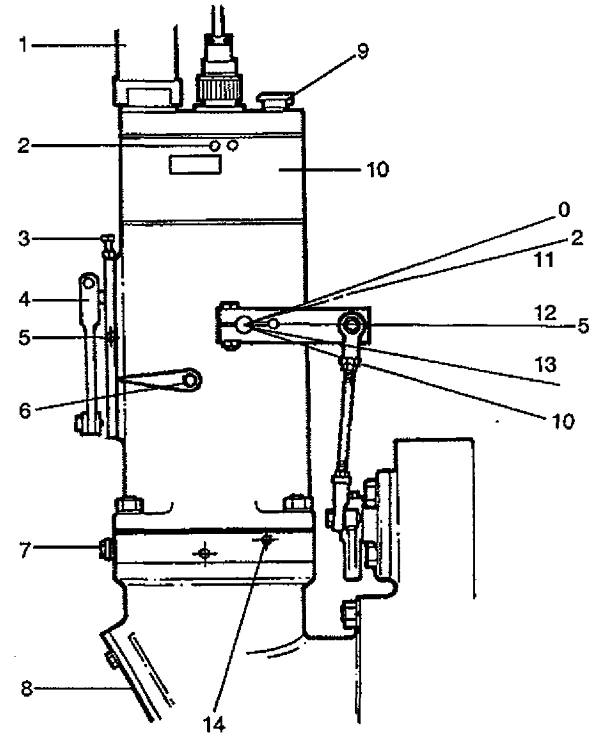



**Fig. 40AA**

**Key**
**(Fig. 40AA)**

**1** Shutdown solenoid
**2** Limiter air signal connection
**3** Low speed stop
**4** Speed control lever
**5** High speed stop (far side)
**6** Compensating adjustment
**7** Compensating needle valve (remove hexagon plug)
**8** Bevel drive cover plate
**9** Oil filler cap
**10** Manifold pressure operated fuel limiter
**11** No fuel
**12** Output levers in line with one another
**13** Max fuel
**14** Oil pressure test plug $^1/_8$" NPT (far side)

6 Adjust the compensation system by loosening the nut holding the pointer enough to set it at its highest position for maximum compensation. This will allow any trapped air to escape.
Next open the needle valve two turns anti-clockwise, as in step 4 above, and again allow the engine to hunt for half a minute to bleed any remaining trapped air.

7 Now lower the compensation pointer as far as it will go for minimum compensation. Tighten the nut again and refit the needle valve hexagon plug.

**NOTE:** The object of the compensation adjustment procedure is to find the particular settings for the compensation needle valve and compensation adjustment pointer, at which the engine will return quickly to the nominal speed (needle valve adjustment) after a speed disturbance, with only a slight over or undershoot (compensation pointer adjustment).

8 Whilst the engine is running, recheck the governor for zero droop. Turn the speed droop knob to zero, and run the engine at normal operating speed near to 0% load. Then load the engine to near 100% load. Speed must be within 0 to 3 r/min lower. If the engine can only be run at partial load, the speed decrease must be proportional to the partial load.

9 If adjustment is needed to obtain zero droop, follow this procedure:
Loosen the locknut (190) on the speed droop screw (189) and turn the screw (189) ccw to reduce droop. Turn the screw cw to increase droop. Tighten the locknut. (See **Fig. 42AA**)
Repeat the above procedure until speed is within 0 to 3 r/min lower when running the engine from no load to full load positions.

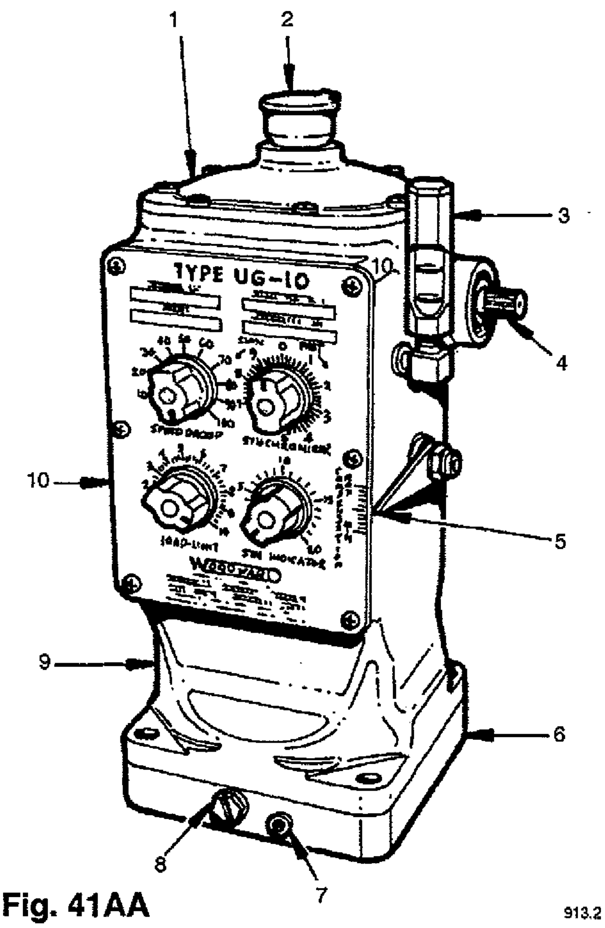



**Fig. 41AA**

**Key**
**(Fig. 41AA)**

**1** Cover
**2** Oil filler cap
**3** Oil sight glass
**4** Output shaft (terminal shaft)
**5** Compensation pointer
**6** Base
**7** Oil drain plug
**8** Compensating needle valve plug
**9** Case
**10** Dial panel

10 To prevent speed setting changes because of engine vibrations, a friction drive (250-256) is installed in the speed setting mechanical drive of the UG Governor. **(See Fig. 44AA).**
The friction drive (250-256) must be tight enough to avoid a speed setting change due to vibrations, and also tight enough to permit the speed setting motor, if used, to turn the speed setting gear.
If the friction drive is too tight, the synchroniser (speed setting) knob can no longer be turned manually.
To adjust the friction on the friction drive, first remove the governor cover (219) **see Fig. 41AA** then the retaining ring (250) **see Fig. 44AA** on the friction drive using No.1 Truarc pliers. Do not let the friction cover (251) or the spring (252) fall into the governor as the friction drive cover is under spring compression.
Check the torque of the friction drive and set it at 1½ to 2½ lb.in. with manual speed settings or 4 to 5½ lb.in with speed setting motor. To increase friction, turn the nut (253) on the shaft cw while holding the speed setting knob. To decrease friction, turn the nut ccw.

11 Reassemble the friction drive.

12 Set the maximum and/or minimum speed limit on the governor. This adjustment can also be made with the engine running. To make the adjustment, first remove the governor dial plate **(see Fig. 44AA)**

**NOTE:** The maximum speed for constant operation for both UG governors is 1500 r/min.

Turn the synchroniser (speed setting) knob cw to increase the speed setting of the governor from its specified maximum plus 10 r/min.
If the friction drive slips before reaching the required high speed setting, mark the intermediate (278) and the synchroniser (269) (speed setting) indicator gears, disengage the synchroniser (speed setting) gear (269), index it one tooth ccw to allow a higher speed setting and engage the gear again (one tooth gives approximately 28 r/min). (see **Fig. 43AA**).
The amount of speed change is not the same if the speeder screw (177) has a coarse thread (18 threads/inch) rather than the fine thread (32 threads/inch) which is normally used **(See Fig. 42AA SPEED DROOP ASSEMBLY Parts Illustration for Dial Governor (1)).**
Engage again the synchroniser indicator gear (269) with the high-speed stop pin, engaging the intermediate gear (278) to prevent further increase in speed. The high-speed stop pin is the pin closest to the gear centre. **Fig. 43AA**.

13 To set the minimum speed limit, turn the synchroniser (speed setting) knob ccw to decrease the speed setting of the governor to its minimum speed position.

14 Set the synchroniser knob at zero on the dial.

15 Set the synchroniser indicator dial panel pointer at zero.

16 Position the synchroniser indicator knob about $^1/_{16}$" from the surface of the dial. This prevents the knob from binding the synchroniser system gear train.

17 On the governors equipped with a solenoid shutdown, please refer to Woodward Governor Company manual 03013 for set up procedures.

18 Turn the load limit knob to zero. The load limit indicator must move to zero. The governor output shaft will move to its minimum fuel position. Reset the load limit knob to the maximum load.

19 Shut down the engine. Remove the pressure gauge and install a 1/8" NTP socket pipe plug. Apply a pipe sealer to the threads, and torque pipe plug down to 90 ib.in.

20 Install the governor cover and dial plate.

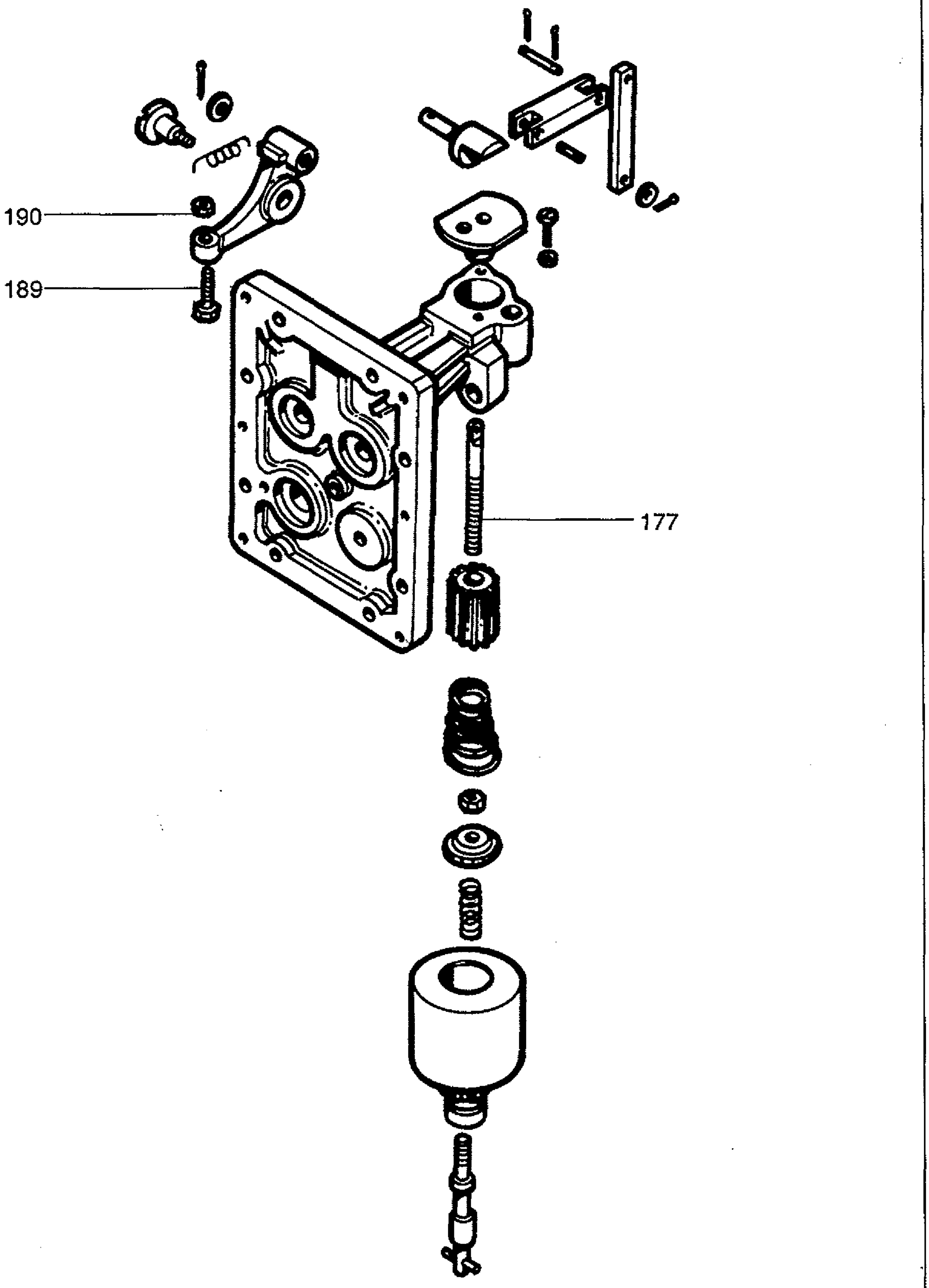



Fig. 42AA

**Key**
**(Fig. 43AA)**
**Speed stop adjustments on the UG Dial Governor**

1 Intermediate gear key
2 Synchronizer (speed setting knob)
3 Stop pin (max speed)
4 Synchronizer (speed setting indicator gear)
5 To raise high speed limit
6 Indicator pointer
7 Pull gear forward
8 Synchronizer (speed setting indicator knob removed)
9 To lower low speed limit

**(Fig. 44AA)**
**FRICTION DRIVE ASSEMBLY**
**Parts Illustration adjustments on UG Dial Governor (2).**

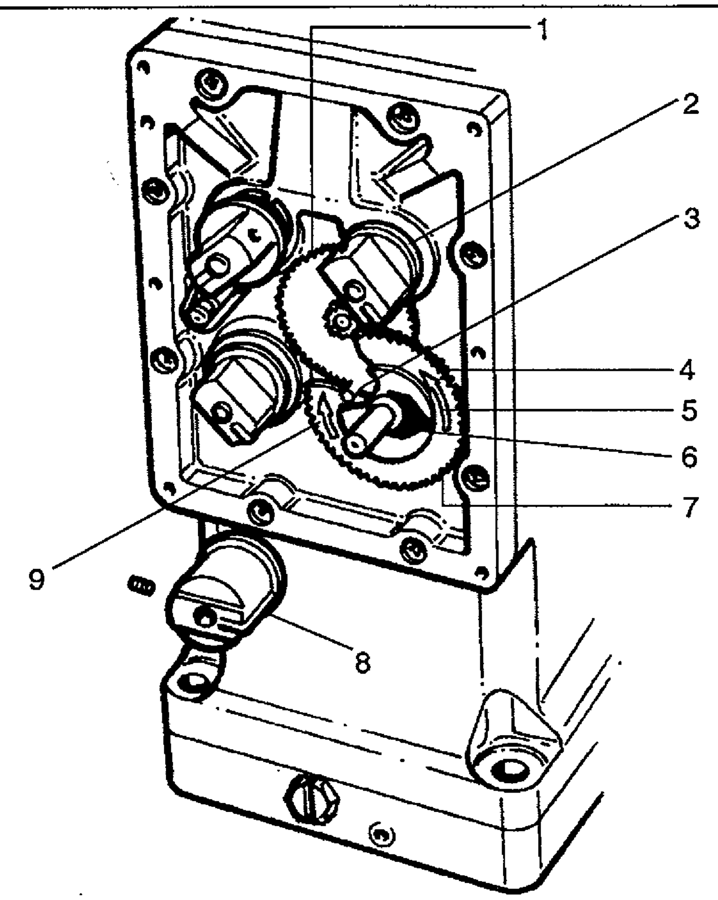


Fig. 43AA

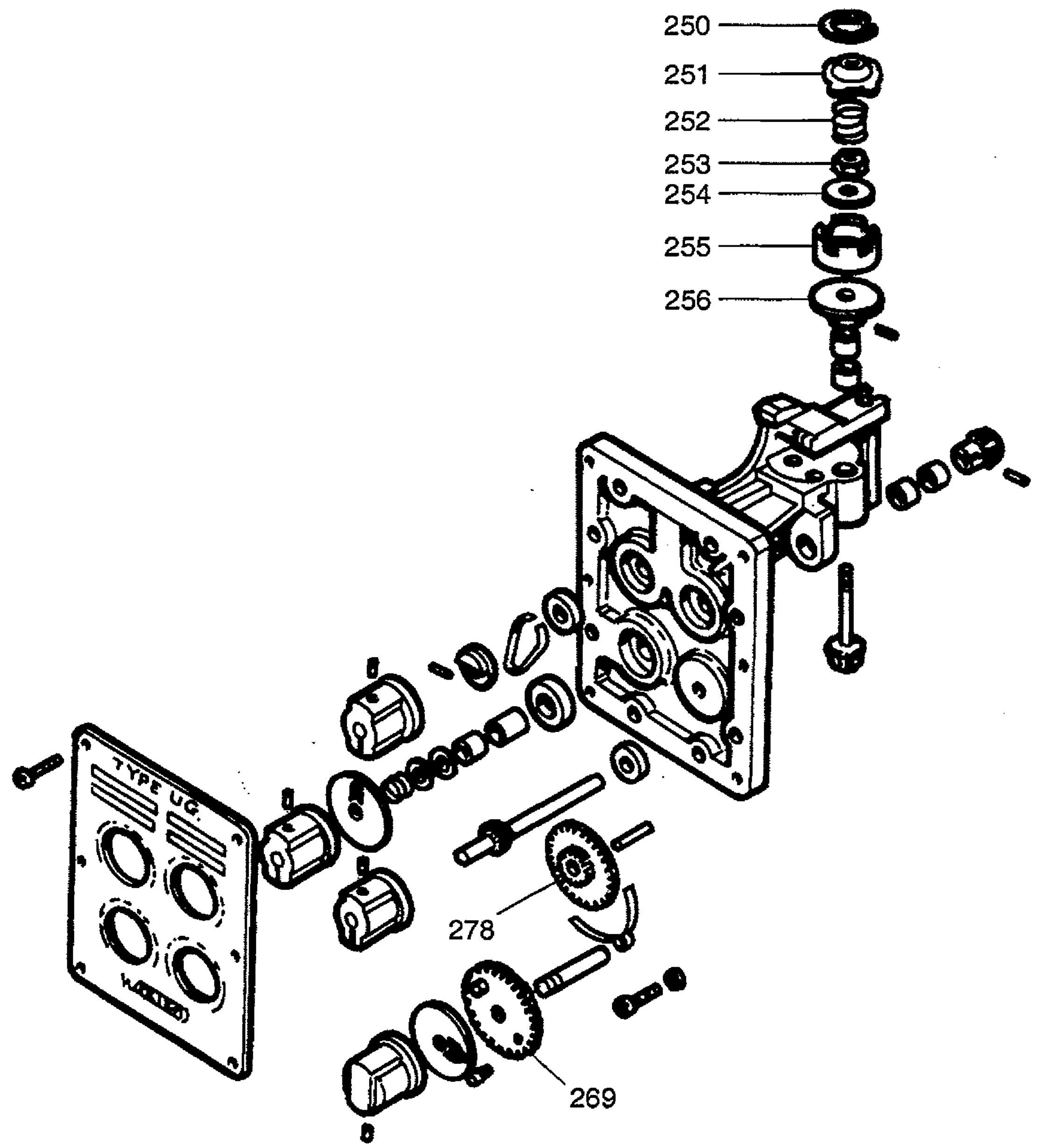



Fig. 44AA

945.2

**WARNING** ⚠ INJURY MAY RESULT IF ACCUMULATOR SPRINGS ARE RELEASED SUDDENLY. USE AN ARBOR PRESS TO RELEASE THE COMPRESSED ACCUMULATOR

8 Gradually close the needle valve until hunting just stops. If hunting does not stop, open the needle valve one turn and move the compensation pointer up by one mark on the front panel indicator scale. Again gradually close the needle valve until hunting stops.
If hunting does not stop, set the needle valve $^1/_4$ turn open and repeat setting the compensation pointer up by one mark. Retest governor until hunting stops.

9 From this setting, open the needle valve one turn and manually disturb the governor fuel setting. (On the dial governor turn the load limit knob to increase the load slightly and bring it back quickly to its original position). Gradually close the needle valve until governor returns to speed with only a small overshoot or undershoot and the needle valve is between $^3/_8$ and $^3/_4$ turn open.

Compensation adjustment determines offspeed, and needle valve adjustment determines the recovery time.

**NOTE:** For most responsive governor control, use as little compensation as possible. Too much compensation causes excessive speed overshoots and undershoots upon load changes.

Also closing the needle valve more than indicated in step 9 makes the governor slow to return to normal speed after a load change.

Opening the needle valve more than indicated above decreases governor stability and can cause hunting.

Once the needle valve adjustment is correct, it is not necessary to change the setting except for large, permanent changes in temperature which affect governor oil viscosity.

When the adjustment is correct, tighten the compensation nut and re-install the needle valve access plug with a copper washer. The plug and the washer will seal oil seepage around the needle valve.

## FAULT TRACING FOR UG10 GOVERNOR (LEVER OR DIAL)

### OIL

Keep the oil level between the marks on the governor sight glass with the unit operating. Only use clean new oil out of clean containers. Remember that oil contaminated with water breaks down rapidly causing foaming and corrodes the governor internal parts leading to poor performance and ultimate failure.

## COMPENSATING ADJUSTMENT AND THE NEEDLE VALVE

These must be correctly adjusted with the governor controlling the engine, even though the compensation has been previously adjusted at the factory.

Although the governor may appear to be operating satisfactorily because the unit runs at constant speed without load, the governor may still not be correctly adjusted to the site load and the derated engine power.

Overspeed and underspeed, or slow return to speed after a load change are some of the results of an incorrect setting of the compensating adjustment and needle valve.

Use the **Fault Tracing Chart** in **Sections AA56 - AA59** to determine the probable cause of faulty operation and take the appropriate corrective action.

**DEFINITIONS OF TERMS USED IN THE FAULT TRACING CHART**

**HUNTING** A rythmic variation of speed which can originate in either the governor or the engine (see **Sections AA56 - AA59** for Fault Tracing details). A hunt usually has a frequency below 50 cycles per minute.

**SURGING** A sudden variation of speed occurring at periodic intervals which again can originate in either the governor or the engine. (See **Sections AA57 - AA58**).

**JIGGLING** A high frequency vibration of the governor output shaft and fuel control linkage. Do not confuse this with the normal controlling action of the governor. A jiggle has a frequency of more than 50 cycles per minute. (See **Section AA58**).

**PRELIMINARY INSPECTION**

Governor troubles are usually revealed in speed variations of the engine, but it does not necessarily follow that such variations are caused by the governor. When improper speed variations appear the following procedure should be followed:

1 Check the load to be sure that the speed changes are not the result of load changes beyond the engine capacity.

2 Check engine operation to be sure that all cylinders are firing properly and that the fuel pump injectors are in good operating condition and properly calibrated.

3 Check the linkage between the governor and the pump injectors to make sure there is no binding or lost motion.

4 Check the setting of the needle valve and the compensation adjustment. (See **Sections AA48 - AA51**).

5 Check that the oil is clean and the oil level is correct at operating temperature. The source of most trouble in any hydraulic governor stems from dirty oil. Grit and other impurities can be introduced into the governor with the oil, or form when the oil begins to break down (oxidise) or becomes sludgy.

The internal moving parts are continually lubricated by the oil within the unit. Valves, pistons and plungers will stick and even seize in their bores due to grit and impurities in the oil.

If this is the case, erratic operation and poor response can be corrected (if wear is not excessive) by flushing the unit with fuel and refilling with SAE 30 or SAE 15W/40 engine oil.

The use of commercial solvents is not recommended as they may damage seals or gaskets.

Drain the oil and flush the governor twice a year by removing the drain plug at the front of the base. Refill the governor with 2 litres of clean fuel and run the engine at low speed, cycling the governor by opening the needle valve two or three turns.

Let the governor hunt for a minute or two, then stop the engine and drain the governor. Flush the governor once again. Refill the governor with new SAE 30 or SAE15W/40 engine oil.

Restart the engine and reset the compensation adjustment and needle valve. See **Sections AA48 - AA51**.

6 Check that the drive to the governor is correctly aligned and free of roughness, side loading and excessive backlash. (See **Wear and Renewal Limits, pages 41-42**).

| TROUBLE | CAUSE | CORRECTION |
|---|---|---|
| 1.If the engine refuses to start | --- | See **Sections AA58** and **AA61**. |
| 2.The engine hunts or surges. | A. The trouble can originate in either the governor or the engine. | Block the fuel levers in the increase in fuel direction (**NEVER** block the governor output shaft in the direction that would prevent a complete shutdown). (The same blocking action may be achieved by using the load limit knob on on dial governors). If hunting and/or surging continues while the governor output shaft is blocked, the problem is with the engine. If after removing the block hunting and/or surging starts again, the problem can be in the governor or the engine. Go through the compensation adjustment procedure for the governor (**Sections AA48 - AA54**). If the problem persists, replace the governor with another. Go through the compensation adjustment procedure for the replacement governor. If the hunting and/or surging continues, the problem is in the engine. |
| | B. Compensation adjustments incorrect. | Adjust needle valve and compensation adjusting pointer. |
| | C. Dirty oil in governor - sludge. | Drain oil, clean governor and refill (see **page 18** in the **Operator's Handbook** and **Section AA55 part 5**). |
| | D. Low oil level which permits air to enter and cause foaming. This is evident in the governor as spongy operation. | Add oil to correct level on the oil sight glass. If oil level decreases and no external leaks can be seen, check the drive shaft for oil leaks. If foaming continues, drain oil and refill, using a different type of oil. |
| | E. Oil varnish which causes sticking of parts. | Repair governor. |
| | F. Lost motion in engine linkage to fuel pump injectors. | Repair linkage to fuel pump injectors. |
| | G. Binding in engine linkage to fuel pump injectors. | Repair and re-align linkage to fuel pump injectors. |
| | H. Governor output shaft lever too short to provide full fuel. | Extend lever to give more travel. (Should not be necessary). |
| | I. Spring on yield linkage to fuel pump injectors too weak. (Not on 4012 or 4016 engines). | Install heavier spring.(Not applicable). |

| TROUBLE | CAUSE | CORRECTION |
|---|---|---|
| 2.The engine hunts or surges. - (continued) | J. Low oil pressure. Normal operating pressure 140 to 150 lb/in$^2$ (Pressure test tapping 1/8" NPT in base of governor below 'A' bank output lever). Pump check valves are not seating or accumulator springs weak. | Return governor to Woodward to replace, check valves and/or accumulator springs. |
| | K. Power piston is sticking. | Check for side play or binding of output shaft. |
| | L. Voltage regulator not operating properly (generator sets only). | Check voltage regulator. Operate in voltage droop or manual. Do not disconnect voltage regulator. Adjust, repair or replace voltage regulator. |
| | M. Governor worn. | Return governor to Woodward for repair. |
| | N. Engine misfiring. (Faulty fuel pump injector). | Check fuel pump injectors and repair or replace. |
| | O. Fuel linkage incorrectly set. This might occur if the governor has been changed or removed and replaced. Relationship of governor travel to power output of engine should be linear. | Rework or reset the linkage from governor to unit to obtain the linear relationship. |
| | P. Faulty linkage. | It should be free of binding and lost motion throughout service life of unit. Check links, shutdown arrangements, etc., to be sure that engine torque changes for very small increments of governor output shaft travel. Stability and good steady-state performance will suffer unless this condition is met. |
| | Q. Incorrect non-linear relationship between governor travel and horsepower output of the engine. Engine may hunt with light loads and be stable with a heavy load. | Adjust linkage from governor to pump injectors to obtain linear relationship between governor travel and engine output. |
| | R. Load limit indicator binding on nameplate or load limit shaft bent. (Dial governors only). | Damaged indicator disc or nameplate must be corrected or replaced. Load limit shaft must be replaced if bent. |
| | S. Negative droop when speed droop knob at zero. (Dial governors oniy). | Droop calibration out of adjustment. Reset (see **Section AA49**, Governor Adjustments). |

| TROUBLE | CAUSE | CORRECTION |
|---|---|---|
| 3. Fuel pump injectors do not open quickly when cranking engine. | A. Cranking speed too low. | May be necessary to use a booster servo-motor. |
| | B. Low oil pressure in governor. | Return governor to Woodward for repair. See **item J** above.<br>Inspect drive mechanism. |
| 4. Jiggle at governor output shaft | A. Rough engine to governor drive. | Inspect drive mechanism<br>- Check alignment of gears<br>- Inspect for rough teeth, eccentric gears, or excessive backlash in gear train.<br>- Check gear key and nut securing gear to drive shaft.<br>- Check for bent drive shaft<br>- Check splined shaft drive for wear and alignment.<br>- Check engine vibration dampers. |
| | **NOTE:** The backlash between the gears must be checked and the gear shimmed so that there is no binding and the backlash is not too great. See **Wear and Renewal Limits Tables pages 41-42.** This should be done each time a new or replacement governor is fitted. | |
| | B. Failure of flexible drive in flyweight head. | Return governor to Woodward for repair. |
| | C. Other possible causes are:<br>- dirty or worn ballhead bearing.<br>- rough or worn gear teeth<br>- bent speeder spring<br>- damaged drive shaft seal retainer. | Return governor to Woodward for repair.<br><br><br><br>Replace seal retainer. |
| | D. Air in governor system can cause a jiggle during starting or transient conditions. | Bleed air see **Section AA48,** paragraph 4. |
| 5. Load does not divide properly on interconnected generator sets. | A. Speed settings of the governors are not the same. | Adjust speed settings so both/all engines run at the same speed. |
| | B. Internal speed droop adjustment incorrect. | Re-adjust droop lever assembly to divide load properly.<br>Increase droop to resist acceptance (or shedding) of load.<br>Reduce droop to increase acceptance (or shedding) of load. |

| TROUBLE | CAUSE | CORRECTION |
|---|---|---|
| 6. The engine is slow to respond to a speed change or load change. | A. Needle valve adjustment incorrect. | Re-adjust compensating needle valve. Open it further if possible to do so without causing instability when running without load. Compensation pointer may be too far towards maximum. |
| | B. Governor is not sensetive in measuring speed change (dead band). | Friction or wear on flyweight toes - sludge in governor. Return governor to Woodward. |
| | C. Low oil pressure in governor. | Return governor to Woodward to inspect pump and check valves if oil pressure is low. |
| | D. Engine may be over loaded. | Reduce load. |
| | E. Restricted fuel supply. | Clean fuel supply filters. |
| 7. The engine will not pick up rated full load. | A. Fuel pump injectors will not open far enough for governor at end of stroke. | Adjust engine to governor fuel linkage. Adjust engine fuel stops. |
| | B. Restricted fuel supply. | Clean fuel supply filters. |
| | C. Engine misfiring. | Check injectors and repair or replace. |
| | D. Voltage regulator not functioning (generator sets only). | Readjust or repair. |
| | E. Load limit knob set to restrict fuel (dial governors only) | Increase load limit setting. |
| 8. Governor does not respond to synchroniser motor switch. | Slipping clutch. Binding or worn bevel gears. | Increase compression on clutch spring. Repair or return governor to Woodward. |
| 9. Engine speed increases with an increase in load. | . Droop in negative when zero is indicated on the dial (dial governor only).<br><br>Droop calibration out of adjustment | Reset droop (see **Section AA48 on**). |

**REPAIRS TO UG10 GOVERNOR**

In the event of a failure in service, the governor should be returned to Perkins Engines (Stafford) Limited or a local Woodward governor service agent, who has the facilities and tools available to repair these governors. However, if the operator still wishes to repair his own governor, the tools may be obtained from Perkins Engines (Stafford) Limited.

This governor is very similar in operation to the UG10 already described in **Section AA47**, particularly with regard to the governor drive, control shafts and their functions. However, it does have a larger oil capacity and approximately 2.2 litres of SAE 30 or SAE 15W/40 engine oil is required when this is changed at 6 monthly intervals. (See **Fig. 45AA**).

**REMOVAL AND REPLACEMENT OF THE 3161 GOVERNOR**

As this governor is driven in the same manner as the UG10, the instructions given in **Section AA47** also apply.

**OPERATION OF THE 3161 GOVERNOR**

The governor has been set up and adjusted on engine test before leaving the Perkins Engines (Stafford) works.

> **WARNING** ⚠ BE PREPARED TO MAKE AN EMERGENCY SHUT-DOWN TO PREVENT THE ENGINE RUNNING AWAY OR OVERSPEEDING WHEN FIRST STARTING THE ENGINE AFTER INSTALLATION.

**ADJUSTMENTS (See Fig. 45AA)**

After starting the engine and the governor has taken control, open the needle valve (on the front of the governor below the speed control lever) by turning it anti-clockwise until the governor operation just becomes unstable. Then slowly close the needle valve (clockwise) until the governor just becomes stable. Allow the governor and engine to reach normal running temperature. As the governor warms up, it may become unstable. If so, slowly close the needle valve until the engine just becomes stable. **DO NOT** fully close the needle valve, as this may cause excessive overspeed on starting or load rejection.

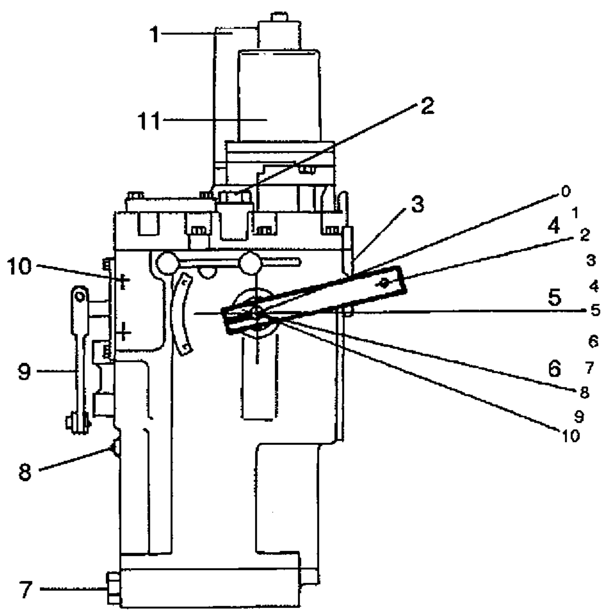



**Fig. 45AA**

**Key**
**(Fig. 45AA)**

**1** Shutdown solenoid
**2** Oil breather cap
**3** Oil level guage
**4** No fuel
**5** Output lever in line with one another
**6** Max fuel
**7** Oil drain plug
**8** Compensation needle valve
**9** Speed control lever
**10** Low speed stop under cover (far side)
**11** Air pressure fuel limiter

**WARNING** ⚠ WITH THE OUTPUT SHAFT OF THE GOVERNOR ROTATED TO THE MINIMUM POSITION, THE ENGINE LINKAGE MUST BE ADJUSTED TO CAUSE SHUTDOWN.

Governor faults are usually revealed as speed variations of the engine. However, it does not necessarily follow that all speed variations indicate governor faults. Check through the governor to localise a problem before substituting another governor, or attempting to dismantle and repair the one originally fitted to the engine.

Use the following **Fault Tracing Chart** in **Sections AA61 - AA64** to diagnose the problem. If governor calibration is indicated, refer to Perkins Engines (Stafford) Limited.

**NOTE:** There is no facility for checking governor oil pressure on the 3161 governor.

## FAULT TRACING CHART FOR 3161 GOVERNOR

**WARNING** TO PROTECT AGAINST POSSIBLE PERSONAL INJURY, LOSS OF LIFE AND/OR PROPERTY DAMAGE WHEN STARTING THE ENGINE, BE PREPARED TO INITIATE AN EMERGENCY SHUTDOWN TO PREVENT ENGINE RUNAWAY OR OVERSPEEDING SHOULD THE GOVERNOR OR SOLENOID, AIR SHUT-OFF VALVES, FUEL CONTROLS, DRIVING MECHANISM, LINKAGES OR CONTROL DEVICES FAIL.

Engine cranks, but governor output shaft does not move from minimum position.

With manual assistance, governor output shaft can easily be moved towards maximum while cranking.

NO

1 Are there any shutdown devices activated or incorrectly adjusted?
2 Is speed setting above cranking speed?
3 Is linkage free from excessive fiction?
4 Is load limit set at zero?
5 If fuel limiter is used, is it correctly adjusted?

YES

1 Is governor filled with oil?
2 Is the rotation of the pump set correctly?
3 Have you cranked the engine for at least 10 seconds to allow the governor time to develop pressure?
4 Is the drive shaft connected?
5 Is the oil viscosity greater than SAE 30 or 15W/40?
6 Is the cranking speed too low?

---

Governor opens fuel, but is slow and sluggish

1 Are shutdowns properly adjusted?
2 Is the governor oil viscosity less than SAE 30 15W/40, or above SAE 70 engine oil?
3 Is the needle valve closed too far?
4 Is the linkage to the engine free?

---

Governor opens fuel, but only part way.

1 Is the load limit adjusted properly, and set at maximum?
2 Is there adequate manifold pressure? (applies to fuel limit type governors)
3 Is the fuel stop on engine adjusted properly?
4 Is the fuel stop in governor set properly?
5 Is the fuel linkage free?

Governor opens fuel and engine starts, but trips out on overspeed.

1 Is the linkage sticky?
2 Is the linkage properly adjusted?
3 Is the overspeed trip set properly?
4 Is the needle valve closed too far?
5 Is the governor speed setting too high?

---

Engine cranks, but governor output shaft does not move from minimum position.

With manual assistance, governor output shaft can easily be moved towards maximum while cranking.

NO

1 Is the load limit set at maximum, and adjusted properly?
2 Is the fuel limiter (if so equipped) set too low?
3 Is there adequate air pressure for the fuel limiter?
4 Is the linkage sticky or improperly adjusted?

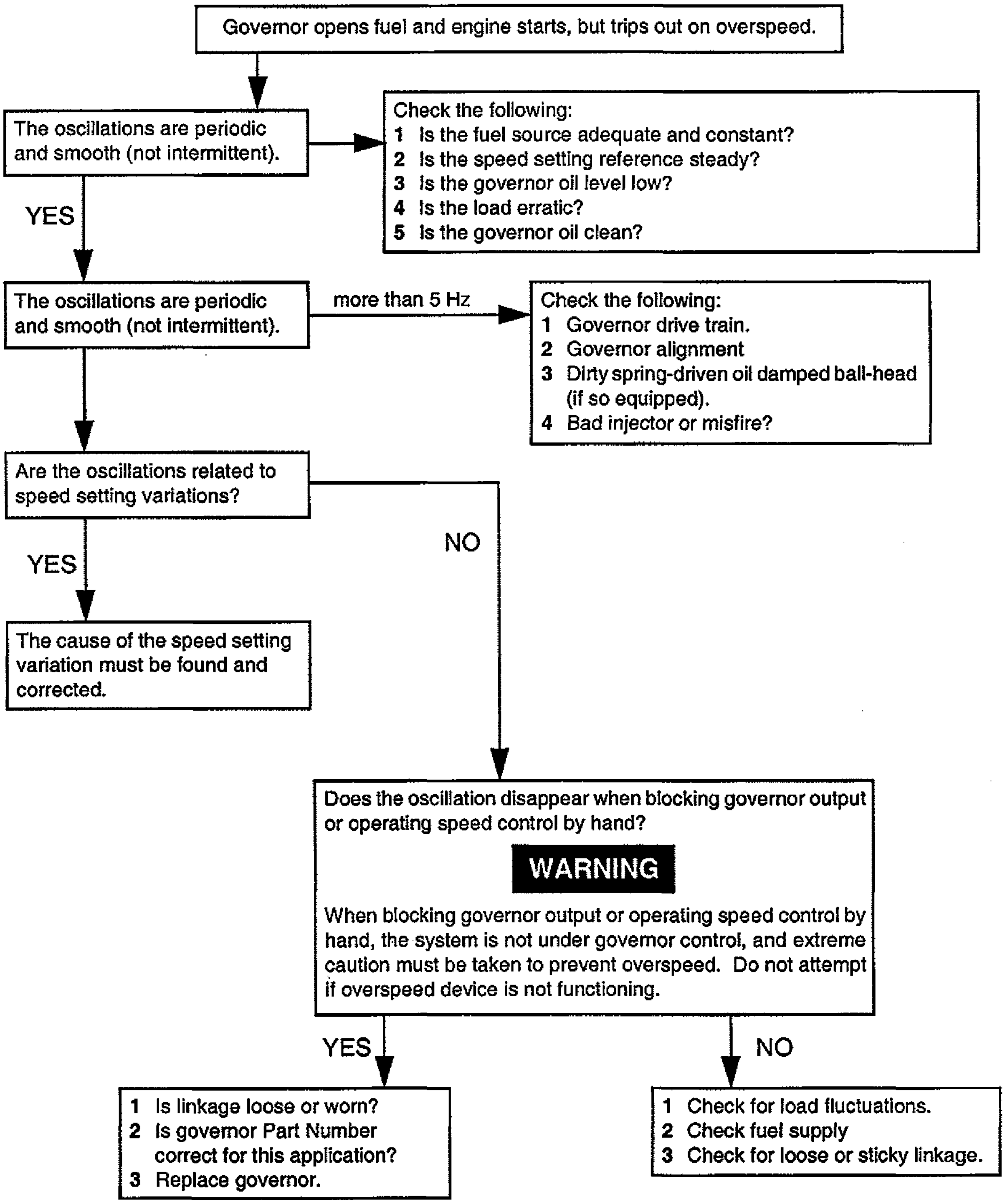
YES

1 Is the linkage adjusted properly?
2 Is the load excessive?
3 Is the voltage regulator (if used) set properly?
4 Is the fuel stop on the engine set correctly?

---

System oscillated and is unstable

Check the following:
1 Is the droop set properly?
2 Is the needle valve correctly adjusted?
3 Is the linkage sticky or worn?


Governor opens fuel and engine starts, but trips out on overspeed.
The oscillations are periodic and smooth (not intermittent).
Check the following:
1 Is the fuel source adequate and constant?
2 Is the speed setting reference steady?
3 Is the governor oil level low?
4 Is the load erratic?
5 Is the governor oil clean?
YES
The oscillations are periodic and smooth (not intermittent).
more than 5 Hz
Check the following:
1 Governor drive train.
2 Governor alignment
3 Dirty spring-driven oil damped ball-head (if so equipped).
4 Bad injector or misfire?
Are the oscillations related to speed setting variations?
NO
YES
The cause of the speed setting variation must be found and corrected.
Does the oscillation disappear when blocking governor output or operating speed control by hand?
WARNING
When blocking governor output or operating speed control by hand, the system is not under governor control, and extreme caution must be taken to prevent overspeed. Do not attempt if overspeed device is not functioning.
YES
NO
1 Is linkage loose or worn?
2 Is governor Part Number correct for this application?
3 Replace governor.
1 Check for load fluctuations.
2 Check fuel supply
3 Check for loose or sticky linkage.

Governor will not shut engine down.

↓

Is the governor at minimum fuel position?

YES → Linkage is improperly set to allow shut-down.

NO →
1 Is the shut-down actuation signal available at the governor?
2 Are the shut-downs properly adjusted?
3 Is the shut-down strap in governor properly adjusted?
4 Close off fuel and replace governor.

## REPAIRS TO 3161 GOVERNOR

In the event of a failure in service, the governor should be returned to Perkins Engines (Stafford) Limited or a local Woodward Governor Service Agent, who has the facilities and tools available to repair these governors.

However, if the operator still wishes to repair his own governor, the tools may be obtained from Perkins Engines (Stafford) Limited.

**WARNING** ⚠ THE ENGINE MUST BE EQUIPPED WITH AN INDEPENDENT SEPARATE OVERSPEED SHUTDOWN DEVICE. WHEN THE ENGINE IS RUNNING THE BATTERY MUST NOT BE DISCONNECTED.

## GENERAL DESCRIPTION

The Woodward Proact 24 Vdc governor system is fitted to the engine and adjusted on test at the works. It comprises:-

1) an electromagnetic pick up, which measures the engine speed by reference to the flywheel gear teeth. See **Fig. 47AA**.
2) a programmable digital speed control panel.
3) an actuator to position the fuel control links.

## OPERATION

**1** The speed pick-up measures the actual speed of the engine at the flywheel gear ring and forwards the information to the control unit. In the control box the actual speed is compared with the set-point speed and the resulting discrepancy causes the control circuity to adjust the actuator position, the fuel delivery rate and thus the engine speed.

**2** If, due to a load change a discrepancy exists between the set-point and speed pick-up figures, the control electronics remove the discrepancy by returning the engine speed to its original settings, i.e. isochronous regulation.

**3** If the speed pick-up signal is interrupted, e.g. by a cable breakage or the engine stopping, a safety circuit ensures the shutdown of the actuator drive.

**4** The internal governor spring returns the actuator lever to the 'stop' position.

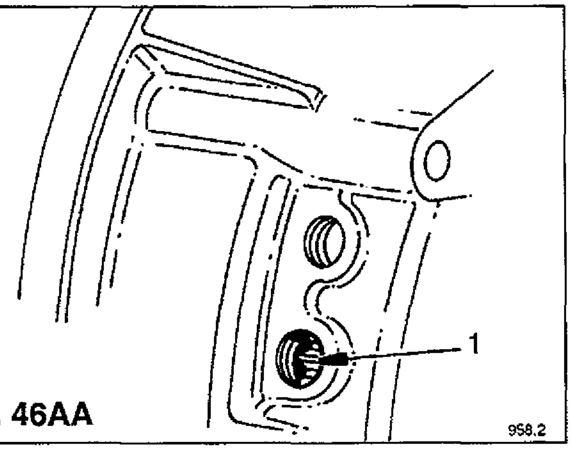



**Fig. 46AA**

**5** Furthermore, if any of the set point potentiometer cables become disconnected, the actuator will move to the 'zero fuel' position until the engine stops.

**6** The shutoff devices described above do not replace the usual engine overspeed protection equipment.

**Key**
**(Fig. 46AA)**

**1** Crest of gear tooth

## INSTALLATION OF THE MAGNETIC PICK-UP

The magnetic pick-up is fitted in the flywheel housing, close to the teeth of the starter ring gear (see **Fig. 46AA**), and should be fitted as follows:-

1 Turn the engine until the top or crest of a gear tooth is in the centre of the pick-up head location diameter (see **Fig. 46AA**).
2 Screw the pick-up head into the flywheel housing.
3 Screw the pick-up head further into the flywheel housing until it lightly touches the crest of the gear tooth.
4 Unscrew the pick-up head half a turn.
5 **Without moving the pick-up**, screw the locknut down to the flywheel housing and tighten the locknut (see **Fig. 47AA**).

**NOTE:** The inside of the flywheel housing should be kept clean, since the pick-up head being magnetic will attract and may be affected by particles of ferrous metal.

## OPERATION

Because of the high pull in current, and the fact that the solenoid is energised to run (E.T.R.), it is important that the following instructions are adhered to:

1 Starting batteries must be a minimum of 232 amp/hour capacity at 20 hour rate.
2 Careful setting of the mechanical linkage is essential to ensure that the solenoid pull in the coil supply is broken when on full stroke. This can be checked by connecting a 24V indicator lamp across the auxiliary terminal on the solenoid and battery negative; the lamp will illuminate when the pull in coil is de-energised. See **Fig. 49AA**.
3 The starting circuit is designed to allow the solenoid to be energised before cranking commences, by the use of a relay, as shown on the wiring diagrams in the **Operators Handbook pages 66 onwards.**

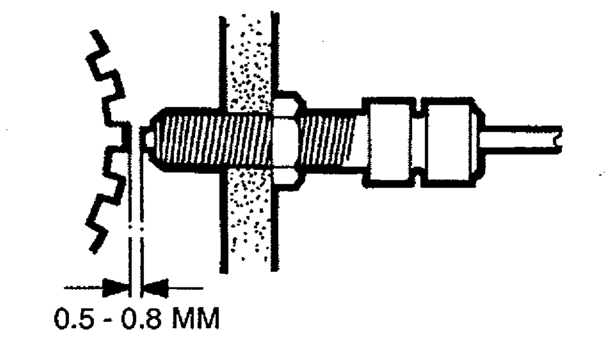



**Fig. 47AA**

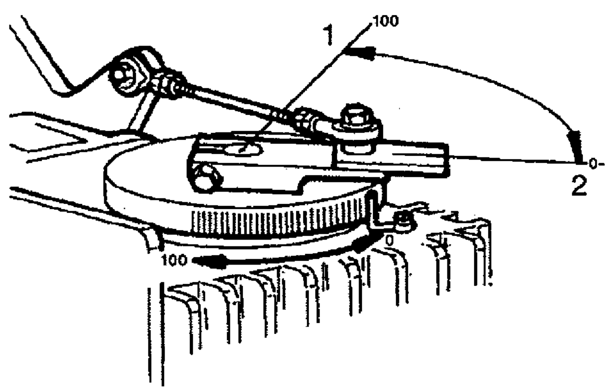



**Fig. 48AA**

**Key**
**(Fig. 48AA)**
1 Maximum fuel position
2 No load position

## FITTING INSTRUCTIONS FOR SYNCHRO-START STOP SOLENOID

1 Align stop levers to governor output levers on actuator output shaft.
2 Set governor output levers in the maximum fuel position (with the pointer towards '100') as far as the levers will go, without disturbing the fuel stops. **Fig. 48AA**.
3 Bench assemble solenoid, brackets and plunger assemblies.
4 Fit solenoid assemblies to actuator support bracket, leaving the securing screws slack.
5 Hold solenoid in energised position, and position assembly so that the plunger clears the roller in maximum fuel position by 1 to 3 mm. **Fig. 50AA**.
6 Tighten securing screws and check movement of lever and alignment of plunger.
7 Wire as per wiring diagram.

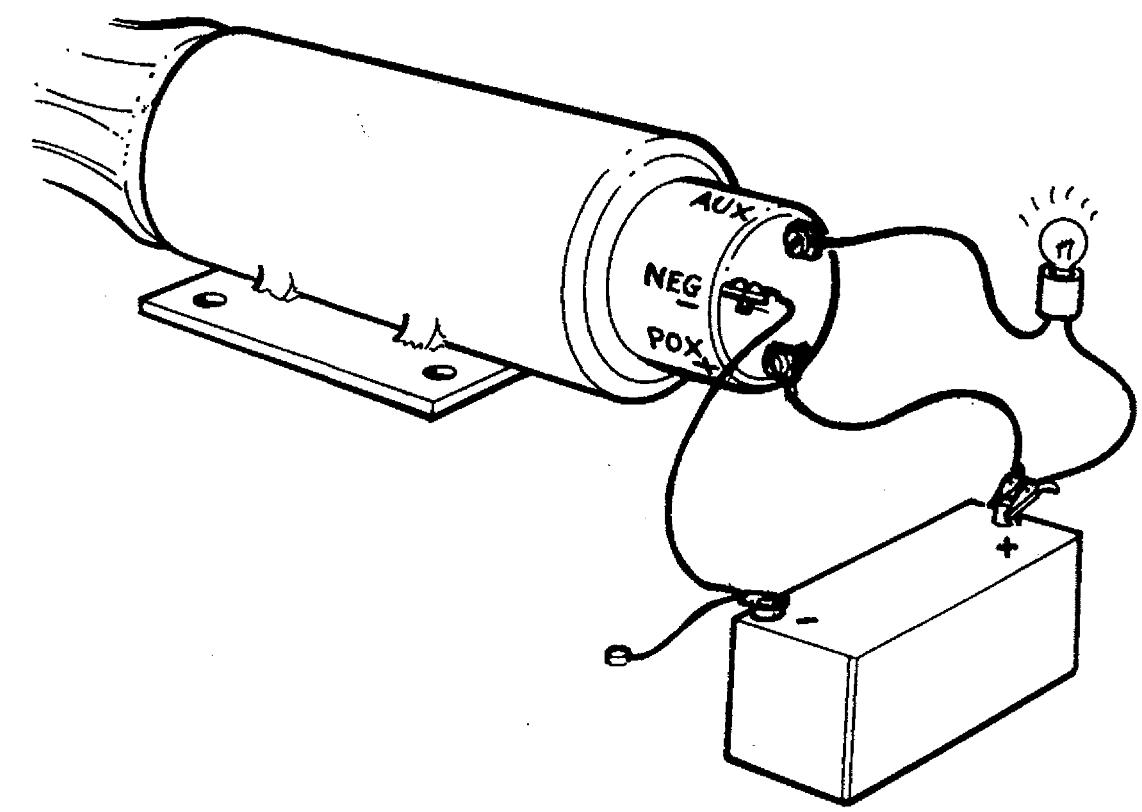



Fig. 49AA

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## REPLACING THE SOLENOID

1 Disconnect the wiring and remove the 4-fixing bolts from the solenoid mounting bracket.
2 Bolt the replacement solenoid to the support bracket.
3 Check that the solenoid assembly (see **Fig. 4Z**) operates as per the above fitting instructions.

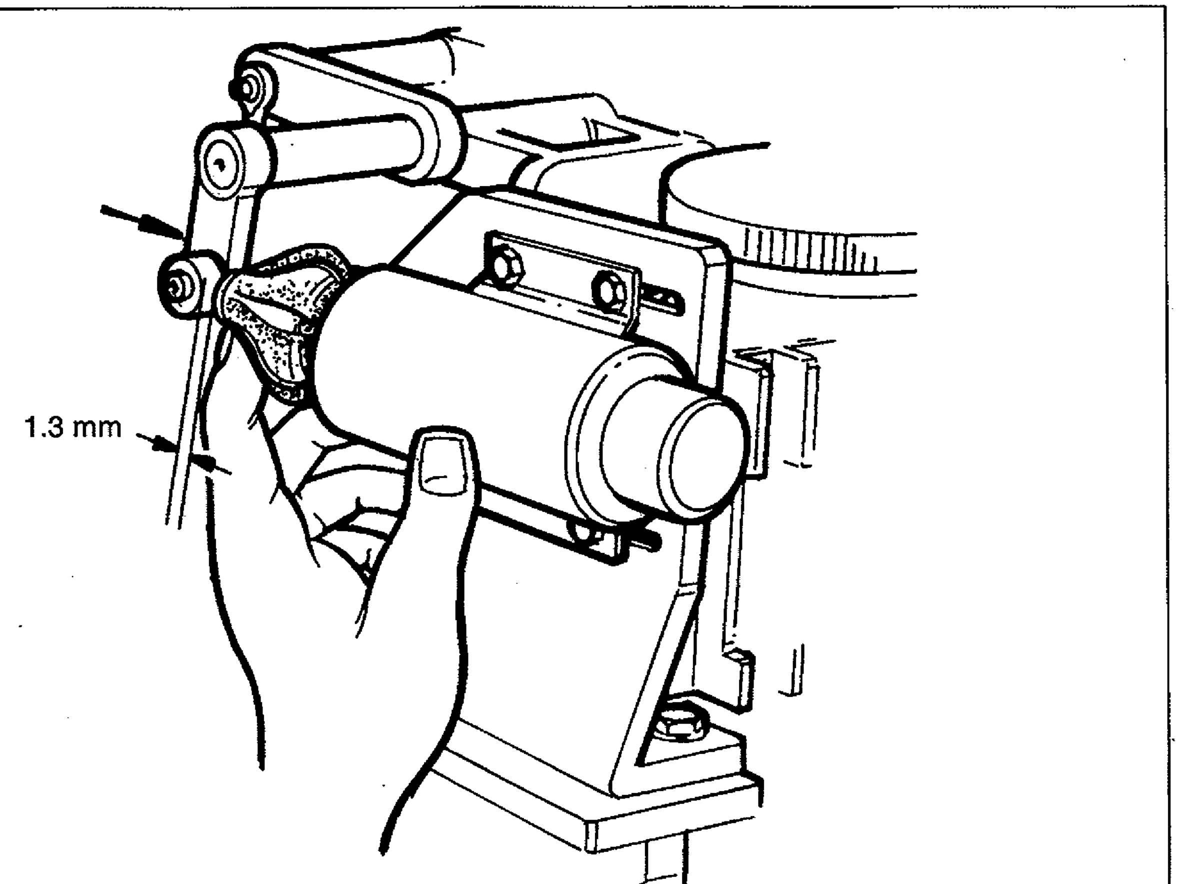


**Fig. 50AA**

**WARNING** ⚠ DISCONNECT BATTERIES AND ALL OTHER MEANS OF STARTING THE ENGINE. FOR SAFE OPERATION, PARTICULARLY THE ABILITY TO STOP THE ENGINE, CHECK THAT THE ACTUATOR WILL POSITION THE FUEL INJECTORS IN THE NO FUEL POSITION i.e. AT ACTUATOR POSITION 10 THE INJECTOR CONTROL ARMS MUST BE IN THE NO FUEL POSITION.

**REMOVING THE ACTUATOR (SEE FIG. 51AA)**

Disconnect the control lever 'A' and the multi-pin plug 'B' remove the four 5/16 UNC screws 'C' from back of the support bracket. Then carefully lift the actuator away from the engine.

**REPLACING THE ACTUATOR (SEE FIG. 51AA)**

Taking a firm grip of the actuator, place it in position and insert the four screws and spring washers 'C', tighten them down to 12.5 - 13,3 lbft (17-18 Nm). With the actuator in the no fuel position (see **Section ??**) fit the control lever 'A', then reconnect the multi-pin plug 'B'.

**WARNING** ⚠ ELECTRONIC EQUIPMENT IS STATIC SENSITIVE. TAKE PRECAUTIONS TO AVOID ELECTROSTATIC DISCHARGES, ESPECIALLY IF WORKING ON THE CONTROL PANEL.

**ELECTRONIC CONTROL PANEL (FIG. 46AA ITEM 2)**

This must not be mounted on the engine and is therefore the responsibility of the generator set manufacturer. It is only connected to the engine by the leads to the actuator and the magnetic pick-up.

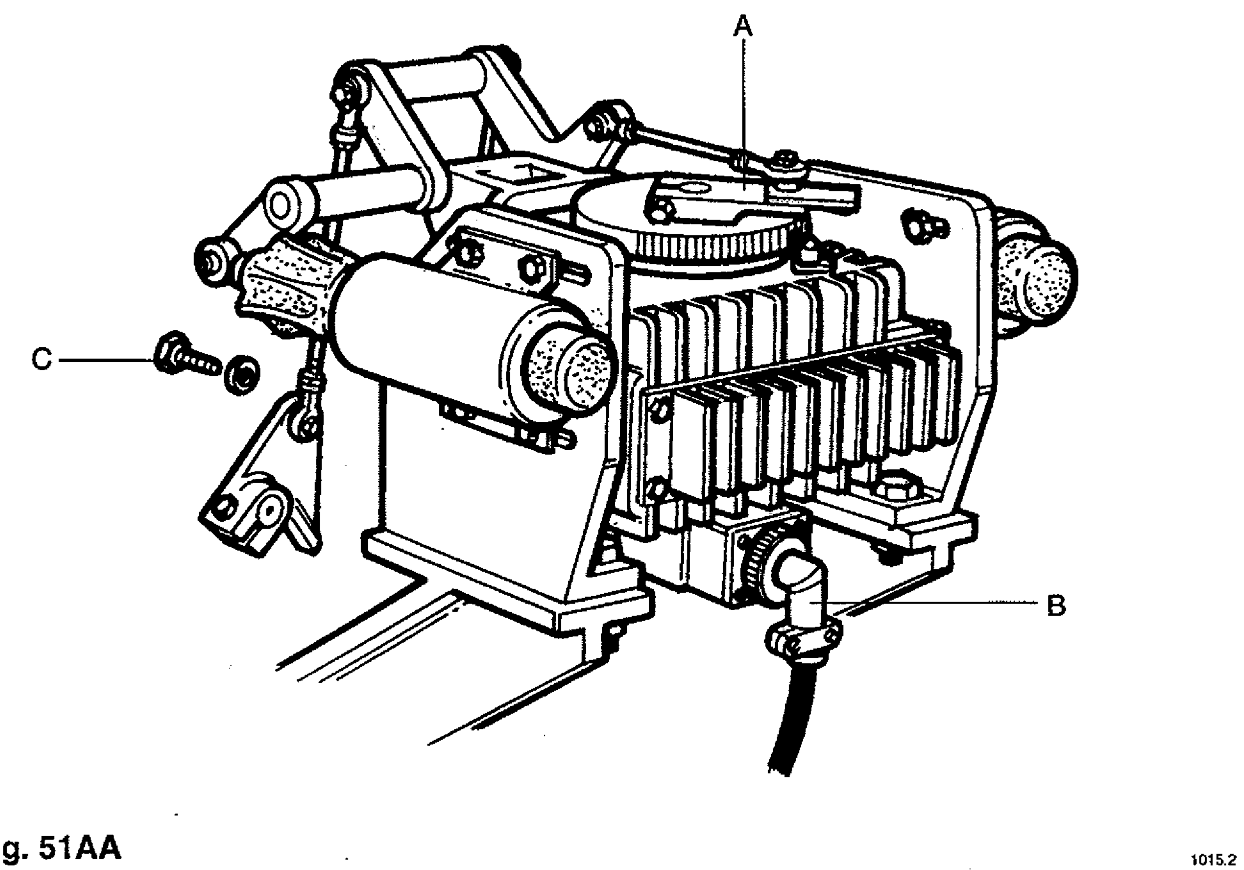


Fig. 51AA

**WARNING** ⚠ NEVER START THE ENGINE WITH THE GOVERNOR LINKAGE DISCONNECTED.

## DESCRIPTION

Fuel pump injector opening is controlled by the actuator/governor mounted at the free-end of the engine.

Movement of the actuator/governor output shaft is transmitted via output levers (1) to control shafts (2) and (3) mounted inside the engine camshaft trough and running the full length of the engine.

Each control shaft is carried in hanger bearings (4) within the crankcase and bearing (5) in the timing cover. Seal (6) prevents leakage of oil from the bearing. Control shaft longitudinal movement is controlled by lever (8) to the front and circlip (7) to the rear of bearing (5). An additional circlip (9) is fitted to the rear end of 'A' bank control shaft (2).

Levers (10) pinned to the control shafts opposite each cylinder position, transmit the motion via connecting links (11), break-back lever assemblies (12) and turnbuckle assemblies (13) to the pump injector operating arms.

The bores of the output levers (1) are serrated to provide a positive fit and are clamped to the shafts, each side of the actuator/governor by nuts and screws.

Levers (8) are keyed to the control shafts and are clamped by nuts and screws which also engage with grooves in the shafts.

The ball-ends have a limited amount of adjustment to provide for equalisation of the effective length of the links (14).

Later engines have turnbuckles with right and left hand threads to facilitate these adjustments.

The break-back lever assemblies (12) are incorporated in the control system to provide for a positive movement to the **'FULL FUEL'** position and a spring return to the **'NO FUEL'** position. Thus should one fuel pump stick, the remaining pumps will be returned to the **'NO FUEL'** position and therefore stop the engine.

Adjustment of the pump injectors relative to one another and to the control shaft levers is by the turnbuckle assemblies (13).

## THE FUEL CONTROL SHAFTS

Under normal circumstances the fuel control shafts need not be removed from the engine, even at a major overhaul. However they must be free to move, so if a tight spot has developed it must be eliminated, as it will affect the governor's ability to control the engine. The end float of the shafts should be limited to 0.005" (0.127 mm) maximum.

**Key**
**(Fig. 1BB)**

- **A** Actuator/governor (typical)
- **1** Actuator/governor lever
- **2** Control shaft 'A' bank
- **3** Control shaft 'B' bank
- **4** Hanger bearing
- **5** Free-end bearing
- **6** Oil seal
- **7** Circlip
- **8** Control shaft lever (outside)
- **9** Circlip
- **10** Control shaft lever (inside)
- **11** Connecting link
- **12** Break-back lever assembly
- **13** Turnbuckle assembly
- **14** Control link

Drain the cooling water system.
Remove the radiator complete with fan guard and belts (if fitted).
Remove the water outlet pipes to thermostats.
Remove the exhaust manifolds as an assembly in one piece, from each bank.
Remove the screw and nut securing connecting link (11), to break-back lever (12), release securing nut and washer and remove break-back assembly complete with turnbuckle (13) from each cylinder. Release the screws and remove the connecting links (11). Remove the oil supply pipes and the cam follower housings.
Remove the screws and control links (14) [complete with turnbuckles and nuts, if fitted].
Remove the governor complete with levers (1). If the levers are to be removed from the governor, mark their positions relative to the shafts before removal to ensure correct replacement later.
Remove the clamping nuts, withdraw the screws from the levers (8), draw the levers off the control shafts and remove the keys.
Remove the screws and bolts and draw the front end control shaft bearings (5) out of the timing cover and off the control shafts.
Remove the screws and spring washers securing the hanger bearings (4) to the crankcase and carefully withdraw them with each control shaft assembly from the crankcase, the timing cover having 'keyhole' shaped apertures to allow the shafts with bearings to be withdrawn through it.

**DO NOT DISMANTLE THE CONTROL SHAFT ASSEMBLIES UNLESS RENEWAL OF ANY OF THE COMPONENT PARTS IS REQUIRED.**

The control shaft assemblies may be dismantled by driving the retaining pins out of the levers and sliding the levers and hanger bearings off the shaft after removal of the circlips (9) and (7).

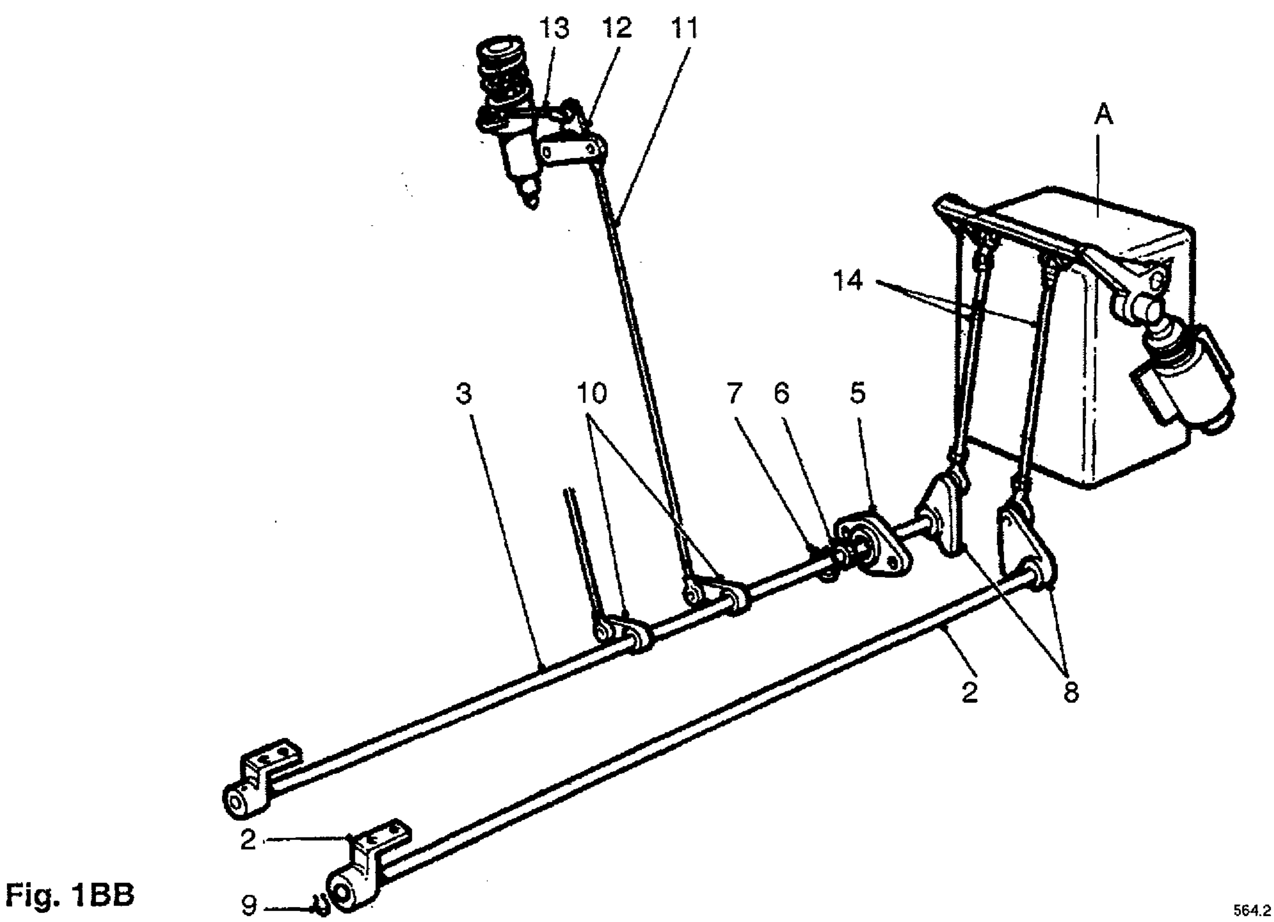


Fig. 1BB

## INSPECTION

As the major portion of the linkage is contained within the camshaft or cylinder head space, it is operating at all times under oil mist conditions and very little wear will occur.

Check the break-back lever assemblies for smoothness of operation on their pins. Check the condition of the break-back lever spring. A minimum load of 2 lb (0.9 kg) should be required to cause the levers to separate. This can be checked by fixing the output break-back lever in a vice, and hooking a spring balance into the input lever bolt hole (see **Fig. 2BB**). If the load is less than 2 lb (0.9 kg) the break-back lever assembly should be dismantled and a new spring fitted.

Examine the fixed length control links (11) for straightness and twist. Renew if bent or damaged in any way. **DO NOT ATTEMPT TO STRAIGHTEN THEM.**

Examine the oil seals (6) fitted to the front end bearing housings (5) for wear to the sealing lips. Check for condition of the seal body material as the seal may have to be changed due to hardening caused by heat and age rather than by wear.

Check the ball joints of the control links (14) for wear. A maximum of 0.005 in (0.127 mm) movement may be allowed before renewal is necessary. **MEASURE AND RECORD THE OVERALL LENGTH OF EACH LINK BEFORE DISMANTLING.**

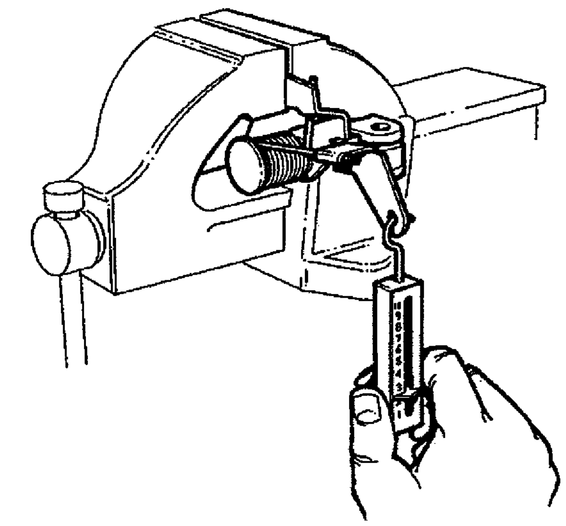

**Fig. 2BB**

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**TO ASSEMBLE AND FIT (refer to Fig. 1BB)**

The following procedure is based on the assumption that the control linkage has been completely dismantled for the renewal of components.

Assemble the levers (10) and bearings (4) to control shafts (2) and (3) as indicated in **Fig. 3BB**. Note that the levers and bearing brackets are reversed for 'A' and 'B' banks. Use new pins when fitting the levers. Fit circlips (7) to the free-ends of both shafts and circlip (9) to the drive-end of 'A' bank shaft.

Insert the control shafts into the crankcase, move the hanger bearings into position on the upper face of the crankcase and secure with screws and spring washers.

Press new oil seals (6) into the free-end bearings (5) and using new joints fit the bearings to the timing cover and secure with screws, bolts and spring washers. Care must be taken when sliding the oil seals onto the shafts not to damage the sealing lips.

Fit the keys to the control shafts, slide the levers (8) onto the shafts, position and insert the screws. Fit the locking nuts and tighten securely.

Fit the levers (1) to the actuator/governor output shafts aligning the shaft to lever markings, fit the clamping bolts and nuts and tighten securely. Check the end float which must be 0.005 in. (0.127 mm) maximum.

Fit the governor or governor actuator to the engine.

Fit the locknuts, turnbuckles and new ball joints to the control links (14) set to the previously recorded dimensions and tighten the locknuts.

Fit the assemblies (14) between the actuator/governor levers and the control shaft levers and secure with screws to the levers.

Position the connecting links (11) on the bossed side of the levers (10) and securely fasten them to the levers with Loctite on the hexagon screw threads.

Fit the cam follower housings, and the heat shields to the centre of the engine 'V'.

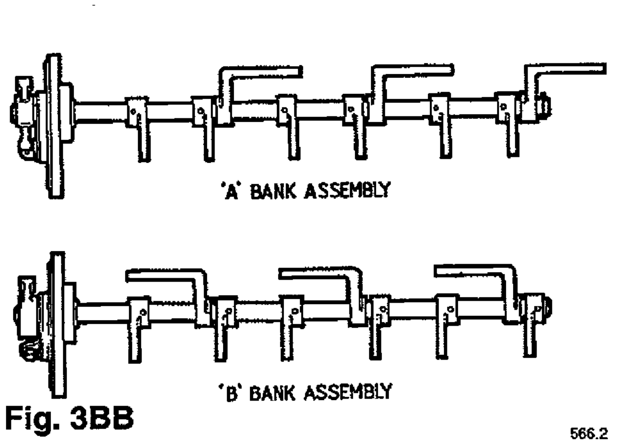


**Fig. 3BB**

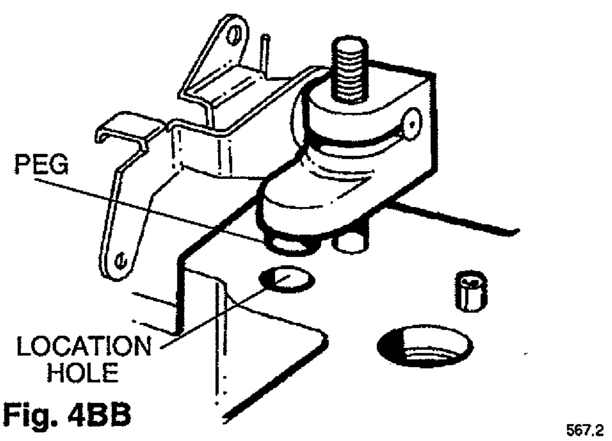


**Fig. 4BB**

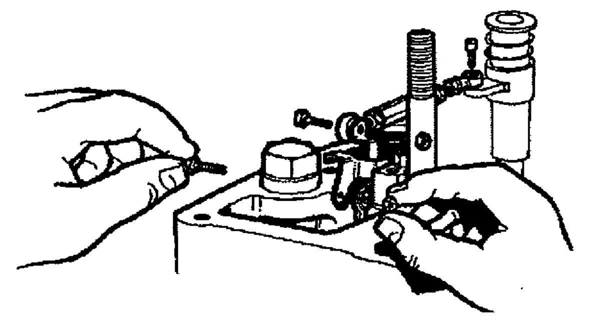


**Fig. 5BB**

Fit the break-back assembly (12) to each cylinder head, ensuring that the location peg (see **Fig. 4BB**) is correctly engaged and secured with a plain washer, spring washer and nut to the fixing stud.

Secure the connecting links (11) to the break-back levers with the screws and locknuts (see **Fig. 5BB**).

**SETTING UP PROCEDURE (refer to Fig. 1BB)**

With the control shaft assemblies fitted on the engine and the connecting links fitted between the control shafts and the break-back levers on the cylinder heads, but with the turn-buckle assemblies still disconnected from the injectors, proceed as follows with reference to **Fig. 6BB**.

Rotate the left hand bank lever (8) as far anti-clockwise as possible, using minimal force, to use this position as a datum. Rotate this lever 5° (±1°) clockwise, mark the bearing housing (5) and the lever (8) and lock up.

Rotate the right hand bank lever (8) as far clockwise as possible, using minimal force, to use this position as a datum. Rotate this lever 5° (±1°) anti-clockwise, mark the bearing housing (5) and the lever (8) and lock up.

**Key**
**(Fig. 6BB)**

**A** Control link
**B** Stop lever
**C** Fuel stop
**D** LH Bank
**E** RH Bank
**F** View on front end
**G** Control link
**H** Stop lever
**I** Fuel stop
**J** Inscribed lines

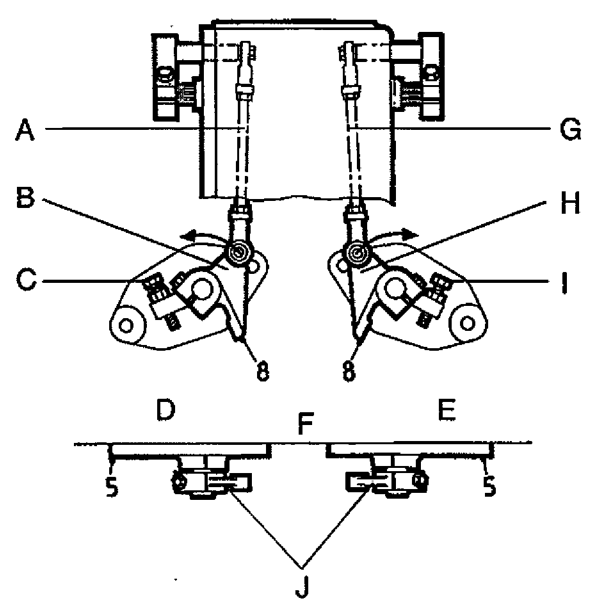


Fig. 6BB

Set the actuator pointer to '0' on Heinzmann E16, Regulateurs Europa type 2100, Woodward UG10 or 3161 governors and lock up. Connect the actuator levers to the respective fuel control links (14) so that the ball joints are free and not binding, ensuring that the correct washers, spacers and locking devices are fitted.
Re-set the actuator pointer to '10' on Heinzmann type E16, position '2' on Regulateurs Europa or the Woodward governors.
Fit the first injector in the clamp and insert it into the cylinder head, rotating the injector clamp anti-clockwise before tightening the clamping capscrew (see **Fig. 7BB**).
With the actuator/governor lever still locked in position '10' on the Heinzmann E16 or position '2' on the Regulateurs Europa or Woodward governors, set No. 1 injector left hand bank to the **NO FUEL** position using the official tool **T6253/177**, then connect the break-back lever to the injector arm with the turnbuckle assembly (13) ensuring that the left hand threaded ball joint is fitted to the injector lever (see **Section P14**) and the thread engagements of the ball joints to the turnbuckle are equal i.e. at least 7 threads (adjust the turnbuckle if necessary) unlock the actuator arm and position the actuator so that No. 1 injector left hand bank is at the calibration position (see **Fig. 24P**) and lock the actuator.
Set all the other injectors at the calibration position (left hand bank and right hand bank) and connect up to the break-back levers with the turnbuckles, then unlock the actuator.
Reposition the actuator/governor lever to '10' on Heinzmann E16 or position '2' on Regulateurs Europa or Woodward governors, lock up and check with tool **T6253/177** that ALL injectors are in the **NO FUEL** position. Unlock the actuator/governor lever and move to the full fuel position (80% on up rate engine) and back to **NO FUEL**. If the injectors do not return to the **NO FUEL** position, reset them.
Check that all the linkage is securely tightened to the recommendations and that it is free in all positions.

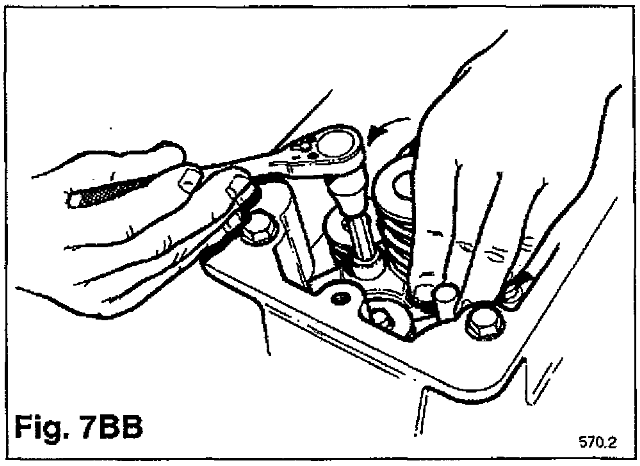

**Fig. 7BB**

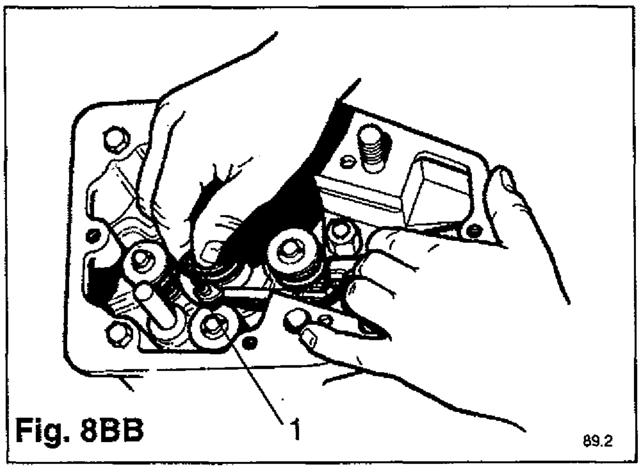

**Fig. 8BB**

Should the engine need to be derated to suit actual site conditions, then the fuel stops will have to be reset to give the lower site rating (see **page 18** for the derating procedure).

**NOTE:** Do not forget to place the spacing collar between each ball joint and the pump injector arm.

Complete the re-assembly of the engine.

**Key**
**(Fig. 8BB)**
**1** Spacing collar

Before resetting protection equipment, it must be established whether special settings (for that individual engine) have been specified in the engine sales contract. This is particularly important with ALL high water temperature settings, and ALL Cogen applications.

## (LOW OIL PRESSURE AND HIGH WATER TEMPERATURE)

## GENERAL DESCRIPTION

The type DBG dual switch unit gives protection against high water temperature (rising signal) and low lubricating oil pressure (falling signal).

To operate the high water temperature switch, the unit is fitted with a sensing phial (1) is immersed in the coolant at the thermostat housing and is sensitive to temperature changes by the expansion of a thermometric fluid. Later engines have a pocket to enable the switch to be removed without draining the water system.

The low lubricating oil pressure switch, operated by a diaphragm piped (2) into the engine lubricating oil circuit (see **Fig. 1FF**) at pre-set temperatures and pressures.

An electrical circuit is made or broken, when fault conditions occur.

The type DBG dual protection switch is wired to work in conjunction with the engine mounted stopping solenoid **(see Operators Handbook page 66).**

The DBG dual switch is preset however should it be necessary to make a slight adjustment, this can be carried out by removing the 4 screws and the front cover marked 'T' (3). The top adjuster screw (4) is for setting the pressure (i.e. one turn 0.65-2.1 bar) and the bottom adjuster screw (5) is for setting the temperature (i.e. one turn 24-30°C).

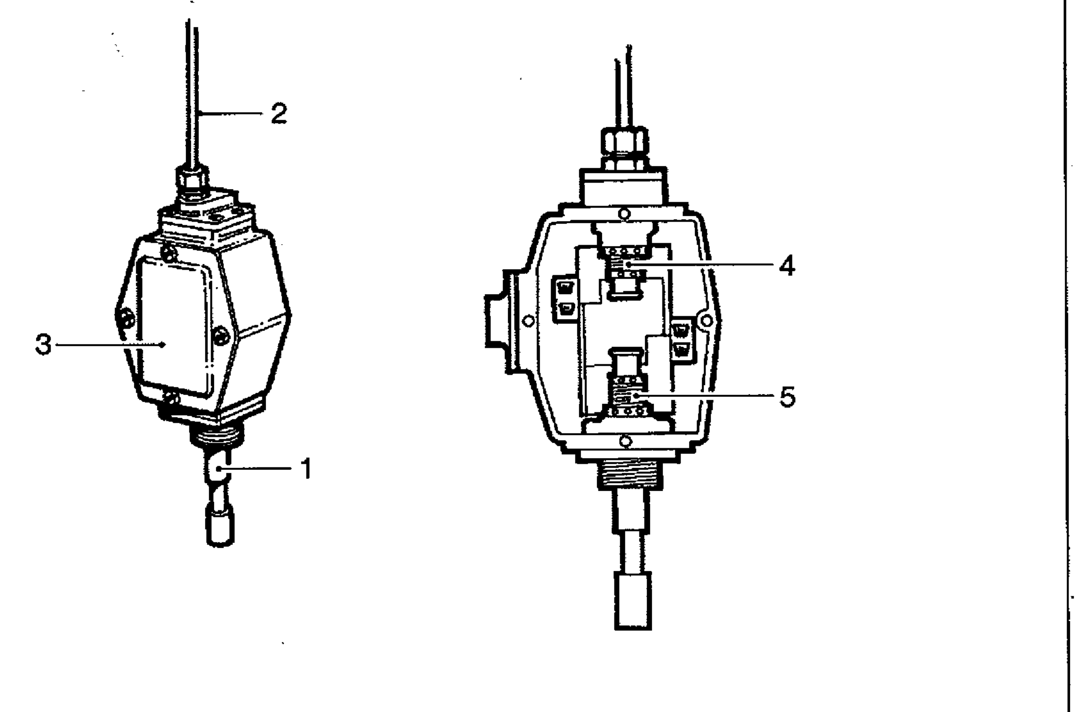


**Fig. 1FF**

## STANDARD SETTINGS

| | Alarm | Shutdown |
|---|---|---|
| High water temperature | | |
| 71°C Thermostat | 91°C | 96°C |
| 85°C Thermostat | 96°C | 101°C |
| 96°C Thermostat | 100°C | 105°C |
| Low oil pressure | 2.06 bar (30lb/in$^2$) | 1.93 bar (28lb/in$^2$) |

**Caution:** The above standard settings do not supersede any settings specified in the engine sales contract.

## WIRING

To reach the terminals for wiring remove the front cover marked 'T' (3). The pressure terminals are marked 1. Common, 3. Mof, 2. Bof, and the temperature terminals are marked 6. Mor, 5. Bor, 4. Common. There is a tab terminal for earth connection adjacent to the No. 6 wiring tab.

**NOTE:** The adjustment details for pressure, temperature and terminal markings are shown on the inside of the front cover (3). Terminal markings Bof = break on fall, Bor = break on rise, Mof = make on fall and Mor = make on rise.

## GENERAL DESCRIPTION

A repeater relay unit is included in the starter motor circuit in case the pinion fails to make a clean engagement when the starting signal is received from a remote location.

If no more than a brief tooth to tooth abutment occurs between the starter motor pinion and the flywheel ring gear, the repeater relay will sense this condition and repeatedly de-energise and re-energise the starter motor until a clean engagement is achieved and the engine is started.

## OPERATION

When the start button 'S' is operated, current flows from the battery via the normally closed contacts 'NC' to the 2ST or 33RA relay to energise the starter and the relay coils RLC1 and RLC2. The return path for these two coils is provided via transistor T1 to the battery negative and a capacitor 'C' is connected in series with RLC1. The diode D1 is provided to protect the unit by short circuiting the reverse polarity voltage spikes which occur when the relay 2ST is switched off.

The two coils RLC1 and RLC2 are wound in opposition and the effect is for them to cancel each other so the contacts 'NC' remain closed. However as capacitor 'C' charges, the current through RLC1 decreases and if the starter does not engage correctly will eventually fail to zero. This allows the current through RLC2 to open the contacts 'NC' and to disconnect the supply to the starter circuit. The capacitor 'C' then discharges through the relay coils and near the end of this discharge allows the contacts 'NC' to close and thus restart the cycle.

If a faultless engagement occurs, the main contacts inside the starter close and apply the battery positive via starter terminal 'A' to terminal 'A' on the 381 repeater relay. This current is applied to the base of transistor T1 via a resistor R1 and causes the transistor T1 to turn off. The current flow through the coils RLC1 and RLC2 is thus interrupted and the relay remains inert. Resistor R2 in conjunction with R1 provides for the correct

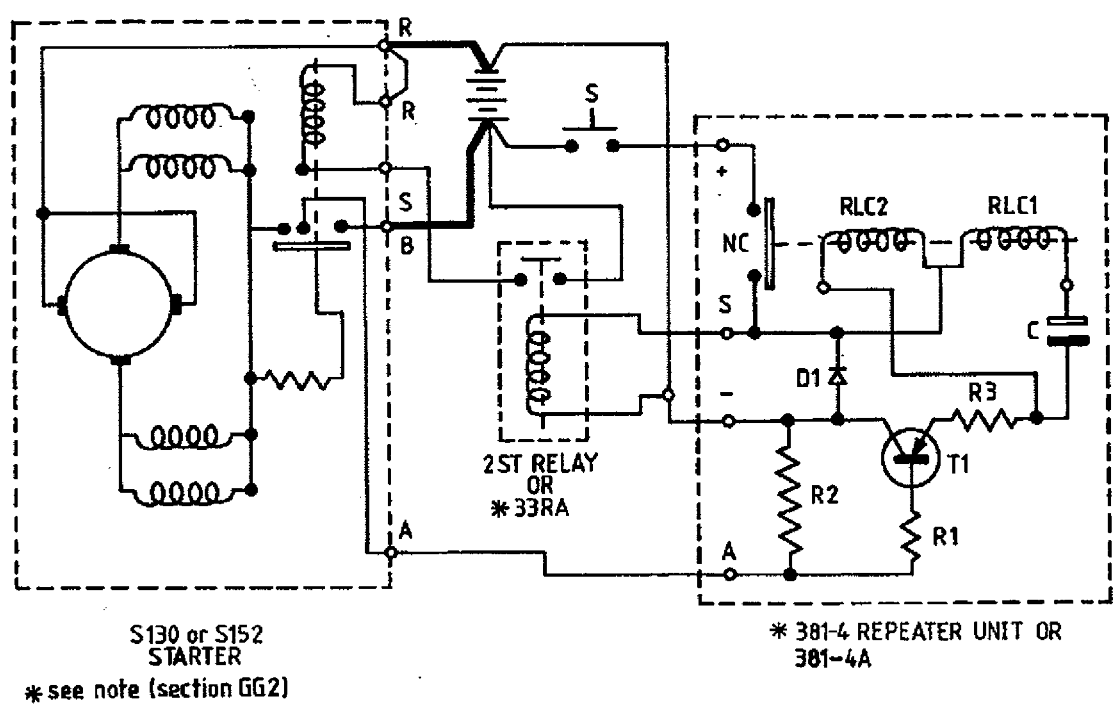


Fig. 1GG

## REPEATER RELAY REPLACEMENT

In the event of a repeater relay failure, then the unit should be replaced by a new one. If the 2ST relay is replaced by a 33RA relay then it is essential that the existing 381-4 repeater relay be replaced by a modified repeater relay, otherwise the starter keeps running after engine start up.

Replacement units are available with modified relays and are identified by means of a black spot of paint as illustrated in **Fig. 2GG**.

**NOTE:** Unmodified repeater relays fitted with start relay type 33RA on engines bearing a serial number where the second group of numbers are 0185 / to / 1085 / showing them to have been built between January and October 1985 should be reported to Perkins Engines (Stafford) Service Department for exchanges to be made.

New relays have been designated type 381-4A and the CAV despatch number changed from 1805733 to 1805734.

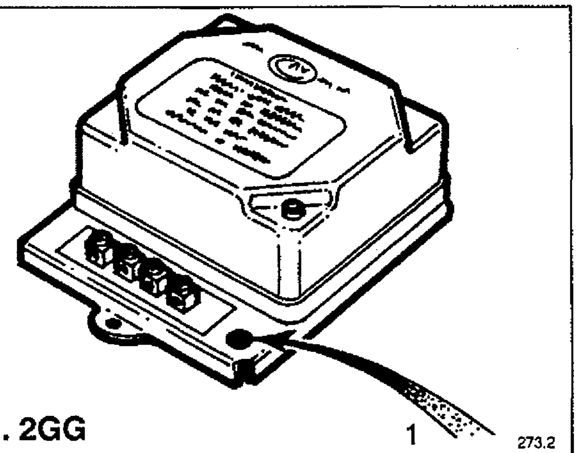


Fig. 2GG

**Key**
**(Fig. 2GG)**

1 Modified relays (identified by black spot)

**WARNING** ⚠ USE CORRECT LIFTING EQUIPMENT. TAKE CARE DURING THIS OPERATION AS THE TV DAMPER IS EASILY DAMAGED AND IS VERY

## DESCRIPTION

A torsional vibration damper is fitted to the engine crankshaft to control resonant torsional vibrations in the crankshaft over a wide range of vibration frequencies. The type RC viscous torsional vibration damper uses high viscosity silicone fluid to generate a damping torque by shearing a thin film of the fluid surrounding a totally enclosed inertia ring. This ring and the fluid are contained in a closely fitting casing permanently sealed by machine rolling or welding.

The clearance between the inertia member and the outer casing is very small and for this reason great care must be exercised when handling the damper. It must be appreciated that denting or other damage will affect the operation by forcing the casing against the inertia member thus hindering its movement. If this should occur, or the damper is accidentally dropped a replacement damper must be fitted to avoid causing serious damage to the engine.

The damper when removed should be laid flat on suitable wooden battens and should not have any other components placed on top of it.

## MAINTENANCE

Under ideal conditions, silicone fluid dampers will remain effective for 20,000 hours or more, but for variable speed applications it is recommended that the damper should be removed every major overhaul period, and returned to Perkins Engines (Stafford) for checking.

Every year or every 5000 hours an external inspection of the damper should be carried out, paying particular attention to the following points:

1) Cover bowed or otherwise distorted.
2) Cover lifting out of the rolled lips.
3) Discoloration of the casing which indicates overheating.
4) Leakage of the damping fluid.
5) Physical damage to the casing or cover surfaces.
6) Loose mounting bolts.

## SYMPTOMS OF A FAULTY TV DAMPER

a) Excessive engine vibration.
b) Excessive timing gear noise or wear.
c) Problems with front end pump drives.
d) Problems with drive couplings or flywheel bolts.

**TORSIONAL VIBRATION DAMPER ON THE 4012 AND 4016 ENGINES.**
**REMOVING THE TORSIONAL VIBRATION DAMPER (see Fig. 1HH)**

it is recommended that the heat exchanger or radiator be removed to give unobstructed access for removing the TV damper and also to accommodate the lifting facilities. Using a lifting sling fitted onto the extension shaft (1), remove the eight bolts (5) holding the extension shaft (including the fan driving pulley) (4), and lift the combined unit off the crankshaft adaptor (3), leaving the damper in place. Now screw in the two special support studs **T6253/157** and using two of the eight bolts as jacking screws in the tapped holes provided in the damper, push the damper off the adaptor onto the studs. Put the sling in place, take the weight off the studs, unscrew them and lift the damper away (see **Fig. 2HH**).

**WARNING** ⚠ THE WEIGHT OF THE EXTENSION SHAFT AND PULLEY MUST BE SUPPORTED BY A LIFTING SLING FITTED ON THE EXTENSION SHAFT. THE TV DAMPER MUST BE SUPPORTED BY A LIFTING SLING BEFORE BEING REMOVED FROM THE FRONT FACE OF THE CRANKSHAFT ADAPTOR AND THE TV DAMPER LIFTED OFF THE CRANKSHAFT BY TWO

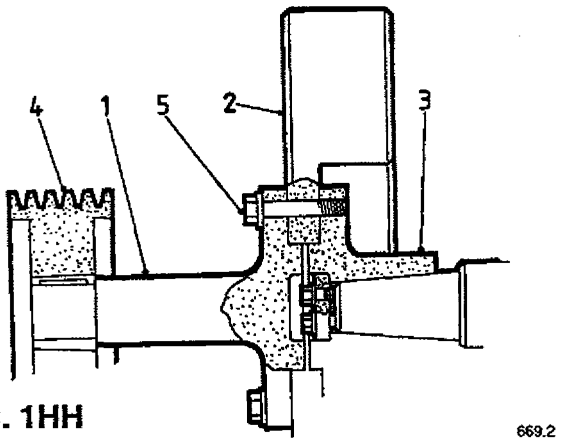

Fig. 1HH

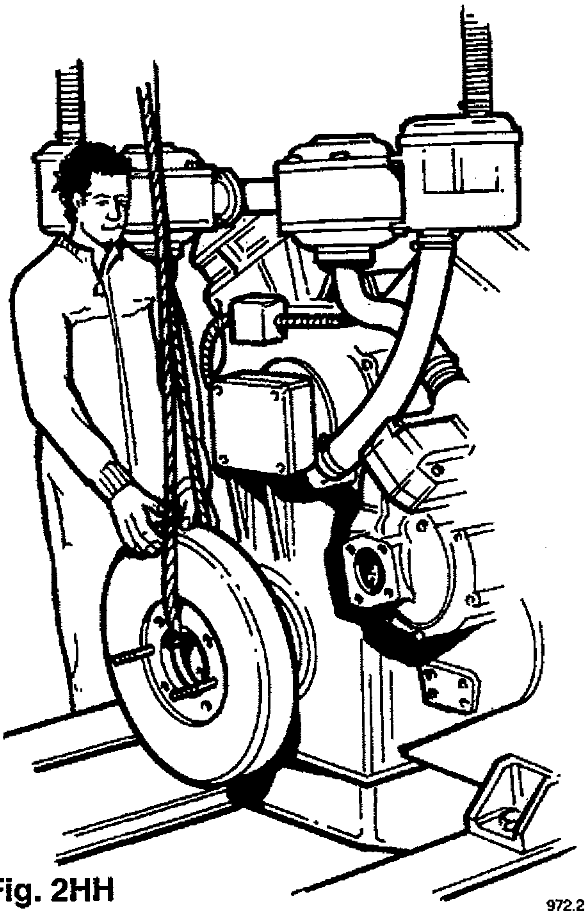

Fig. 2HH

## TWIN TORSIONAL VIBRATION DAMPERS ON 4016 UP-RATE ENGINES

The later 4016 engines are fitted with two torsional vibration dampers, using a similar adaptor to the 4012. (See **Fig. 2U, Section U1 & Fig. 3HH Layout of twin dampers on 4016 engines**).

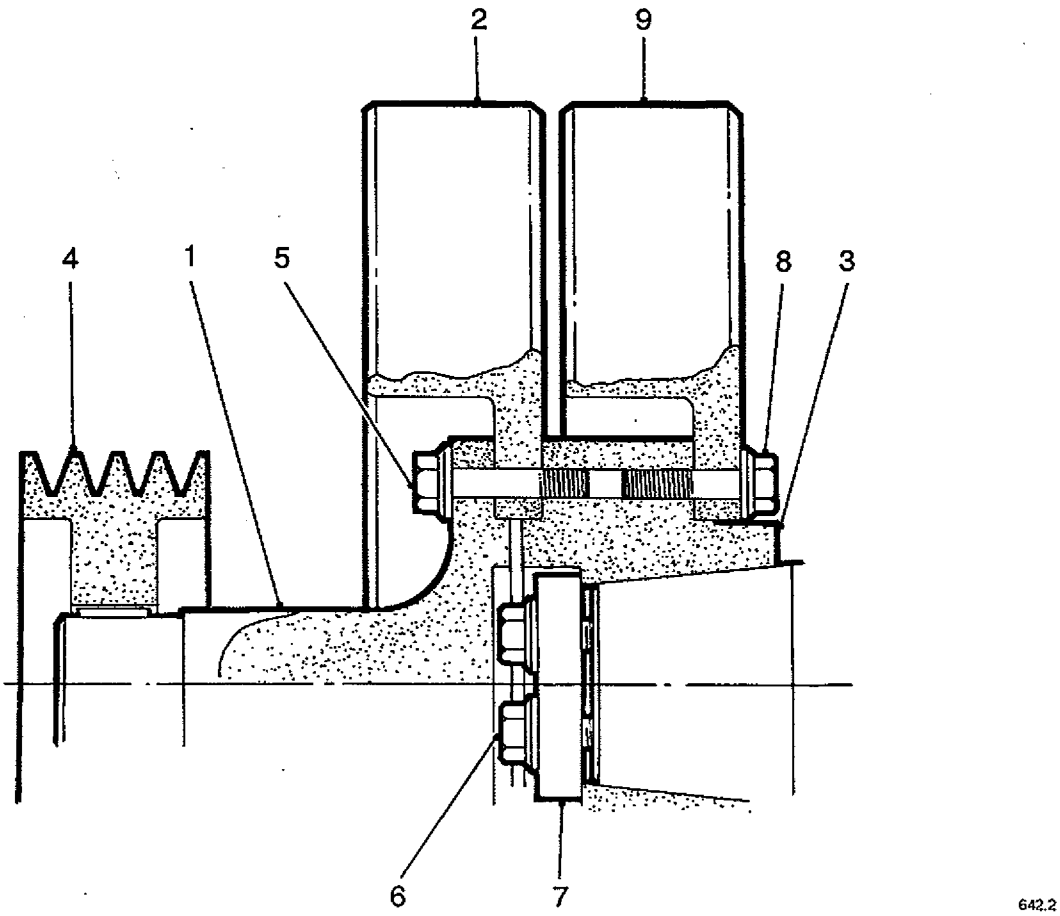


**Fig. 3HH**

## REMOVAL OF THE DAMPERS

Place a sling in position to support the weight of the pulley (4), stub shaft (1) and front damper (2). Unscrew two diametrically opposite bolts (5) and replace them with **T6253/157** studs. Remove the other six bolts (5) and carefully ease the stub shaft away from the front damper (2), leaving it in position on the studs. **Fig. 2HH.** Lift away the stub shaft (1) and pulley (4) and then, using two M16 bolts (5) as jacking screws in the tapped holes in the damper flange, push the damper off its spigot, so that it is clear of the adaptor (3) and resting solely on the studs. Use the sling or **T6253/214** to support its weight whilst unscrewing the studs, and lift the damper carefully away. **Fig. 4HH.** Now remove the three bolts (6) and the retaining plate (7) from the end of the crankshaft, and again with a sling or **T6253/214** in position, use extractor **T6253/209** (see **Section U2**) to remove the adaptor (3) complete with the rear damper (9).

Remove the eight M16 bolts (8), inserting two of them in the jacking holes to push the rear damper off the adaptor, as previously described.

**Key**
**(Fig. 5HH)**
**1** Damper lifting tool T6253/214

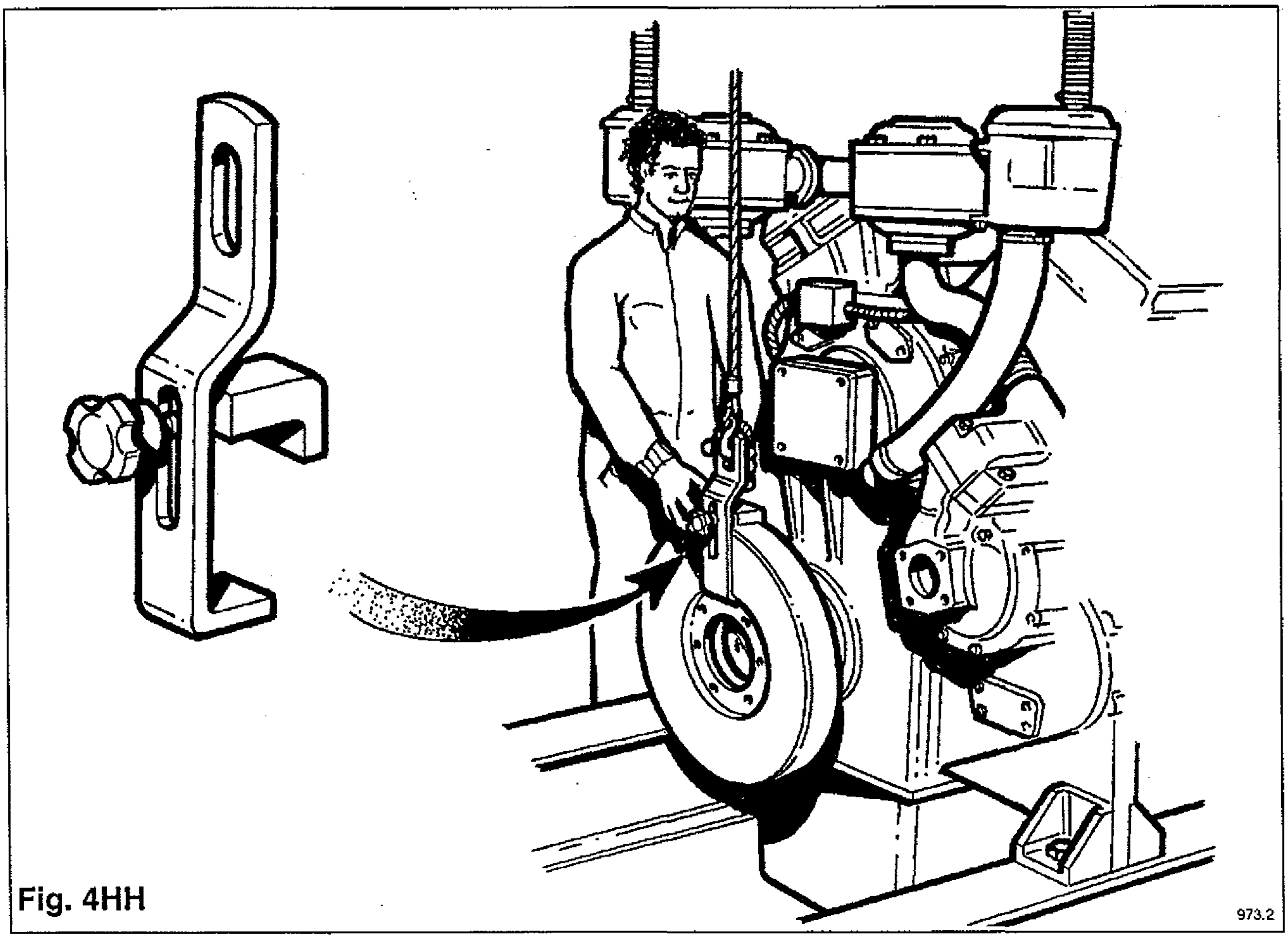


Fig. 4HH

## REFITTING THE DAMPERS

This is a reversal of the dismantling procedure, but now tightening the securing bolts (see **Fig. 5HH tightening sequence**) and the required torques. (See **Torque Settings pages 38-40**).

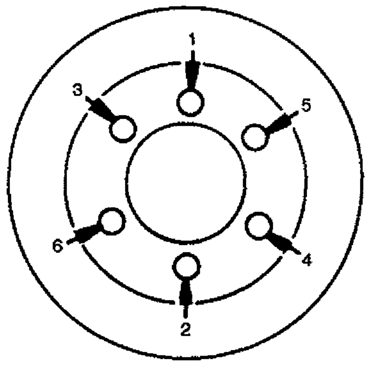


Fig. 5HH

## DESCRIPTION

An air shut off valve provides positive shutdown protection against engine and alternator damage in the unlikely event of engine overspeed due to governor malfunction or any other cause, such as combustible vapours being present in the intake air. Under such conditions the engine may overspeed on the vapour and air mixture even if the fuel is shut-off.

**WARNING** ⚠ THE VALVE MUST BE MOUNTED WITH THE AIR FLOW IN THE SAME DIRECTION AS THE ARROW ON THE VALVE BODY. WHEN MORE THAN ONE AIR SHUT-OFF VALVE IS USED, IT IS ESSENTIAL THAT ALL UNITS TRIP

An air shut-off valve uses a butterfly disc throttle to provide intake air shut-off.
A replaceable 'O' ring provides positive sealing around the disc and a slot in the end of the valve shaft shows the position of the valve disc.

## MAINTENANCE

Properly applied and installed, the air shut-off valve requires minimal maintenance. A careful inspection of the unit at yearly intervals is adequate for normal service
To replace the 'O' ring in the valve, remove the operating mechanism from the mounting bosses on the top of the valve body, by unscrewing the two nuts, and lifting the complete unit off the mounting studs.
Remove the valve spindle lever by knocking out the taper pin and sliding the lever off the valve spindle.
Remove both the top and bottom valve spindles to allow the shut-off valve to be withdrawn from the valve body.
Roll the 'O' ring over the front lip out of the groove in the valve and reverse the stripping sequence to reassemble.

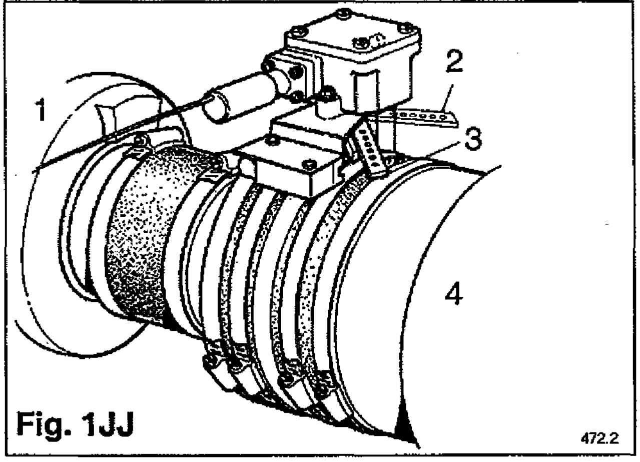

**Fig. 1JJ**

## INSTALLATION

Each air shut-off valve is installed up stream of the turbo-charger directly after the air filter, the turbo-charger seals being able to cope with the negative pressure when the air shut-off valve is closed (see **Fig. 1JJ**).
It is essential that the valve be kept clean and corrosion free, to enable it to operate correctly.

**Key**
**(Fig. 1JJ)**
**1** Turbocharger
**2** Closed (stop)
**3** Latched in (run)
**4** Air filter

## AIR SHUT-OFF VALVES AS FITTED ON EARLIER 4012TAG, 4012TWG, 4012TEG, 4016TAG, 4016TWG AND 4016TEG ENGINES

These engines are fitted with 2 air shut-off valves (as shown in **Fig. 2JJ**) which, when a fault occurs, close simultaneously and stop the engine, (see **Fig. 6JJ** for the wiring diagram).

## AIR SHUT-OFF VALVES AS FITTED ON LATER 4012TAG, 4012TWG/2, 4012TAG1, 4012TAG2 AND 4012TEG ENGINES

These engines are fitted with 2 air shut-off valves (as shown in **Fig. 3JJ**) which, when a fault occurs, close simultaneously and stop the engine, (see **Fig. 6JJ** for the wiring diagram).

**Key**

**(Fig. 2JJ & 3JJ)**

**1** Air shut-off valves

**(Fig. 4JJ)**

1 Four air shut-off valves

**(Fig. 5JJ)**

**1** Valve closed
**2** Valve opened
**3** Trip button
**4** Manual trip lever (if fitted)
**5** Solenoid
**6** Manual reset

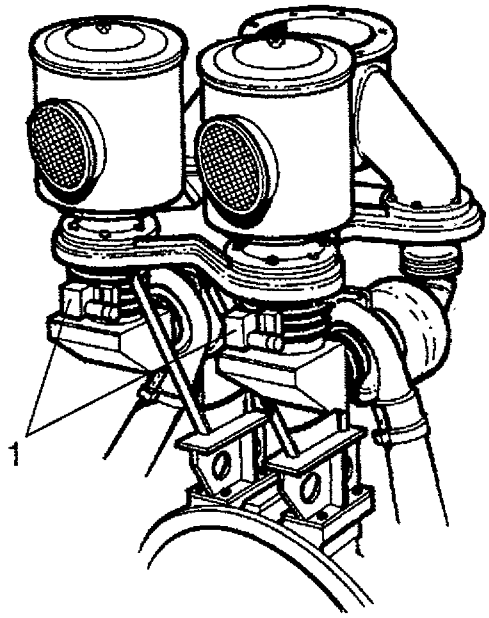


**Fig. 2JJ**

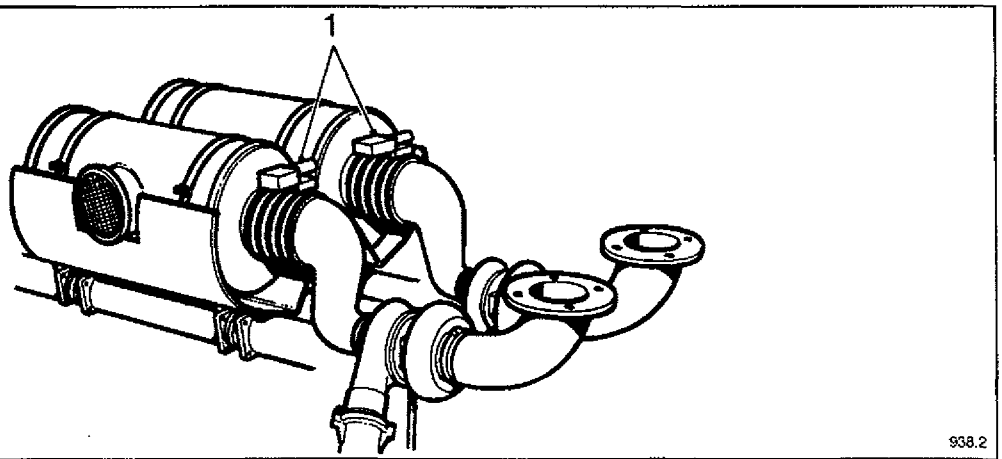


**Fig. 3JJ**

## AIR SHUT-OFF VALVES FITTED TO 4016TAG2, 4016TWG AND 4016TEG2 ENGINES

Each of the four turbochargers has its own air shut-off valve, but all are linked electrically to ensure their simultaneous operation in the event of an emergency. See **Fig. 7JJ** for the wiring diagram.

## OPERATION

The air shut-off valve is spring operated through a solenoid actuated trip mechanism. This is energised by the engine's 24V electrical system after being initiated by the overspeed switch via relays in the control panel. It is reset manually to the open position after the fault has been corrected and before the engine can be restarted.

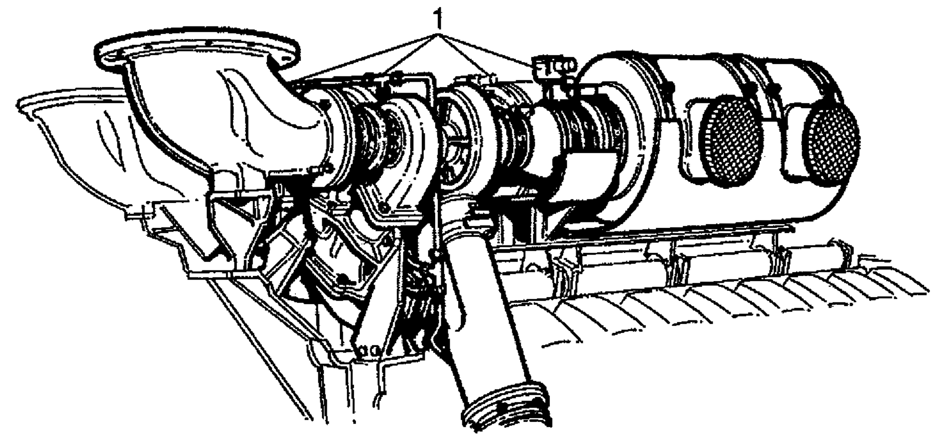


**Fig. 4JJ**

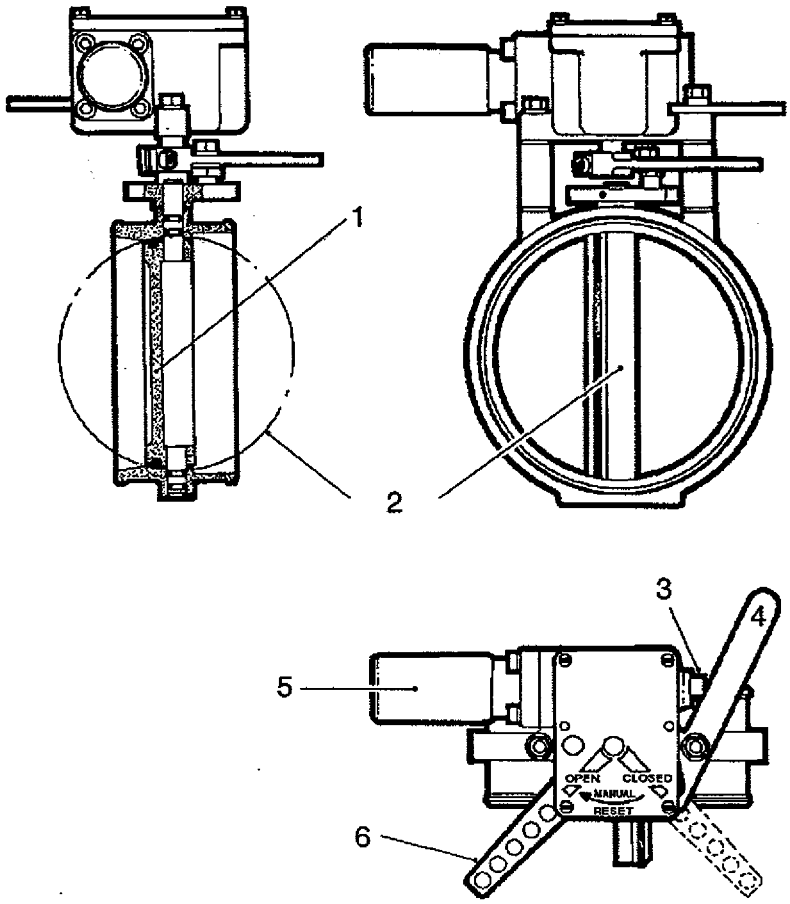


**Fig. 5JJ**

The overspeed fault condition is sensed by a magnetic pick-up mounted in the flywheel housing which measures engine speed from the teeth on the flywheel gear ring. The pick-up signal is fed to an electronic speed switch which operates protection relays in the control panel.
The control panel must provide a 24V supply to energise the shut-off valve solenoid, which trips a spring loaded cam mechanism to allow the butterfly valve to operate through 90× to seal off the air intake to the turbo-charger.
The air shut-off valve solenoid is short-time rated, therefore provision must be made to de-energise the solenoid once the butterfly valve has closed and stopped the engine. This prevents the solenoid burning out, and allows for the air shut-off valve to be reset manually.
With more than one air shut-off valve, it is essential to prevent any attempt to operate the engine with one valve closed (which would result in turbo-charger damage). A microswitch is fitted to all valves, and these must be interconnected electrically to ensure that if one valve is tripped manually the others close immediately after, (see **Fig. 6JJ** for two valves and **Fig. 7JJ** for four air shut-off valves).
The position of the air shut-off valve should be shown by panel indication, and cranking inhibited by means of a lock-out relay in the event of the valves being closed.

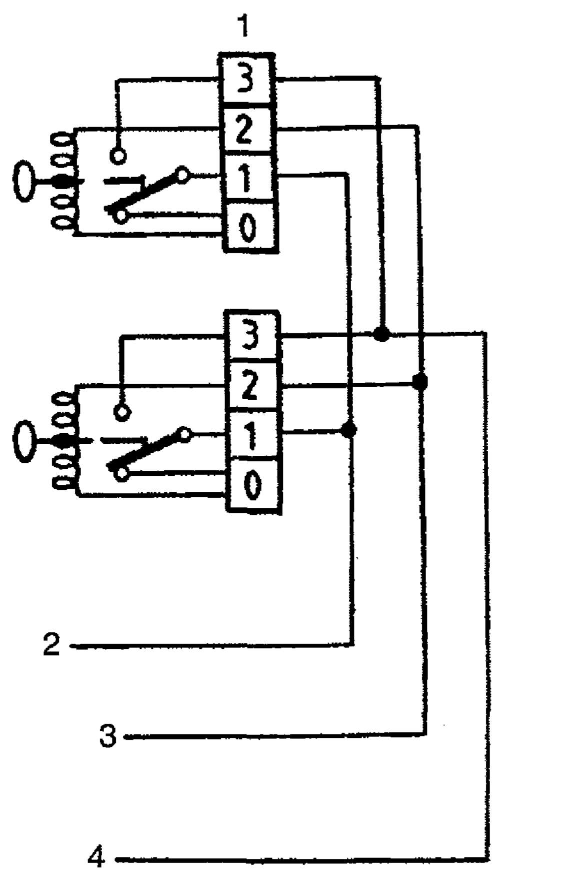

**Fig. 6JJ**

**Key**
**(Fig. 6JJ)**

1 Engine fitted with two type SE423 air shut-off solenoid valves
2 24 volt +ve overspeed fault signal
3 24 volt permanent battery -ve
4 24 volt +ve signal from oil pressure switch on engine run up

**Key**
**(Fig. 7JJ)**
**1** Engine fitted with four type SE423 air shut-off solenoid valves
2 24 volt +ve overspeed fault signal
**3** 24 volt permanent battery -ve
**4** 24 volt +ve signal from oil pressure switch on engine run up

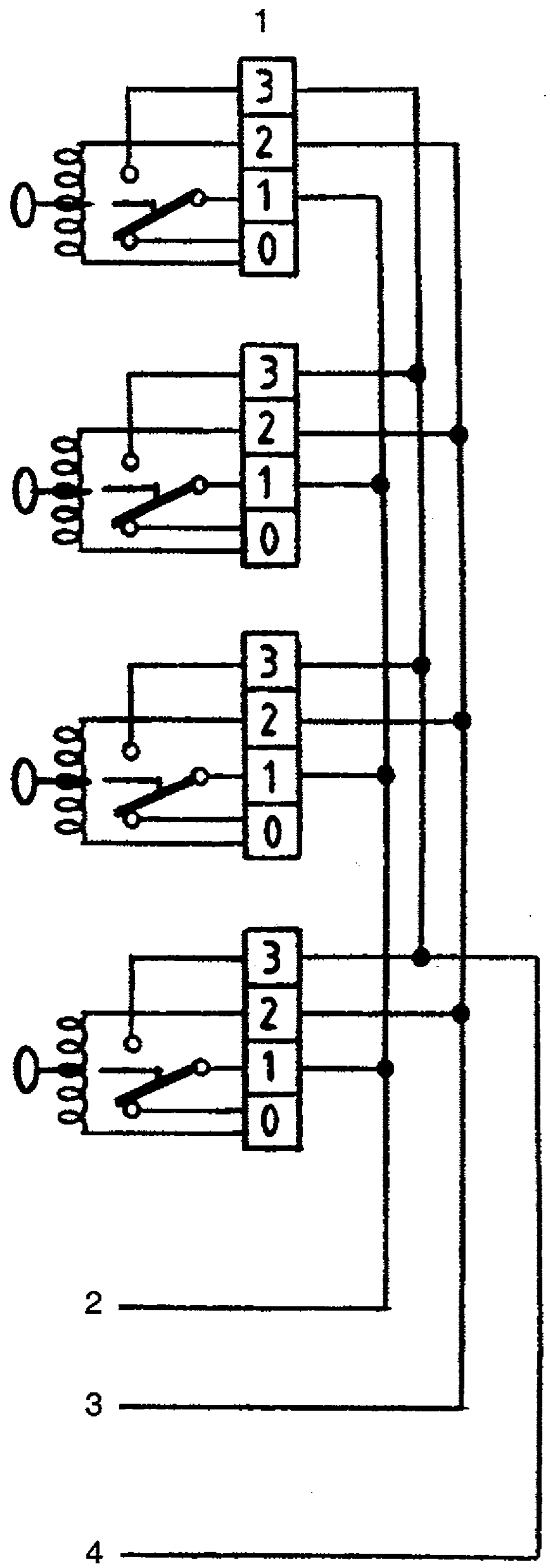


**Fig. 7JJ**

## THE FUEL LIFT PUMP

In the event of failure or if the engine is undergoing a major overhaul, service exchange fuel lift pumps are supplied since the fuel lift pump is a non serviceable item.

## REMOVING THE FUEL LIFT PUMP FROM THE ENGINE

Disconnect the fuel pipes to and from the fuel lift pump. Remove the two nuts retaining the fuel lift pump to the oil pump, withdraw the lift pump from the oil pump. Plug the fuel pipes and cover the lift pump mounting flange on the oil pump to stop the ingress of dirt.

## FITTING A NEW FUEL LIFT PUMP

Clean the fuel lift pump mounting flange on the oil pump making sure no jointing material is left on its surface. Using a new joint fit the fuel lift pump to its mounting flange, being careful to align the lift pump shaft with the oil seal and the drive dog as it is fitted to its mounting studs.

Tighten the retaining nuts evenly, pulling the fuel lift pump squarely to its mounting flange. Unplug the fuel pipes, and reconnect them to the fuel lift pump, prime the fuel system as described in **Sections P38 - P40.**

If the fuel tank is position below the level of the lift pump ensure that all the unions and fittings are air tight and that the non-return valve operates freely, otherwise loss of prime or aeration will occur.

## REPLACING THE FUEL PUMP DRIVE DOG - See Sections G4 - G5

**Key**
**(Fig. 1KK)**

**1** Fuel lift pump
**2** Oil seal
**3** Drive dog
**4** Joint
**5** Oil pump

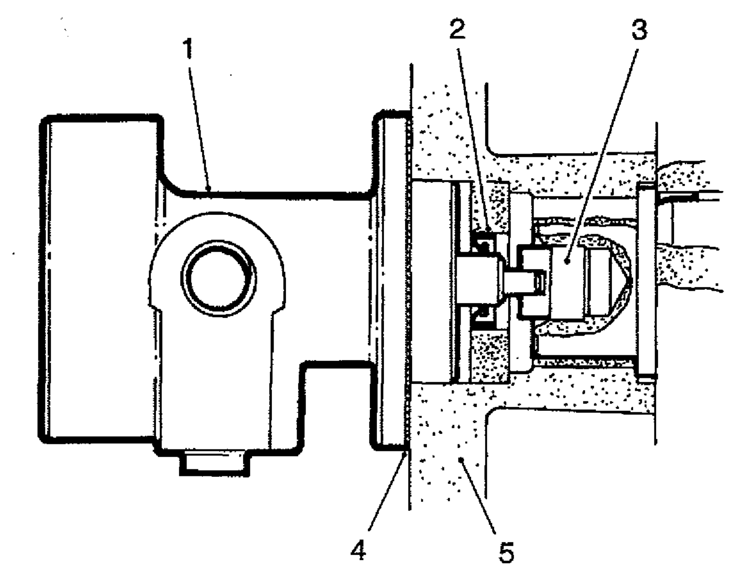


Fig. 1KK

## GENERAL DESCRIPTION
## THE 'HOLSET' RB COUPLING

The flexible coupling has two main metal parts, an outer driving member (1) with blades extending radially inwards, and an inner driven member (2) with similar blades extending radially outwards. Between these blades rubber blocks (3) are inserted to cushion the drive, de-tune torsional vibrations and accept misalignment. The cover (4) provides a limit to the axial elongation of the blocks when under compression (see **Fig. 1LL**).

Under steady drive conditions only half the number of blocks are under load, these being referred to as driving blocks. The blocks in the alternate cavities to these driving blocks are referred to as trailing blocks, which come into operation during conditions of torsional oscillation (see scrap view).

No lubrication of the coupling is required and the coupling should operate for prolonged periods of time with no attention.

**Key**
**(Fig. 1LL)**
**A** Scrap view looking in direction of flywheel
**B** Driving block
**C** Trailing block
**D** Bore for driven shaft

## INSPECTION

A flexible coupling operating in a correctly assessed system requires the minimum of maintenance, but periodic inspection is recommended every 5,000/10,000 hours of operating life, allowing an assessment to be made of the rubber blocks' remaining life.

A simple visual inspection should be made to determine whether any damage or change has occurred, and in cases of deterioration, arrangements should be made to renew the blocks at the next convenient overhaul.

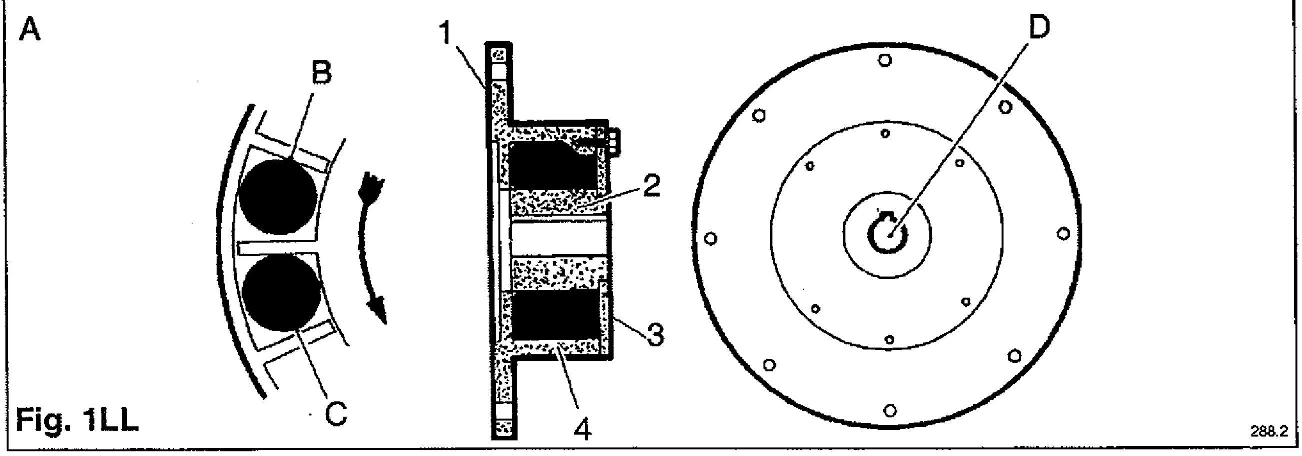


**Fig. 1LL**

**POINTS TO LOOK FOR ARE:**

**ABRASION** The evidence of rubber dust in small amounts is normal, but large quantities of dry dust require application of silicone fluid to the blocks and cavities to provide surface lubrication. Blocks abraded so as to be loose in the cavities should be changed as soon as possible as the rate of abrasion on loose blocks increases rapidly.

**CUTTING** Deeply cut blocks indicate the application of excessive torque loadings and these blocks require renewal.

**DEFORMATION** Blocks greatly distorted when unloaded show the effects of operation under hot conditions and should be replaced.

**RUBBER** The physical deterioration of the rubber is shown by:

**DETERIORATION**
1. Crumbly texture
2. Surface cracking
3. Brittleness
4. Stickiness

**NOTE:** Any of these would indicate that the rubber structure is undergoing change and that the blocks should be replaced.

**RUBBER HARDNESS CHANGE** On torsionally critical applications, rubber blocks which have hardened or softened more than 10 Shore degrees from the hardness number shown on the identification mark should be replaced, as the coupling will have changed to an unspecified stiffness.

**STORAGE OF SPARE RUBBER BLOCKS**

The British Standards Institute recommends the following storage conditions to avoid softening, hardening, cracking or other deterioration.

Deterioration can be accelerated by a combination of heat, light, humidity, oxygen and ozone.

**TEMPERATURE** The storage temperature should be less than 25°C. For long term storage a 15°C maximum is recommended.

**HUMIDITY** Moist conditions should be avoided and no condensation should occur.

**LIGHT** All polymeric products should be protected against light, especially sunlight or artificial light with ultra-violet content.

**OXYGEN & OZONE** Where possible components should be protected from air circulation by storage in containers. Ozone is particularly damaging and for this reason, parts should not be stored near electrical equipment where sparks or silent discharges are possible.

**DEFORMATION** Mouldings should be stored in a strain-free condition.

**CLEANING** If cleaning is required for storage, soap and water is relatively harmless. The washed components should be allowed to dry at room temperature.

**STORAGE TIME** Where items have been stored for five years or more, a laboratory check on quality must be carried out before use.

## REMOVAL OF RUBBER BLOCKS

The cover (4) must be removed and placed as far back as possible along the shaft. If this is not possible due to space limitation, then the flexible coupling driving flange should be disconnected from the engine flywheel and the complete coupling removed with the driven unit. The coupling can now be taken off the driven shaft to gain access to remove the cover (4).

Each cavity of the coupling contains one rubber block which can be removed from the cover side of the coupling.

The use of a lever such as a bar or screwdriver is recommended to ease the blocks from their cavities. This should be inserted at the corner of the cavity giving the widest point of access and using a lever action against the cavity edge, the block should then become free. It may be necessary to repeat this at opposite corners of the cavity.

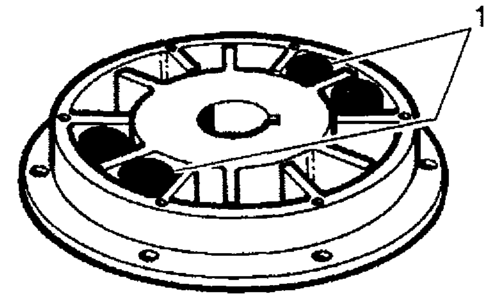


**Fig. 2LL**

## REPLACING RUBBER BLOCKS

(1) Brush the walls of each cavity with silicone fluid of between 300 and 1000 centi-Stokes viscosity as an assembly lubricant. Without this essential lubrication, fitting would be difficult and may result in damage to the blocks.

(2) Brush each rubber block with silicone fluid before inserting.

(3) Insert the blocks in pairs, using a non metallic hammer. The second pair should be diametrically opposite the first and the third and fourth pairs at 90° (see **Fig. 2LL**).

(4) Refit cover (4) to the outer member, ensuring that the cover screws are tightened to the required torque (see **pages 38-40**).

**Key**
**(Fig. 2LL)**
**1** Rubber blocks

## REFITTING THE COUPLING

### Close coupled units

It is essential that the flywheel counterbore (dia A) is concentric with the flywheel housing counterbore (dia B) to a maximum eccentricity of 0.13 mm (0.005"), to comply with SAE standards SAE J162a and J1033 (see **Fig. 3LL**).

Firstly the distance (depth) between the rearmost machined face of the flywheel housing and face 'F' (see **Fig. 3LL**) of the flywheel (dimension 'X' **Fig. 3LL**) should be measured by means of a straight edge and rule.

The flexible coupling should now be fitted to the driven shaft. It should be knocked on just far enough so that dimension 'X' **Fig. 3LL** is equal to dimension 'X' **Fig. 4LL**.

The alternator should now be offered up to the engine so that both the drive coupling and the housing spigot engage at the same time, rotating the flywheel to align the bolt holes with the coupling holes.

Firstly the bolts retaining the alternator housing to the flywheel housing should be fitted and fully tightened. Then the drive disc to flywheel bolts should be fitted and tightened to the correct torque.

Finally check with feeler gauges for gaps between the driver unit mounting feet and the baseframe mounting pads, insert shims where necessary, and tighten the securing bolts to the correct torquue (see **Torque Settings pages 38-40**).

For further details see the **Installation Manual.**

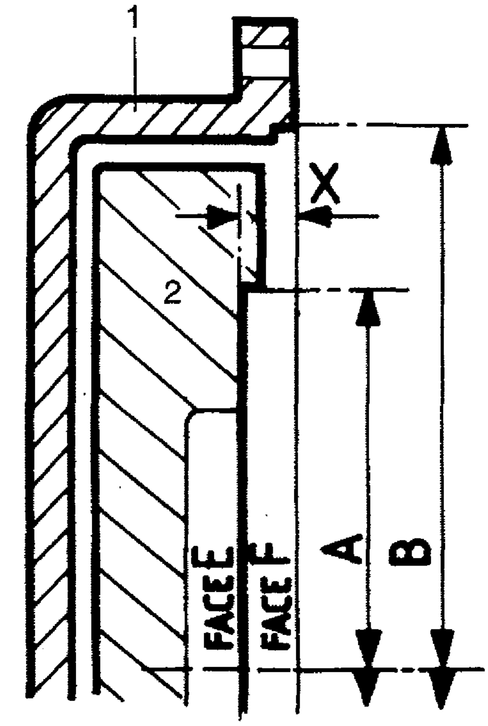

Fig. 3LL

**Key**
**(Fig. 3LL)**

**1** Flywheel housing
**2** Flywheel

Check that the faces 'E' and 'F' are parallel and concentric with one another to within a maximum runout of 0.005" (0.13mm).

**Key**
**(Fig. 4LL)**
**1** Flywheel
**2** Drive flange
**3** Alternator frame
**4** Corner of drive flange chamfered to ensure easy fit into flywheel recess
**5** Flexible drive plates (single bearing) Flexible coupling two bearing

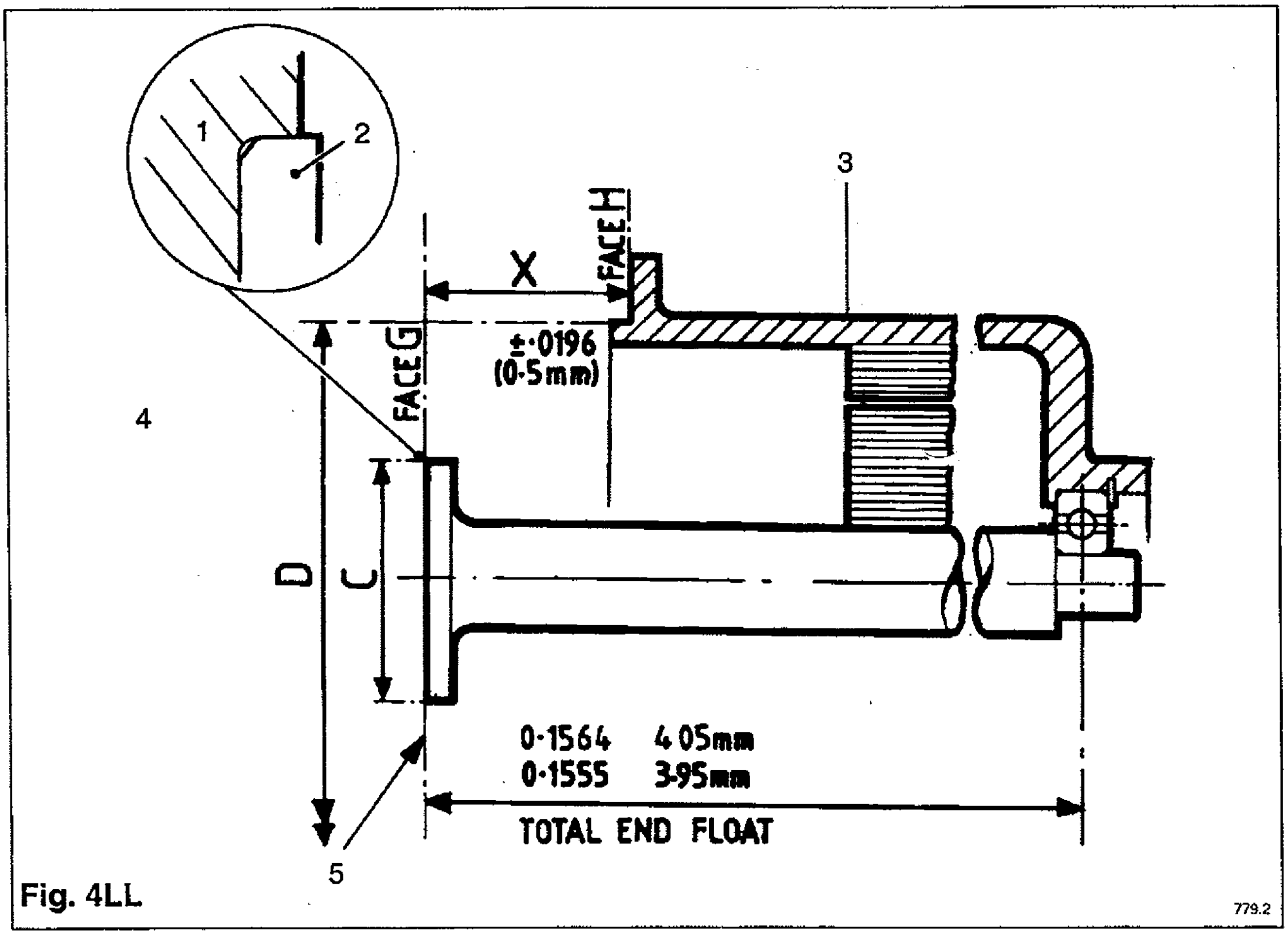


Fig. 4LL

## Open coupled units

It is essential that the flywheel counterbore (dia A) is concentric with the flywheel housing counterbore (dia B) to a maximmum eccentricity of 0.13 mm (0.005") to comply with SAE J162a and SAE J1033 (see **Fig. 3LL**).

The driven shaft and flywheel should be checked for alignment by fixing a dial test indicator as shown in **Fig. 5LL**. In practice most people would prefer to check with one DTI at a time, starting with indicator 2.

Alignment should be checked by rotating the driven shaft and observing the readings on the DTI.

Corrections to misalignment should be made as follows:-

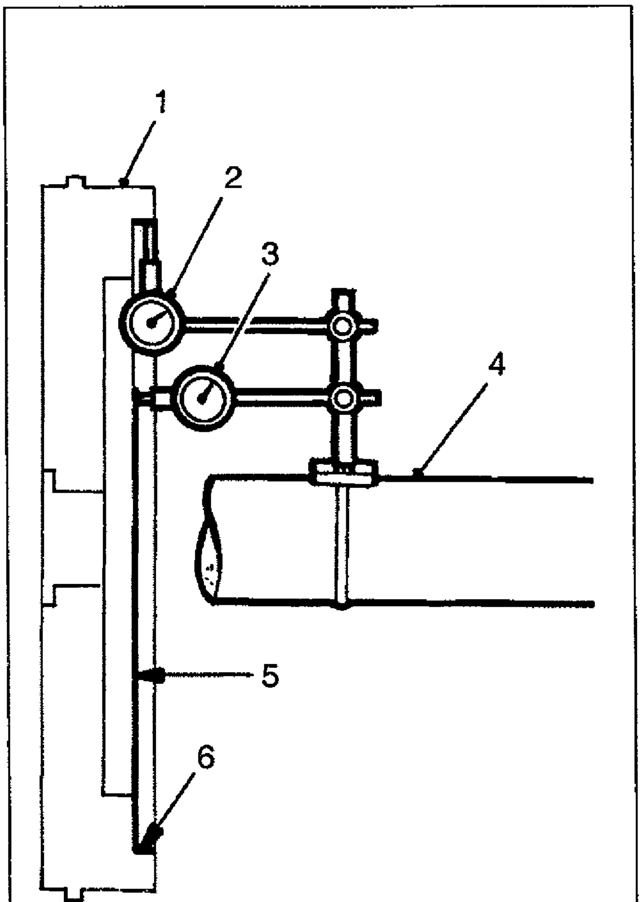

**Fig. 5LL**

**Key**
**(Fig. 5LL)**

**1** Flywheel
**2** Indicator 1
**3** Indicator 2
**4** Driven shaft
**5** Face E
**6** Diameter H

**(a) Radial misalignment as indicated by indicator 2.**
The object here is to get the flywheel and driven flange flat and parallel to each other. Radical misalignement has two components, horizontal and vertical. The horizontal component will be shown by the DTI readings at three o'clock and nine o'clock, and is corrected by moving the tail of the driven unit towards the negative reading (widest gap). The vertical component will be shown by the DTI readings at 12 o'clock and 6 o'clock. if there is a negative reading at 12 o'clock, then the tail of the driven unit is low, and should be shimmed until the reading is correct. If there is a negative reading at 6 o'clock, then the tail of the driven unit is high, and shims should be inserted at the front mounting point until a correct reading is observed.

**(b) Axial misalignment as indicated by indicator 1.**
This is to ensure that the flywheel and driven shaft are on the same axis (or centre line). Once again, this has two components, horizontal and vertical. The horizontal component will be shown by the DTI readings at three o'clock and nine o'clock. This is corrected by moving the complete machine towards the negative reading. The vertical component will be shown by the DTI readings at 12 o'clock and 6 o'clock. If there is a negative reading at 12 o'clock, then the driven unit is too low, and should be packed up with shims equal at both front and rear. If there is a negative reading at 6 o'clock, then the engine is too low, and should be packed up with shims equaly at both front and rear.
Finally, both radial and axial alignment should be re-checked and adjusted if necessary. This should be repeated until the alignment is observed to be correct, i.e. do not make an adjustment and presume that the alignment has been corrected, always make a final check.

The installation alignment should always be as accurate as possible to allow for future bearing wear or foundation movement.
**NOTE:** Conical misalignment is a function of radial and axial misalignment and so is not directly checked.

| HOLSET COUPLING SIZE | ALLOWABLE INSTALLATION MISALIGNMENT | | |
|---|---|---|---|
| | AXIAL mm | RADIAL mm | CONICAL DEGREES |
| 2.15 | 0.45 | 0.3 | 0.1 |
| 3.86 - 5.5 | 0.6 | 0.3 | 0.1 |

**WARNING** ⚠ NEVER RUN THE ENGINE WHILST THE HEATER IS OPERATING.

## GENERAL DESCRIPTION

To cater for easier starting under cold climatic conditions, the engine jacket cooling water is maintained at a suitable temperature by heating with electrically operated immersion heaters (see **Fig. 1MM**). The tank type heaters are piped into the engine fresh water cooling circuit, the system being designed to circulate hot water to the engine water jackets when the engine is stationary.

**Key**
**(Fig. 1MM)**

**1** Contactor unit
**2** Immersion heater
**3** Water tank
**4** Drain plug
**5** Hose connection
**6** Thermostatic switch

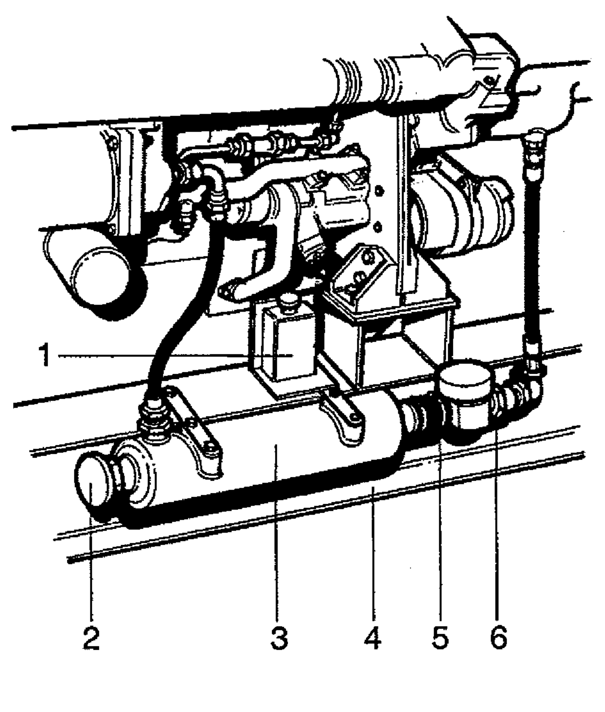


**Fig. 1MM**

## OPERATION

Two 4kW tank heaters are piped into the engine fresh water cooling circuit between each suction pipe from the radiator (or heat exchanger) to the engine water pumps and the engine oil coolers (one on each side of the engine).

When the heaters are switched on, water flows from the suction pipes via rubber diaphragm check valves in the tanks over the elements and to the engine oil coolers.

The immersion heaters are controlled by a thermostat i.e. a switch fitted near to each tank heater, which when the water temperature has reached 37.8°C (100°F), automatically cuts off the electrical supply to the heaters.

When the temperature of the jacket water drops to 26.7°C (80°F), the immersion heaters are automatically switched on again.

To prevent the immersion heaters being in operation when the engine is running, the heater circuit is fitted with an engine oil pressure switch which is set to switch off the immersion heaters when the engine oil pressure reaches 45 lb/in$^2$. The oil pressure switch operates on the coil of a contactor which then switches off both heaters simultaneously.

The purpose of the rubber diaphragm check valve incorporated in each tank heater is to prevent the hot water flowing in the wrong direction when the engine is running.

With the immersion heaters switched off, the water in the tank is static and isolated from the normal engine cooling circuit.

**WARNING** ⚠ THE MAINS ELECTRICAL SUPPLY MUST BE SWITCHED OFF BEFORE REMOVING AN IMMERSION HEATER FROM A TANK.

## REMOVAL OF AN IMMERSION HEATER

Before removing an immersion heater from a tank the engine cooling system must be drained by removing the drain plug in the bottom of the water tank, having first removed the radiator filler cap.

To remove the immersion heater disconnect the cables after removing the cover of the terminal box. Remove the two screws holding the terminal box to the heater and unscrew the heater element from the tank using a suitable spanner. Remove the tank end cover using a $^3/_8$" a/f spanner, inspect the 'O' ring in the flap valve and check that it operates freely.

**REPLACING AN IMMERSION HEATER**

Ensure that the heater face on the tank is clean and that no joint material remains on this face, avoiding aggressive solvents which may harm 'O' rings. It is imperative that the end cover is fitted in the correct position for the flap valve to operate satisfactorily. Re-fit the end cover to the tank using a new 'O' ring (if necessary) and a silicone sealant to form a joint between the tank and the flange. Refit the heater element using a lubricant on the thread. Fit the terminal box, reconnect the cables (see **Fig. 2MM**) and refit the cover of the terminal box. Ensure that the drain plug is fitted in the tank, refill the radiator (see **Section F2**) and bleed the system at the highest point to eliminate air locks.

Start the engine and run on light load for a few minutes; stop the engine. Check for water leaks and top up the radiator or heat exchanger if necessary.

Switch on the immersion heaters to check that both operate correctly.

**Key**
**(Fig. 2MM)**

**1** Oil pressure switch
**2** Contactor 20 amp
**3** Thermostat
**4** 4kw heater
**5** Thermostat

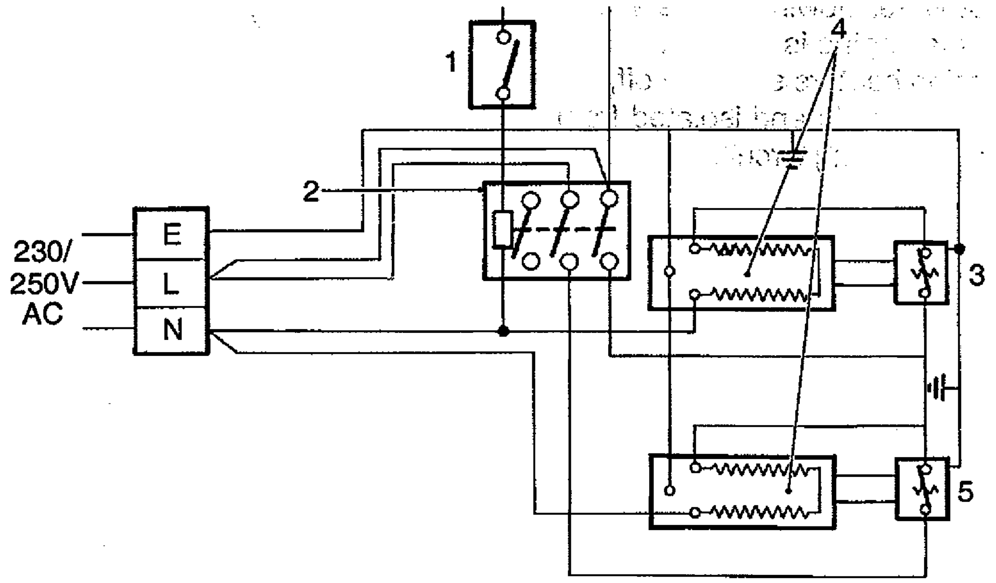


**Fig. 2MM**

## GENERAL DESCRIPTION

To enable an engine to operate for a long unattended period, a Ren valve may be fitted to the lubricating oil system to automatically replenish the sump (see **Fig. 1NN**).

The Ren valve is a ruggedly designed engine mounted float valve insensitive to vibrations, which can be adjusted so that the centre line of the ¼" thick clear plastic sight window corresponds with the running sump oil level. The valve is fitted with a vent pipe to equalise any build up in the crankcase pressure and since the valve is continually immersed in clean oil, wear and vibration problems are eliminated.

## OPERATION

From a separate make-up lubricating oil tank mounted near to the engine, the Ren valve delivers only that amount of oil required to maintain a constant oil level in the engine sump.

i.e. While the engine is running the level of oil is in the centre of the sight glass.

On shut down, oil drains into the sump from the oil galleries etc., increasing the level in the sight glass.

**NOTE:** The oil level in the sump should be checked on the dipstick before start up.

The position of the make-up tank should be above the **Ren** valve to ensure a gravity feed. The oil in the sump should be changed at the normal intervals (every 250 hours normally, but see **page 61 in the Operators Handbook**).

## REMOVAL OF REN VALVE

Should it be necessary to remove the Ren valve from the engine, the lubricating oil system must be drained by removing the sump drain plug, and the oil supply from the make-up tank should be turned off.

Unscrew all the flexible pipe clip connections on the Ren valve, taking care not to spill any oil remaining in these pipes.

The Ren valve may now be removed from its mounting bracket.

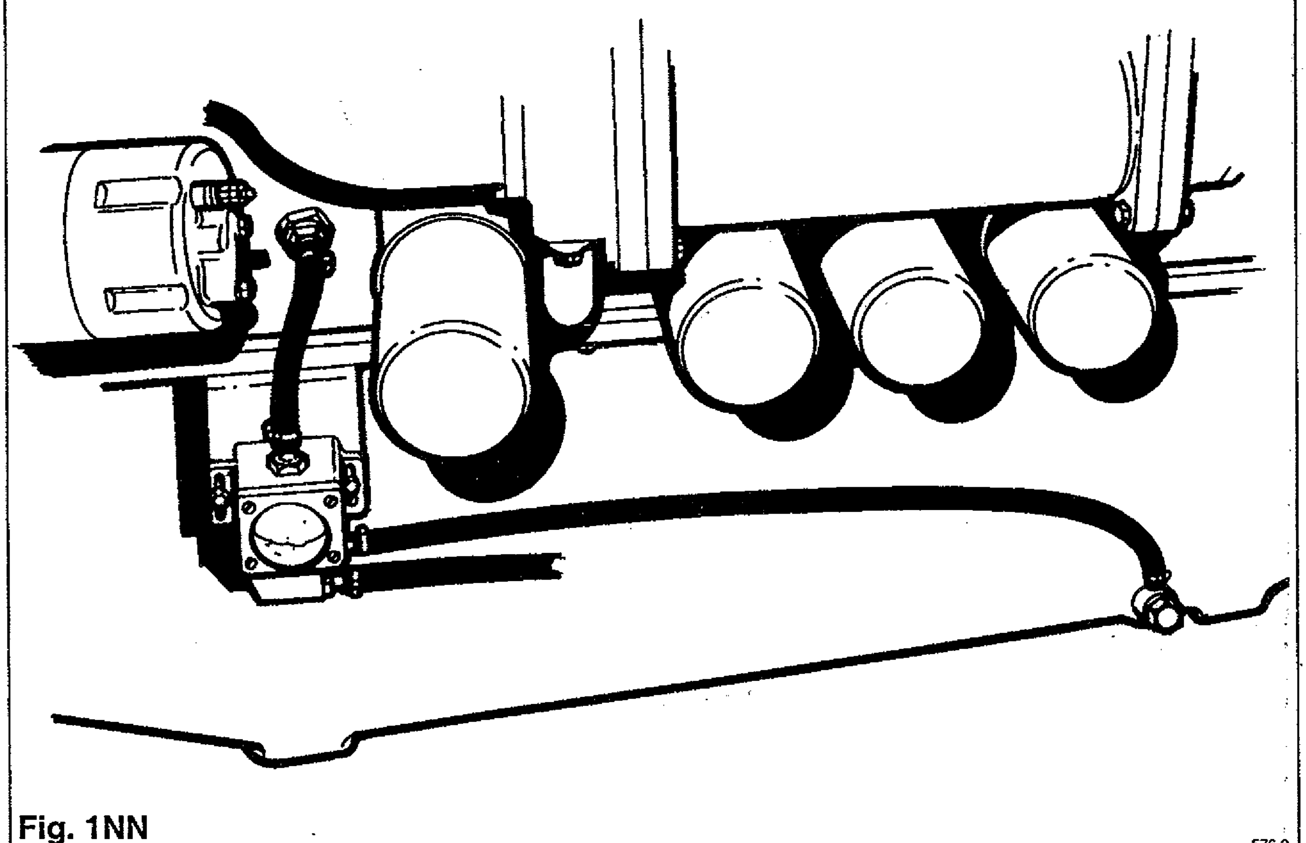


**Fig. 1NN**

## REPLACING THE VALVE

Bolt the replacement Ren valve to the mounting bracket, and reconnect all the flexible pipes, positioning the valve as described previously.

Ensure that the drain plug in the sump is fitted, and refill the sump with the correct lubricating oil (see **pages 26-27**) to the maximum oil level on the dipstick. Start the engine and run on light load for a few minutes. Check the oil level in the sight glass, and top up the sump if necessary to bring the oil level to the centre of the sight glass. Stop the engine.

Turn on the oil supply from the make-up tank, and check for oil leaks.

## TYPICAL REN VALVE SYSTEM

A typical Ren valve system as shown in **Fig. 2NN** is used to extend the servicing interval on an unattended engine to avoid having to replenish the sump at the normal times.

## GROUNDING SWITCH AND TERMINAL

The Ren valve is fitted with an electrical switch as shown in **Fig. 2NN**, which can be used to activate an external electrical circuit for any purpose such as a signal light, alarm or shutdown in response to an abnormally low oil level, such as would occur following the exhaustion of the oil supply.

When the grounding switch is used to complete the electrical circuit, the grounding terminal (a screw fitted in the mounting bracket) must be used, unless the above warning device is already adequately grounded through its mounting.

**Key**
**(Fig. 2NN)**

1 Flexible pipes
2 Isolating tap
3 Vent
4 Filler
5 Make up tank
6 Anti-vibration mounting
7 Grounding switch wired to terminal box
8 Ren valve
9 Terminal box
10 In line engine shown

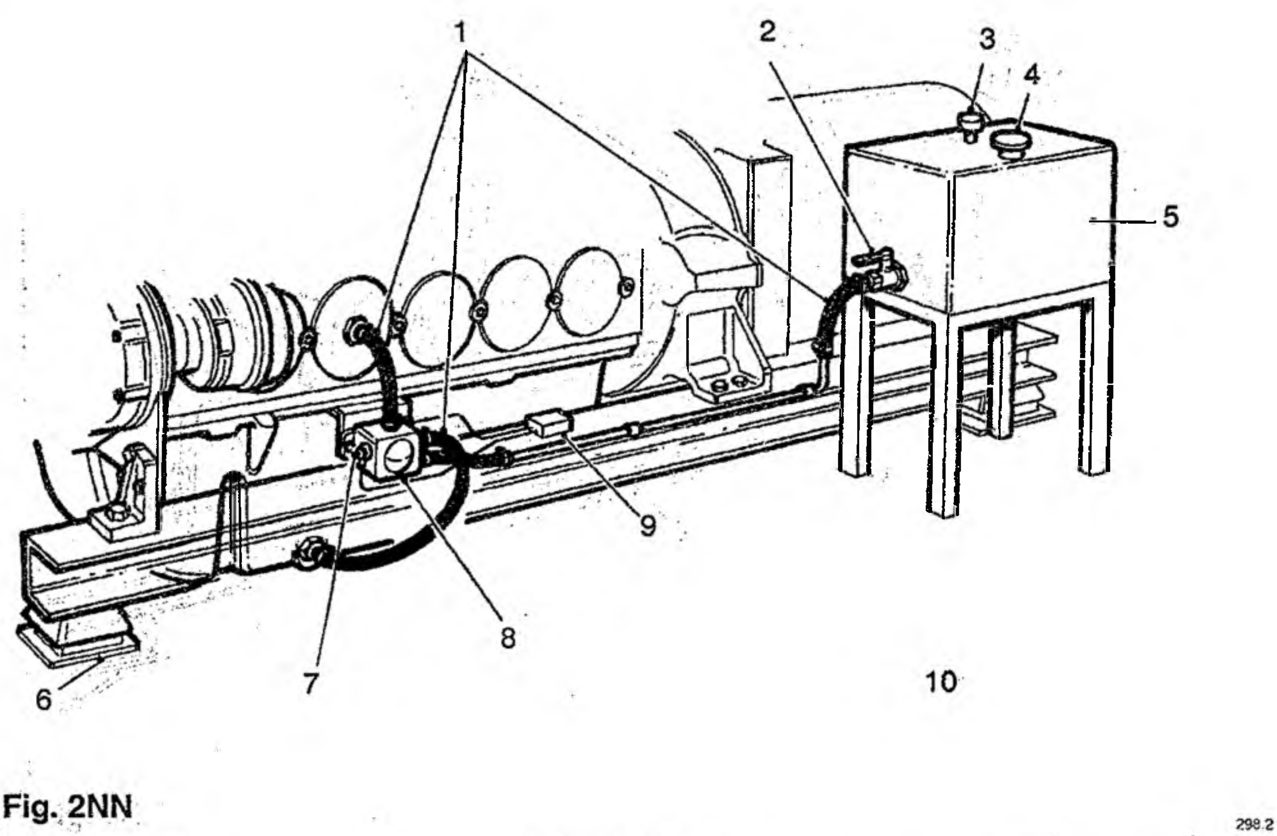


Fig. 2NN