
Perkins 4000 Series

Model 4016-E61TRS

USER'S HANDBOOK

Sixteen cylinder turbocharged gas engines

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This publication is divided into six chapters:

- 1 General information**
- 2 Engine views**
- 3 Operation instructions**
- 4 Preventive maintenance**
- 5 Gas and engine fluids specification**
- 6 Fault diagnosis**

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1

General information

Introduction

The 4016-E61TRS is a 16 cylinder turbocharged engine designed by Perkins Engines Company Limited, a world leader in the design and manufacture of high-performance gas engines.

Perkins approved assembly and quality standards, together with the latest technology, have been applied to the manufacture of your engine to give you reliable and economic power.

Read and remember the "Safety precautions" on page 2. They are given for your protection and must be used at all times.

Note: The terms 'left side' and 'right side' apply when the engine is seen from the flywheel end.

Special tools are required to perform certain operations. A list of those required for the operations described in this handbook is given in "Service tools" on page 9. Reference to the relevant special tools is also made at the beginning of each operation, along with those which are universally available (UA) and any additional specialist supplied equipment (SP) required.

Danger is indicated in the text by two methods:

Warning! *This indicates that there is a possible danger to the person.*

Caution: *This indicates that there is a possible danger to the engine.*

Note: Is used where the information is important, but there is not a danger.

Safety precautions

General

For safe and reliable operation of the engine it is very important that these safety precautions, and those **Warnings** and **Cautions** given throughout this handbook, are observed, and where necessary the special tools indicated are used.

All safety precautions should be read and understood before operating or servicing the engine.

Improper operation or maintenance procedures are dangerous and could result in accidents, injury or death.

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

You must also refer to the local regulations in the country of use.

Note: Some items only apply to specific applications.

Guards

- Ensure that guards are fitted over exposed rotating parts, hot surfaces, air intakes, belts or live electrical terminals (high and low tension).

Protection equipment

- Ensure that correct protection equipment is worn at all times.
- Always wear protective gloves when using inhibitors or anti-freeze, removing the pressure cap from the radiator or heat exchanger filler, changing the lubricating oil/filter or changing the electrolyte in the battery.
- Always wear ear protection when working in an enclosed engine room.
- Always wear suitable eye protection when using an air pressure line.
- Always wear protective boots when working on the engine.
- Always wear protective headgear when working on or underneath the engine.

Naked flames

- Ensure that no smoking or naked flames are lit when checking battery electrolyte, working in the engine room or when operating or servicing the engine.

Fuel/oil pipes

- Ensure that all pipes are regularly checked for leaks.
- Ensure that all pipes and the surrounding area are regularly checked for spilt oil (and cleaned up where necessary).
- Always apply suitable barrier cream to hands before any work is carried out.

Gas pipes

- Always check for gas/air mixture leaks.
- Ensure that the gas line and valves meet local safety standards.
- Ensure that the gas line pressure is correct.

Shutdown equipment

- Always test that the protection system is working correctly.
- When stopping the engine in case of overspeed, high water temperature or low oil pressure should be provided.
- For heat sensors, methane and smoke protectors should be provided (if applicable).
- Always be in a position to stop the engine (even remotely).

Start-up

- When working on the engine always ensure that the battery has been disconnected, and that any other means of accidental start-up has been disabled.
- Never start the engine with the governor linkage disconnected.
- Do not hold the stop lever in the run position when starting the engine.
- Always hold the stop lever in the stop position when cranking only.

Electrical equipment

- Always check that electrics are earthed to local safety standards.
- Always disconnect the electrical supply to the jacket water heater (if fitted) before working on the engine.
- Take care to prevent any danger of electric shock.
- Never re-adjust the settings of electronic equipment without reference to the Workshop Manual.

Freezing or heating components

- Always use heat resistant gloves and use the correct handling equipment.

Exhaust system

- Check the system for leaks.
- Ensure that the engine room is correctly ventilated.
- Check that all the guards are fitted.
- Check that the pipework allows the exhaust gas to escape upwards.
- Check that the pipework is supported.

Stopping the engine

- 1 Disengage the engine load.
- 2 Run the engine on NO LOAD for 15 minutes before stopping.

Note: This will allow the circulating lubricating oil to dissipate heat from the bearings, pistons, etc. It will also allow the turbochargers, which run at a very high speed, to slow down while there is still oil flow through the bearings.

Ensure that the engine is stopped before performing any of the following operations:

- Changing the lubricating oil.
- Filling or topping up the cooling system.
- Beginning any repair work on the engine.
- Adjusting belts (where fitted).
- Adjusting bridge pieces / valve clearance.
- Changing spark plugs.
- Changing air or oil filters.
- Tightening any fixing bolts.

Flammable fluids

- Ensure that these are never stored near the engine.
- Ensure that they are never used near a naked light.

Clothing

- Do not wear loose clothing, ties, jewellery, etc.
- Always wear steel toe cap shoes/boots.
- Always wear the correct head, eye and ear protection.
- Always wear suitable overalls.
- Always replace a spillage contaminated overall immediately.

Lifting heavy components

- Always use the correct lifting equipment.
- Never work alone.
- Always wear a helmet, if the weight is above head height.

De-scaling solution

- Always wear both hand and eye protection when handling.
- Always wear overalls and correct footwear.

Waste disposal

- Do not leave oil covered cloths on or near the engine.
- Do not leave loose items on or near the engine.
- Always provide a fireproof container for oil contaminated cloths.

Note: Most accidents are caused by failure to observe basic safety precautions and can be prevented by recognising potentially dangerous situations before an accident occurs. While there are many potential hazards that can occur during the operation of the engine which cannot be always be anticipated, and thus a warning cannot be included to cover every possible circumstance that might involve a potential hazard, by following these basic principles the danger can be minimised.

How to care for your engine

This handbook has been written to assist you to maintain and operate your engine correctly, and to carry out routine servicing of the engine.

The instructions contained in this handbook will, provided that they are correctly carried out, ensure the safe operation of the equipment.

Before undertaking any work on the engine the relevant chapter in the Workshop Manual should be read and fully understood.

The information contained within this handbook is based on such information as was available at the time of print. In line with Perkins Engines Company Limited, Stafford 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.

Users are respectfully advised that it is their responsibility to employ competent persons to operate the equipment in the interest of safety.

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, see "Engine identification" on page 10.

If any doubt exists regarding the installation, use or application of the engine, the Installation Manual should be consulted. For further advice contact the Applications Department at Perkins Engines Company Limited, Stafford.

To obtain the best performance and the longest life from your engine, you must ensure that the maintenance operations are done at the intervals indicated in the "Service schedule" on page 22. If the engine works in a very dusty environment or other adverse conditions, certain maintenance intervals will have to be reduced.

Oil change intervals may be changed according to operating experience by agreement with Perkins Engines Company Limited and subject to oil analysis being performed at regular intervals. Refer to "Oil and filter change programme" on page 42.

Ensure that all adjustments and repairs are done by personnel who have had the correct training. Perkins distributors have this type of personnel available. You can also obtain parts and service from your Perkins distributor.

Note: Where reference is made to 'A' and 'B' banks of cylinders: 'A' bank is to the left and 'B' bank is to the right when viewed from the front of the engine, the crankshaft damper/turbocharger end.

Caution: Do not use mobile phones within 2 meters of the engine as the transmitted signal can affect the electronic management system of the engine.

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.

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

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

- 1 Prevent 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 Prevent 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, 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 eye damage, suitable eye protection 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.

Danger from 'fluorosilicone' (Viton) 'O' ring seals

All of the engines 'O' ring seals are made from fluorosilicone material.

It is a safe material under normal conditions of operation, but if it is burned the extremely dangerous hydrofluoric acid is produced.

If it is necessary to come into contact with components which have been burnt, follow the precautions below:

- Allow the components to cool.
- Use Neoprene gloves and a face mask.
- Wash the contaminated 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.

Caution: *If there is contamination of the skin or eyes, wash the affected area with a continuous supply of clean water. Obtain immediate medical attention.*

Practical information for cleaning components

Use suitable gloves for protection when components are degreased.

Keep the work area clean and ensure that components are protected from dirt and debris. Ensure that dirt does not contaminate the fuel system.

Before a component is removed from the engine, clean around the component and ensure that all openings, disconnected hoses and pipes are sealed.

Remove, clean and inspect each component carefully. If it useable, put it in a clean dry place until needed. Ball and roller bearings must be cleaned thoroughly and inspected. If the bearings are usable, they must be flushed in low viscosity oil and protected with clean paper until needed.

Before the components are assembled, ensure that the area is free from dust and dirt as possible. Inspect each component immediately before it is fitted, wash all pipes and ports, and pass dry compressed air through them before connections are made.

Engine preservation

Ex-works preservation treatment

The preservation treatment will give up to 12 months shipping and storage protection under normal enclosed storage conditions of -15 °C to +55 °C and up to 90% relative humidity.

- 1 The oil used on engine test will give protection for up to 12 months after despatch from the works.
- 2 After test the oil is then drained from the sump.
- 3 The corrosion inhibited anti-freeze at 50% dilution with clean water used on engine test will give protection for up to 12 months after despatch from the works.
- 4 After spray painting, all openings in the engine (including points where pipework has been removed and air cleaner inlets, etc.) are sealed with plastic plugs or covers.
- 5 The drive face of the flywheel is coated with Valvoline Tectyl 506 preservative.

Parts and service

Service literature

Workshop manuals, installation drawings and other service publications are available from your Perkins distributor.

Training

Local training for the correct operation, service and overhaul of engines is available at certain Perkins distributors. If special training is necessary, your Perkins distributor can advise you how to obtain it at the Perkins Customer Training Department or other main centres.

Service Bulletins

Service procedures and engine design are checked continuously at Perkins Engines. As a result of this development work, it may become necessary to alter the information in manuals and other service publications. Between revisions of the literature, all relevant personnel are provided with full details of changes as they occur. The information is produced as a Service Bulletin; these are supplied to distributors for distribution as necessary.

Service tools

The tools and equipment which follow are required for the operations described in this handbook.

Universally available tools

Description	Qty
8 mm Allen key (rocker box capscrews)	1
Screwdriver (bridge piece and valve clearance adjustment)	1
17 mm Combination spanner (bridge piece adjuster locknut)	1
19 mm Combination spanner (rocker adjuster locknut)	1
Feeler gauge set (to set bridge piece and valve clearance)	1
Strap wrench (oil filter removal)	1
30 mm combination spanner (sump drain)	1
Tool box	1

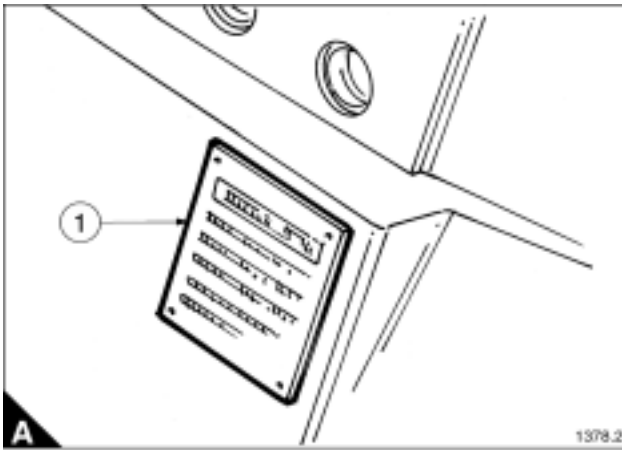
Perkins supplied tools

Part No	Description	Qty
27610190	Spark plug removal tool	1
27610178	Cylinder head spark plug thread cleaning tool	1
T6253/312	Valve and seat recession tool	1
SE253	Engine cranking device	1

Engine identification

The engine number and its build specification details are given on its data plate.

The data plate is fastened to the crankcase above the flywheel housing on cylinder No. 8, 'A' Bank (A1).



Engine specifications

Engine data

Number of cylinders	16
Cylinder arrangement	60° Vee
Cycle	4 stroke, spark ignition
Induction system	Turbocharged
Compression ratio	12:1
Bore	160 mm
Stroke	190 mm
Cubic capacity	61,123 litres
Direction of rotation	Anti-clockwise viewed on flywheel
Firing order	1 ^A , 1 ^B , 3 ^A , 3 ^B , 7 ^A , 7 ^B , 5 ^A , 5 ^B , 8 ^A , 8 ^B , 6 ^A , 6 ^B , 2 ^A , 2 ^B , 4 ^A , 4 ^B
Estimated total weight (dry)	5,600 kg

Ratings

Electrical ratings are based on average alternator efficiency and are for guidance only (1.0 power factor being used).

Operating point

Engine speed	1500 rev/min
Ignition timing	25° BTDC
Mixture cooler water temperature	40 °C
Cooling water exit temperature	<98 °C
Exhaust emissions	1/2 TA-Luft (NO _x) / TA-Luft (NO _x)

Fuel data

Fuel type	Natural Gas (UK)
Lower calorific value	34,710 kJ/Sm ³ (45,671 kJ/kg)
Density	0,76 kg/Sm ³
Stoichiometric air requirement	16 kg/kg
Minimum methane number	75

Cooling system

Recommended coolant:

50% inhibited ethylene glycol or 50% inhibited propylene glycol and 50% clean fresh water. For combined heat and power systems and where there is no likelihood of ambient temperatures below 10 °C, then clean 'soft' water may be used, treated with 1% by volume of Perkins inhibitor (part number OE45350).

Maximum jacket water pressure in crankcase ... 2 bar

Jacket water data:

Coolant flow	15 kg/s
Coolant exit temperature (max)	98 °C
Coolant entry temperature	84 °C

Charge cooling water data (2nd circuit):

Coolant flow	10 kg/s
Coolant entry temperature (max)	40 °C

Charge cooler	Bar and plate on engine
Coolant pump	not fitted
Maximum static pressure head on coolant inlet above engine crank centre line	7 m
Coolant immersion heater capacity	4 kW (2 off)

Lubrication system

Recommended lubricating oil (for Natural Gas fuel applications). ESSO HPC 40

Lubricating oil capacity:

Total system.. 286 litres

Sump maximum. 257 litres

Sump minimum.. 147 litres

Lubricating oil temperature (maximum to bearings).. 105 °C

Lubricating oil pressure (at 85 °C temperature to bearing gallery) 4,5 bar

Oil consumption (after running-in - typically after 250 hours) 0,25 g/kW.hr

Oil flow rate from pump 7,8 l/s

Sump drain plug tapping size. G1

Oil pump... .. Positive displacement gear pump

Normal operating angles:

Fore and aft... .. 5°

Side tilt 10°

Fuel system

Recommended fuel. Natural Gas LHV at 34,71 MJ/m³

Gas supply pressure 6 kPa to 10 kPa at full rated flow conditions

Carburettor type. Woodward Tecjet 50

Notes:

- Gas supplies must be filtered to the same standard as the engine intake air, i.e. maximum particle size not to exceed 5 microns.
- Installation of gas supply and shut-off valves to be in accordance with local regulations.

Fuel consumption gross	Units	¹ / ₂ TA-Luft	TA-Luft
Continuous baseload rating	kJ/kWs	2,53	2,47
Mass flow data	Units	¹ / ₂ TA-Luft	TA-Luft
Fuel	kg/h	201	198
Volume flow data (100kPa)	Units	¹ / ₂ TA-Luft	TA-Luft
Fuel (15 °C)	m ³ /h	265	261

Induction system

Emissions data with combustion air temperature of 25 °C at continuous baseload rating.

Emissions data	Units	¹ / ₂ TA-Luft	TA-Luft
Oxygen (O ₂)	%	9.4	9.3
Oxides of nitrogen (NO _x) ⁽¹⁾	mg/Nm ³	250	500
Carbon monoxide (CO) ⁽¹⁾	mg/Nm ³	1100	850
Total hydrocarbons (THC) ⁽¹⁾	mg/Nm ³	1411	1372

(1) Figures corrected to 5% O₂ in the exhaust stream.

Mass flow data	Units	¹ / ₂ TA-Luft	TA-Luft
Combustion air	kg/h	5760	5544
Maximum inlet depression	kPa	4,8	5,9

Exhaust system

Exhaust outlet size 210 mm (internal)

Exhaust data	Units	¹ / ₂ TA-Luft	TA-Luft
Exhaust gas flow (wet)	kg/h	5961	5742
Exhaust gas temperature	°C	498	497
Lambda	λ	1,80	1,75
Maximum allowable exhaust back pressure	kPa	6,5	7,0

Electrical system

Starter motor. 24 volts
 Starter motor power 16,4 kW
 Number of teeth on flywheel.. . . . 156
 Number of teeth on starter motor 12
 Minimum cranking speed.. . . . 120 rev/min
 Pull in current of starter motor solenoid 26,8 amps at 24 volts
 Hold in current of starter motor solenoid 9 amps at 24 volts

Engine management system

Full electronic engine management system controlling:

- Speed governing
- Air/Fuel ratio
- Start/Stop sequence
- Anti-knock
- Engine protection and diagnostics

Ignition system

Primary voltage.. . . . 24 volts
 Polarity Negative earth
 Ignition coils.. . . . 1 per cylinder
 Spark plug type.. . . . 18 mm
 Spark plug gap 0,25 mm
 Ignition timing 25° BTDC

Performance data

Note: All data based on operation to ISO 3046/1, BS 5514 DIN 6271 standard reference conditions.

Test conditions

- Air temperature - 25 °C
- Barometric pressure - 100 kPa
- Relative humidity - 30%

General installation

Designation	Units	Continuous baseload rating	
		50 Hz; 1500 rev/min	
		¹ / ₂ TA-Luft (NO _x)	TA-Luft (NO _x)
Gross engine power	KW	1042	1042
BMEP gross	Bar	13,6	13,6
Combustion air flow	m ³ /min	82,7	79,8
Exhaust gas temperature max (after turbo)	°C	498	497
Exhaust gas flow (max)	m ³ /min	220	212
Overall electrical efficiency	%	38.2	39.2
Mean piston speed	m/s	9,5	9,5
Charge coolant flow	l/s	10	10
Nominal excess air factor (Lambda)	λ	1,80	1,75
Typical Gen Set 25 °C (100 kPa) electrical output (unit 1.0pf)	kW	1008	1008
Assumed alternator efficiency	%	96.7	96.7

Energy balance

Continuous baseload rating	Units	1500 rev/min ¹ / ₂ TA-Luft (NO _x)	%	1500 rev/min TA-Luft (NO _x)	%
Energy in fuel (fuel heat of combustion)	kW	2638	100	2574	100
Energy in power output (net) (engine shaft power)	kW	1042	39.5	1042	40.5
Energy to exhaust cooled to 120 °C (TA Luft)	kW	688	26.1	673	26.1
Energy to coolant (jacket, oil and 1st circuit of c/c)	kW	544	21.0	548	21.3
Sum of useable heat	kW	1340	50.8	1314	51.0
Sum of useable energy	kW	2382	90.3	2356	91.5
Energy to radiation (surface radiation and other losses)	kW	79	3.0	49	1.9
Energy to charge cooler 2nd circuit	kW	98	3.7	93	3.0
Waste energy from exhaust gas	kW	177	6.7	171	6.6

Note: Not to be used for CHP design purposes. (Indicative figures only). Consult Perkins Engines Company Limited. Assumes complete combustion.

2

Engine views

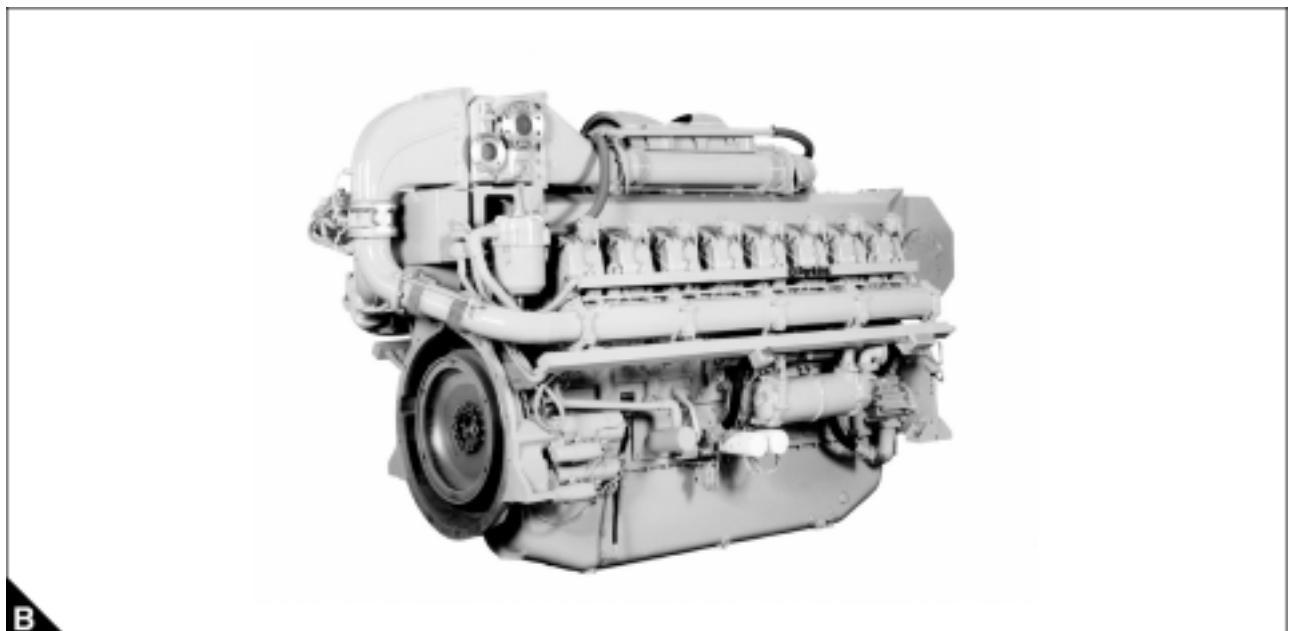
Introduction

Perkins engines are built for specific applications and the views which follow do not necessarily match your engine specification.

'B' Bank (gearcase end)



'A' Bank (flywheel end)



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3

Operating instructions

Introduction

Information for the mechanical maintenance of the 4016-E61TRS gas engine is given in this User's Handbook (TSL 4230) and the Workshop Manual (TSL 4235).

Information on the EMS system which controls all functions on the engine, including oil circuit priming, starting and stopping sequences is given in the OEM Application, Installation and Commissioning Manual (TSL 4232) and the Diagnostic Manual (TSL 4233) issue 3.

These publications should be understood and used together for the safe operation of the engine.

Note: For oil and coolant details refer to Chapter 5, Gas and engine fluids specification.

How to fill the engine with oil

1 Remove the sump drain plug and check that the sump is clean and empty. Refit and tighten the plug.

Note: The oil filler and sump dipstick are at the front end of the engine, on the 'B' Bank side.

2 Remove the oil filler plug by rotating the T-bar (A1) anti-clockwise.

3 Fill the sump to the maximum mark on the dipstick (A2) with the correct grade of lubricating oil as specified in "Lubricating oil recommendations" on page 42.

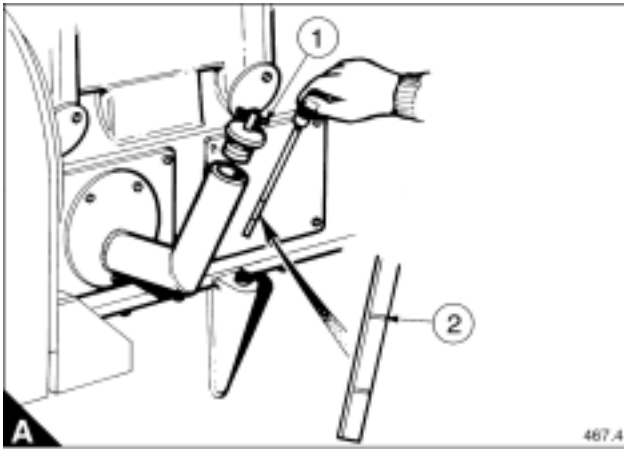
4 Refit the oil filler plug.

Quantity of oil

Maximum	257 litres
Minimum	147 litres
Total system.. . . .	286 litres

Caution: Use the oil priming sequence before the engine is run, see the OEM Application, Installation and Commissioning Manual (TSL 4232) issue 3.

Note: When using the engine for the first time, it should be run until it reaches normal working temperature, stopped, checked for oil leaks and, if necessary, the sump topped up to the full mark (A2) on the dipstick.



How to fill a CHP type cooling system

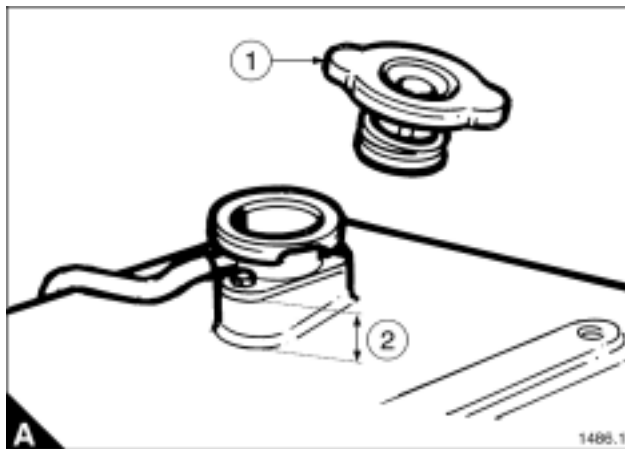
The siting of the cooling system filler cap and air vent plugs is dictated by each OEM's individual installation. The operator must be aware of their position.

Caution: All trapped air must be vented from the engines cooling system. If an airlock is present on engine start up localised overheating will occur, possibly causing engine damage.

Note: A solution of clean water and anti-freeze, or clean water and corrosion inhibitor, must be used in the cooling system. Refer to "Coolant specification" on page 43.

Warning! Always stop the engine and allow the pressurised system to cool before removing the filler cap. Avoid skin contact with the coolant mixture.

- 1 Remove the cooling system filler cap (A1).
- 2 Loosen the appropriate air vent plugs.
- 3 Fill the cooling system until air free coolant flows from the vent plugs.
- 4 Stop filling and tighten the vent plugs.
- 5 Fill the cooling system to 25 mm (1 inch) (A2) below the filler neck.
- 6 Replace the filler cap.



How to fill a radiator type cooling system

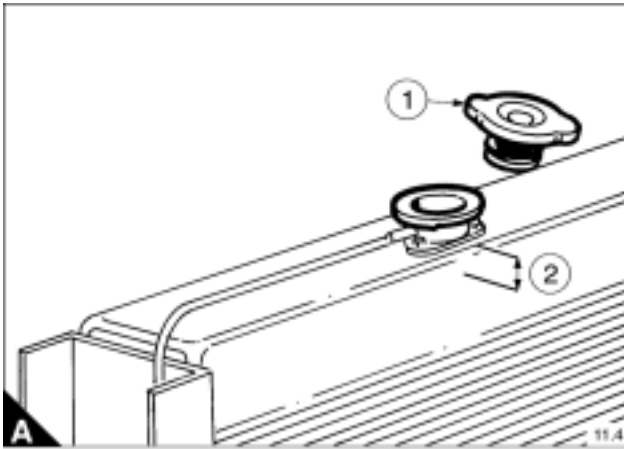
The siting of the cooling system air vent plugs is dictated by each OEMs individual installation. The operator must be aware of their position.

Caution: All trapped air must be vented from the engines cooling system. If an airlock is present on engine start up localised overheating will occur, possibly causing engine damage.

Note: A solution of clean water and anti-freeze, or clean water and corrosion inhibitor, must be used in the cooling system. Refer to "Coolant specification" on page 43.

Warning! Always stop the engine and allow the pressurised system to cool before removing the filler cap. Avoid skin contact with the coolant mixture.

- 1 Remove the radiator filler cap (A1).
- 2 Loosen the appropriate air vent plugs.
- 3 Fill the radiator until air free coolant flows from the vent plugs.
- 4 Stop filling and tighten the vent plugs.
- 5 Fill the radiator to 25 mm (1 inch) (A2) below the filler neck.
- 6 Replace the filler cap.



4

Preventive maintenance

Maintenance procedures

The service schedule is suitable for an engine working under average conditions.

If your engine is working under particularly dirty or dusty conditions, more frequent servicing will be necessary particularly in respect of the lubricating oil and air cleaners.

Correct and regular maintenance will help prolong engine life.

Warnings!

- *Make quite certain that the engine cannot be started before undertaking any maintenance.*
- *This is particularly important in the case of automatically starting generating sets or remote starting engines.*
- *Personal protective equipment must always be worn.*

Service schedule

Oil and filter change intervals

For engines running on gas to the specification given in "Gas specification" on page 41 and using the approved lubricating oil given in "Lubricating oil recommendations" on page 42, the oil and filters must be changed after the first 500 hours of operation.

Subsequent oil and filter changes must be determined using an oil analysis programme. For further details refer to "Oil and filter change programme" on page 42.

The procedures indicated in the service schedule require reference to the following publications:

- User's Handbook - TSL 4230 **(UH)**
- Workshop Manual - TSL 4235 **(WM)**
- Diagnostic Manual - TSL 4233 **(DM)**

A service - First 500 hour

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Oil and filter change	UH
Clean the filter gauze for the piston cooling jet oil gallery	UH
Equalise bridge pieces and set valve clearances	UH
Check and clean spark plugs, reset gap	UH

B service - 2,000, 6,000, 18,000 and 22,000 hours

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Equalise bridge pieces and set valve clearances	UH
Check valve and seat recession	UH
Check and clean spark plugs, reset gap	UH
Closed circuit breather element - renew	UH
Air filter - renew (<i>subject to environmental conditions</i>)	UH
Check emissions, adjust if necessary	DM

C service - 4,000 and 20,000 hours

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Clean the filter gauze for the piston cooling jet oil gallery	UH
Equalise bridge pieces and set valve clearances	UH
Check valve and seat recession	UH
Check and clean spark plugs, reset gap	UH
Breather element - renew	UH
Air filter - renew (<i>subject to environmental conditions</i>)	UH
Calibrate oxygen sensor	UH - DM
Check emissions, adjust if necessary	DM

D service - 8,000 and 24,000 hours

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Clean the filter gauze for the piston cooling jet oil gallery	UH
Equalise bridge pieces and set valve clearances	UH
Check valve and seat recession	UH
Check and clean spark plugs, reset gap	UH
Breather element - renew	UH
Air filter - renew (<i>subject to environmental conditions</i>)	UH
Charge cooler - clean and fit new gasket	WM
Test sensors and protection systems annually	DM
Check coolant anti-freeze/inhibitor strength annually	UH
Calibrate oxygen sensor, renew if necessary	UH - DM
Calibrate turbine inlet temperature interface module	DM
Check emissions (adjust if required)	DM
Magnetic pick-ups - clean and adjust	WM
Check and calibrate ignition timing	DM

E service - 10,000, 14,000, 26,000 and 30,000 hours

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Equalise bridge pieces and set valve clearances	UH
Check valve and seat recession	UH
Check and clean spark plugs, reset gap	UH
Breather element - renew	UH
Air filter - renew (<i>subject to environmental conditions</i>)	UH
Calibrate oxygen sensor, renew if necessary	UH - DM

F service - 12,000 and 28,000 hours

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Clean the filter gauze for the piston cooling jet oil gallery	UH
Equalise bridge pieces and set valve clearances	UH
Check valve and seat recession	UH
Check and clean spark plugs, reset gap	UH
Breather element - renew	UH
Air filter - renew (<i>subject to environmental conditions</i>)	UH
Calibrate oxygen sensor, renew if necessary	UH - DM
Check emissions, adjust if necessary	DM

G service - 16,000 hours

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Equalise bridge pieces and set the valve clearances	UH
Check valve and seat recession	UH
Check and clean spark plugs, reset gap	WM
Breather element - renew	WM
Air filter - renew (<i>subject to environmental conditions</i>)	WM
Cylinder heads - renew	WM
Charge cooler - clean and fit new gasket	WM
Test sensors and protection systems annually	DM
Check coolant anti-freeze/inhibitor strength annually	UH
Replace oxygen sensor	UH - DM
Calibrate interface module for turbine inlet temperature	DM
Check emissions, adjust if necessary	DM
Oil cooler assembly - overhaul	WM
Turbocharger - renew	WM
Clean gas mixer (see air filter change)	UH
Magnetic pick-ups - clean and adjust	WM
Check and calibrate ignition timing	DM
Inspect ignition coils	UH

H service - 32,000 hours

Description	Manual
Check EMS logged events and record	DM
Check EMS logged diagnostic codes, record and rectify	
Clean the filter gauze for the piston cooling jet oil gallery	UH
Equalise bridge pieces and set valve clearances	UH
Check and clean spark plugs, reset gap	UH
Breather element - renew	UH
Air filter - renew (<i>subject to environmental conditions</i>)	UH
Cylinder heads - renew	WM
Charge cooler - clean and fit a new gasket	WM
Test sensors and protection systems annually	DM
Check coolant anti-freeze/inhibitor strength annually	WM
Calibrate oxygen sensor, renew if necessary	UH - DM
Calibrate interface module for turbine inlet temperature	WM - DM
Check emissions, adjust if necessary	DM
Oil cooler assembly - overhaul	WM
Turbocharger - renew	WM
Clean gas mixer (see air filter change)	UH
Magnetic pick-ups - clean and adjust	WM
Check and calibrate ignition timing	DM
Governor actuator - renew throttle valve	WM
Fuel valve/tecjet - renew	WM
Butterfly valve - overhaul	WM
Inspect ignition coils	UH
Pistons, rings and liners - renew	WM
Big end bearings - renew	WM
Small end bearings - inspect and renew if necessary	WM
Camshaft, camshaft bushes and cam-follower assembly - renew	WM
Starter motors - renew	WM
Front and rear crankshaft oil seals - inspect and renew if necessary	WM
Pushrods - check for wear and straightness	WM
Timing gears - inspect	WM
Torsional vibration dampers - renew	WM
Exhaust manifold - check and renew if necessary	WM

Notes:

- Maintenance schedule from 32,000 hrs to 64,000 hrs is the same as 20,000 to 32,000 hrs.
- At 64,000 hrs operation consult Perkins Engines Company Limited, Stafford, with reference to major overhaul and service exchange engine components.

How to check the lubricating oil level

- 1 Stop the engine and wait 5 minutes to allow the oil to drain into the sump.
- 2 Withdraw the dipstick and wipe clean.
- 3 Insert the dipstick and wait 2 seconds.
- 4 Withdraw the dipstick and check the level against the high and low marks.
- 5 If necessary, put more oil into the sump. Use the same grade and specification as that already in the system.

Caution: Do NOT overfill.

How to check the coolant level

Warning! Always stop the engine and allow the pressurised system to cool before removing the filler cap. Avoid skin contact with the coolant mixture.

- 1 Remove the filler cap.
- 2 The coolant level should be 25 mm (1") below the top of the filler neck.

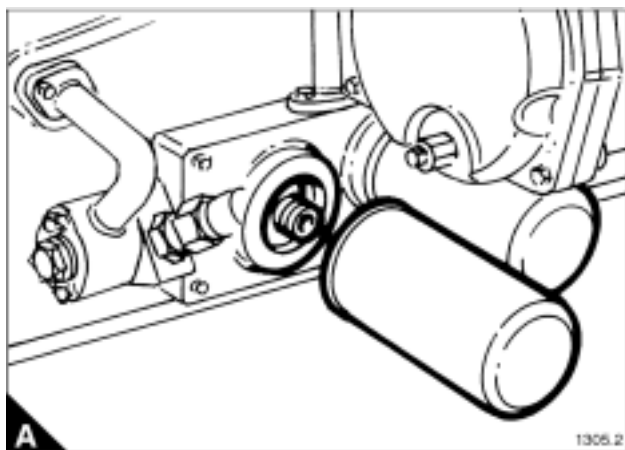
Caution: If coolant is added to the system during the service, it must consist of the same original mixture as used to fill the system.

- 3 Refit the filler cap.

How to change the engine oil and filters

- 1 Place a container with a capacity of 250 litres (35 gal) under the sump drain plug.
- 2 Remove the sump drain plug and allow the oil to drain into the container.
- 3 Place a container with a capacity of 5 litres (1 gal) under the filters to catch the oil which will be released as they are removed.
- 4 Remove the oil filters using a strap wrench, turning the filter anti-clockwise (A).
- 5 Clean the sealing faces and the threaded bosses of the oil filter header.
- 6 Lightly lubricate the sealing ring of the new filters with engine oil.
- 7 Screw each filter up to the header using firm hand pressure.
- 8 Refit the sump drain plug and refill the engine with the correct grade of lubricating oil as given in "Lubricating oil recommendations" on page 42.

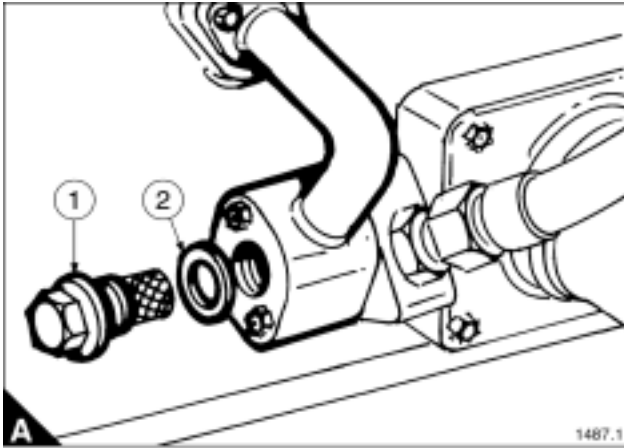
Caution: Use the oil priming sequence before the engine is run, see the OEM Application, Installation and Commissioning Manual (TSL 4232).



How to clean the plug filter fitted in the oil gallery for the piston cooling jets

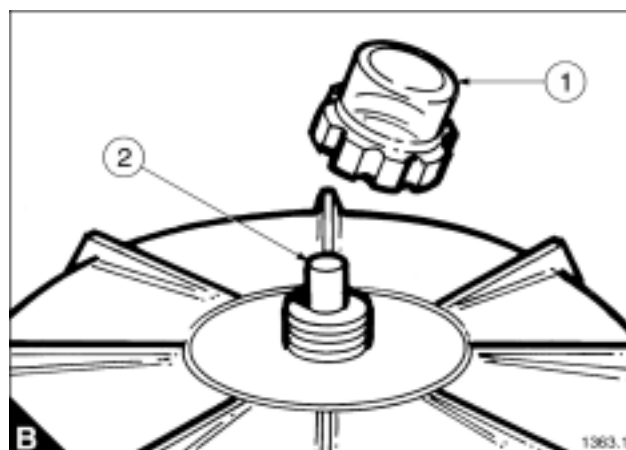
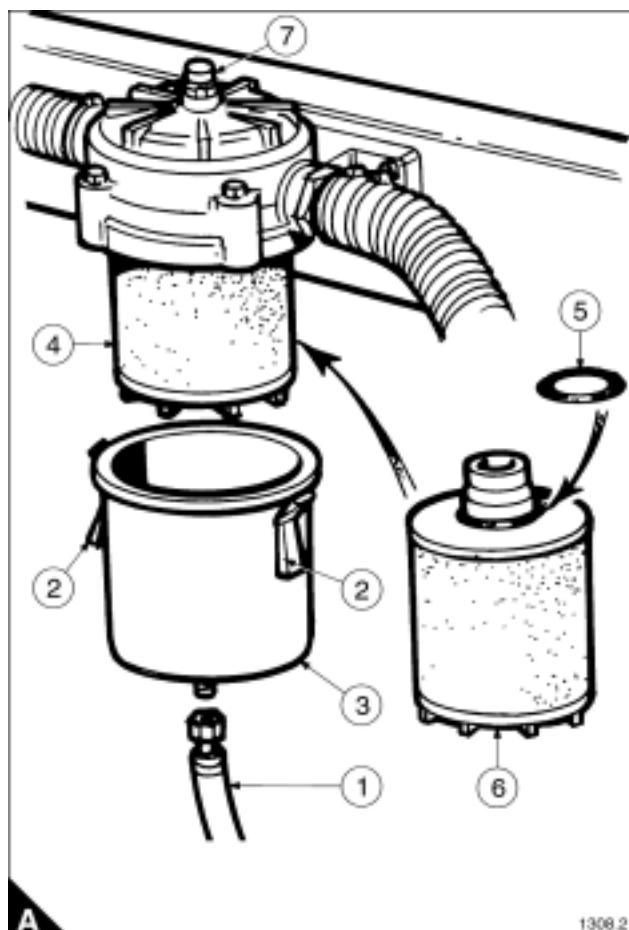
- 1 Remove the plug filter (A1).
- 2 Clean the filter using a suitable solvent, if necessary use compressed air to remove small particles from the gauze.
- 3 Refit the plug filter (A1), complete with a new sealing washer, part number 036620 (A2), and tighten to a torque of 70 Nm (50 lbf ft).

Caution: Use the oil priming sequence before the engine is run, see the OEM Application, Installation and Commissioning Manual (TSL 4232).



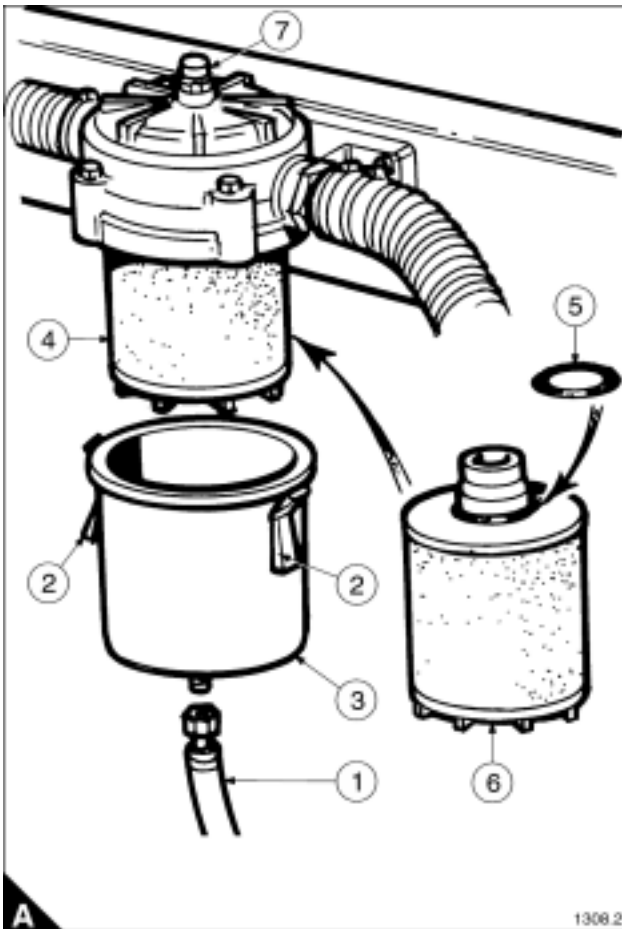
How to check the filter restriction indicator for the closed circuit breather

- 1 Examine the clear plastic cover (A7) on the breather filter. If the red indicator button is not showing the filter is in serviceable condition.
- 2 When the filter reaches its contamination limit the red restriction indicator button will show. At this point the filter element must be renewed, see "To change the filter element of the closed circuit breather" on page 30.
- 3 When the filter element has been changed, reset the indicator button: remove the clear plastic cover (B1), press the indicator button (B2) and refit the cover.



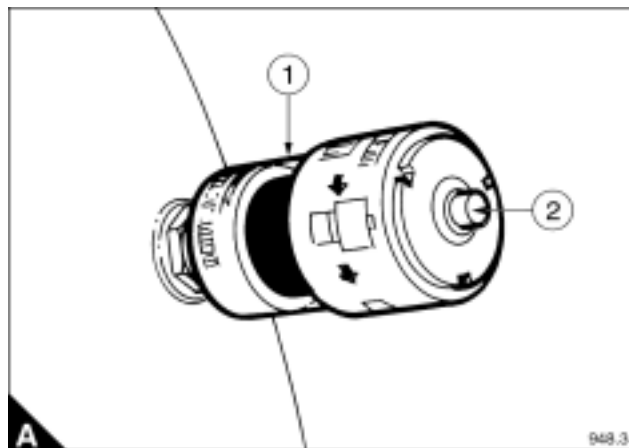
To change the filter element of the closed circuit breather

- 1 Disconnect the oil drain pipe (A1).
- 2 Release the three retaining clips (A2) and lift the filter container (A3) from the filter body.
- 3 Pull the filter element (A4) down from the filter body and discard it.
- 4 Clean the oil deposits from the filter container and the filter body.
- 5 Fit the sealing/retaining 'O' ring (A5) to the new filter element (A6).
- 6 Push the filter element into its location in the filter body.
- 7 Fit the filter container to the filter body. When locking down the retaining clips check the container is squarely seated on the filter body.
- 8 Refit the oil drain pipe (A1).



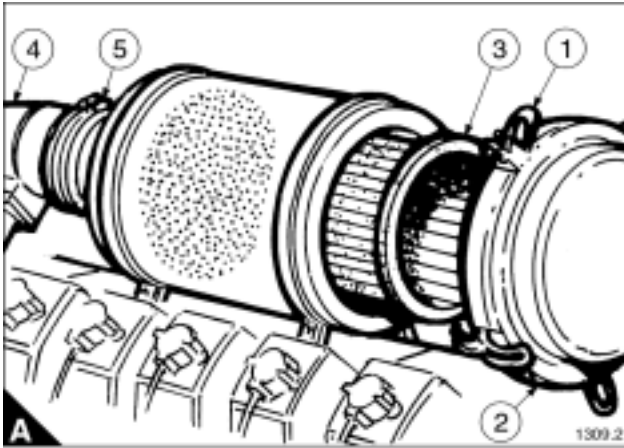
How to check the air cleaner restriction indicator

- 1 Examine the middle section of the restriction indicator (A1). It will remain clear while the air cleaner is in serviceable condition.
- 2 When the filter reaches its contamination limit the restriction indicator will sense the change in manifold pressure and the middle section will change to red.
- 3 At this point the air filter must be changed, see "How to change the air filter element and clean the gas mixer" on page 32.
- 4 When the air filter has been changed reset the indicator by pressing the button (A2).



How to change the air filter element and clean the gas mixer

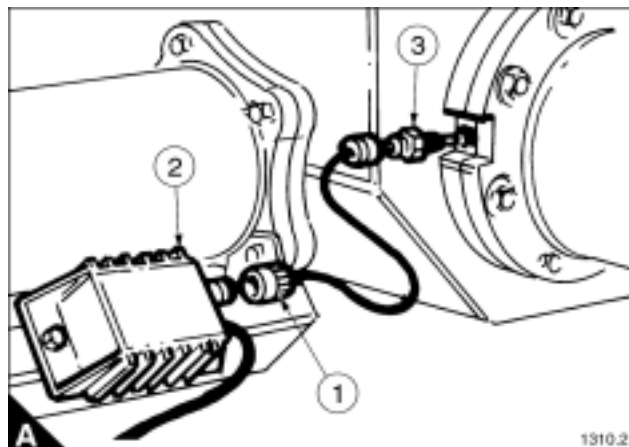
- 1 Release the five over-centre catches (A1) and remove the air filter end cover (A2).
- 2 Pull out the filter element (A3).
- 3 Clean any dust accumulation from inside the air filter body and the gas mixer (A4) using a clean cloth. If necessary remove the coupling hose (A5) to give access.
- 4 Fit a new filter element into the filter body.
- 5 Fit the end cover locating it in the filter element and on the filter body, then lock down the over-centre catches.



How to change the oxygen sensor

- 1 Disconnect the multi-pin plug (A1) on the oxygen sensor power cable from the connector on the oxygen sensor interface (A2).
- 2 Remove the oxygen sensor (A3) from the turbocharger outlet.
- 3 Fit the new oxygen sensor into the turbocharger outlet tighten it down to 25 Nm (18 lbf ft).
- 4 Reconnect the multi pin plug (A1).

Note: Calibration of the EMS system will be required when the oxygen sensor is changed. Refer to the Diagnostic Manual (TSL 4233).



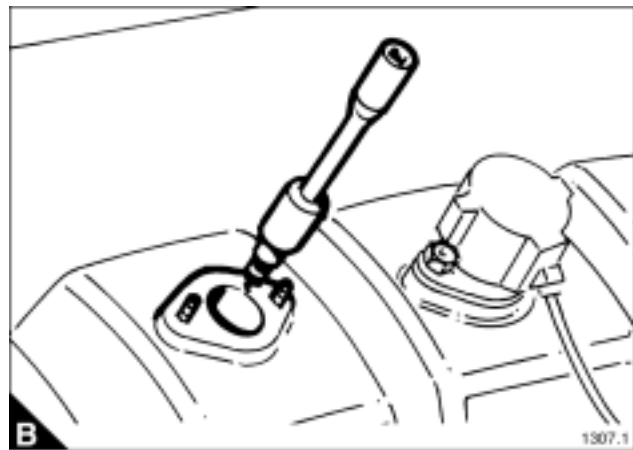
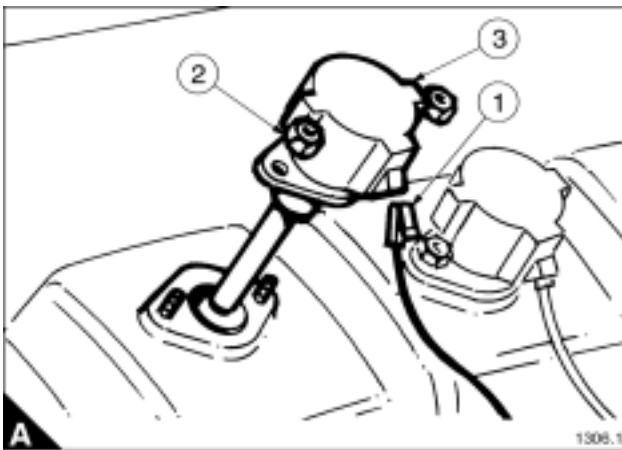
How to remove a spark plug

Special requirements

Special tools	
Description	Part number
Spark plug removal socket and extension bar	27610190

- 1 Disconnect the power lead (A1) to the ignition coil.
- 2 Remove the two retaining nuts (A2).
- 3 Pull the combined ignition coil/plug cap (A3) out of the rocker cover.
- 4 Remove the spark plug (B).

Note: Store the spark plugs in their cylinder order as the combustion deposits on the plugs will give a guide to the conditions in each cylinder.



How to clean, set and fit a spark plug

Special requirements

Special tools	
Description	Part number
Cylinder head spark plug thread cleaning tool	27610178

1 Clean any carbon/ash deposits from the spark plug thread and ceramic insulator using a suitable solvent and a dry cloth.

Note: A light coating of ash evenly deposited on the electrodes indicates the plug is in good condition with a clean burning mixture.

2 Clean any loose ash deposit from the end of the spark plug (A1) using a nylon brush.

Caution: Do not use a metal brush to clean a spark plug as the porcelain around the centre electrode will be scratched allowing ash deposits to build rapidly on the roughened surface causing plug failure.

3 Set the spark plug gap to 0,25 mm (0.010 in) (A2).

Note: The centre and ground electrodes of the spark plug are tipped with a hard surface which must not be filed or cleaned using abrasive paper.

4 Every time a spark plug is refitted the sealing washer (A3) must be renewed. Use sealing washer part number Y98/00038.

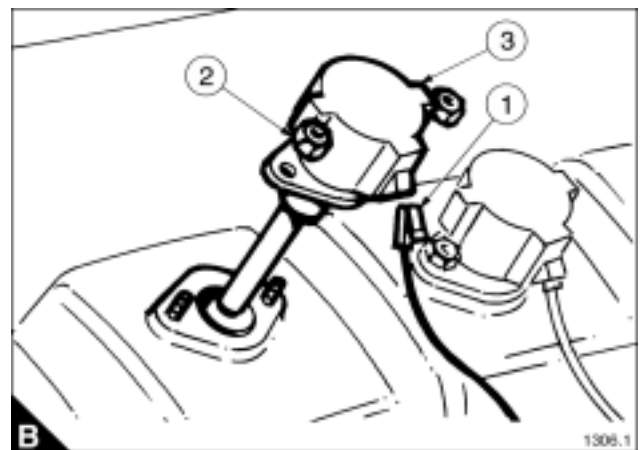
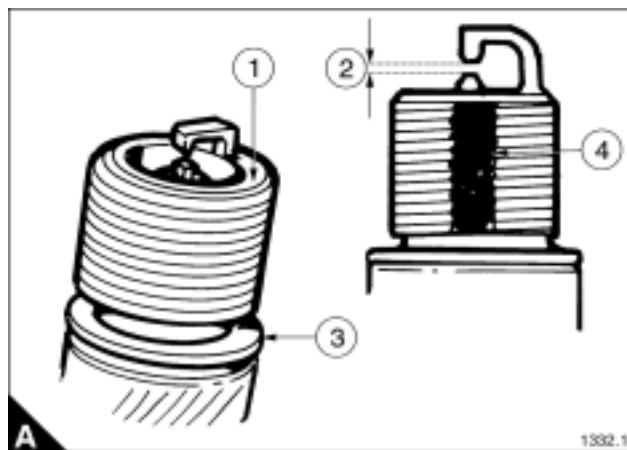
Caution: The spark plug should be finger tightened into the cylinder head, if resistance is felt clean the plug thread in the cylinder head using a thread chaser. Never use a thread tap.

5 Apply a very small amount of Poly Butyl Cuprysil grease to the thread of the spark plug (A4).

6 Fit the spark plug carefully locating it in the cylinder head. Tighten down finger tight, then torque to 50 Nm (35 lbf ft).

7 Refit the ignition coil (B3) and tighten the retaining nuts (B2) to 13,5 Nm (10 lbf ft).

8 Refit the power lead (B1).



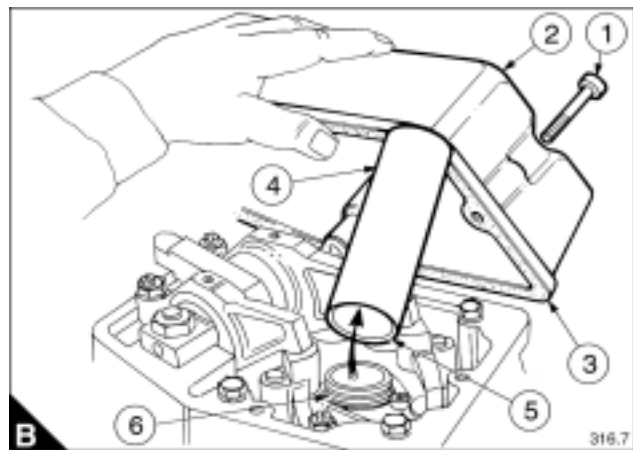
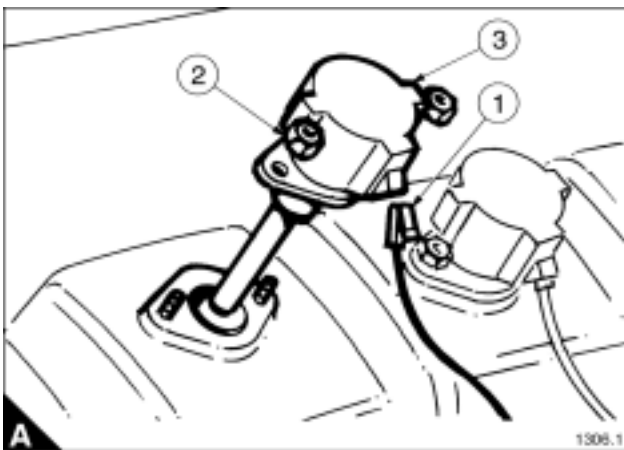
Preparation for equalising bridge pieces and setting valve clearances

Special requirements

Special tools	
Description	Part number
Engine cranking device	SE253

- 1 Disconnect the power lead (A1) from the ignition coil.
- 2 Remove the two retaining nuts (A2).
- 3 Pull the combined ignition coil/plug cap (A3) out of the rocker cover.
- 4 Remove the four retaining capscrews (B1) from each rocker cover (B2).
- 5 Lift off the rocker cover, remove and discard the gasket (B3).
- 6 Pull the spark plug cover tube (B4) out of the cylinder head.

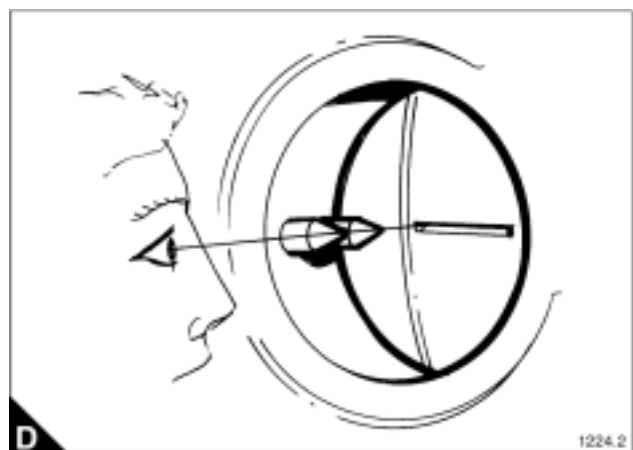
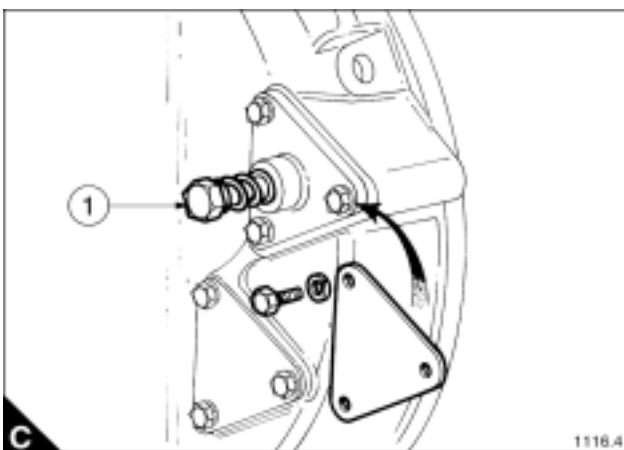
Warning! When refitting the spark plug tube (B4), the internal chamfer (B5) must be fitted against the 'O' ring (B6).



7 To rotate the engine to the positions required for this procedure fit the engine cranking device to the spare starter motor mounting in the flywheel housing (C).

8 Using a socket and ratchet wrench press against the spring loaded bolt head (C1) until the pinion engages with the flywheel gear, then crank the engine to the desired position. Refer to "Bridge piece and valve clearance setting sequence" on page 37.

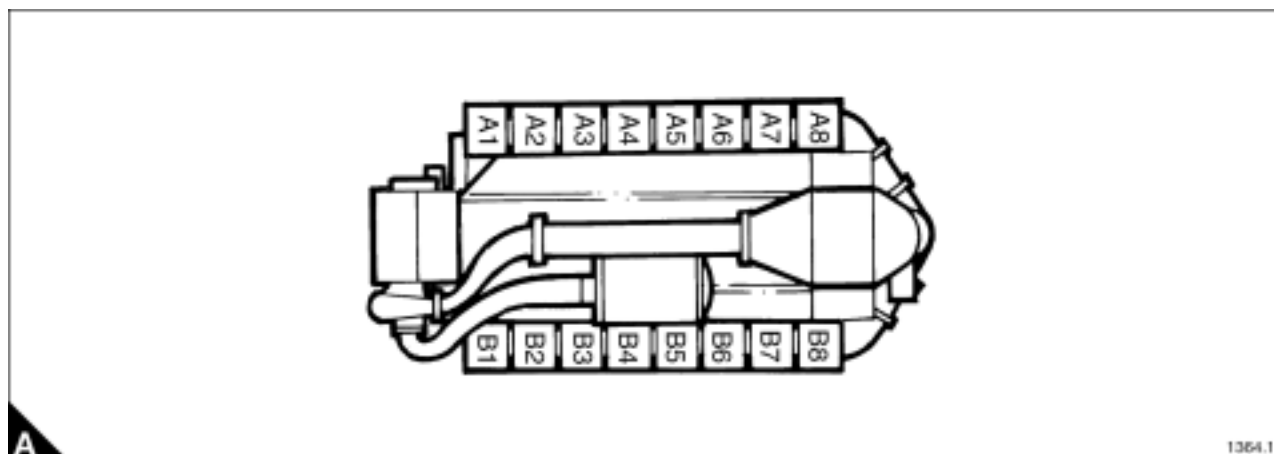
9 The engines flywheel is marked giving the T.D.C. (top dead centre) position of each cylinder. They are viewed through an inspection hole in the flywheel housing. To get an accurate reading line up by eye the tip of both pointers with the marks on the flywheel (D).



Bridge piece and valve clearance setting sequence

T.D.C. (Top Dead Centre)	Valves rocking on cylinder No.	Set bridge piece and valve clearance on cylinder No.
A1 - A8	A8	A1
B1 - B8	B8	B1
A3 - A6	A6	A3
B3 - B6	B6	B3
A7 - A2	A2	A7
B7 - B2	B2	B7
A5 - A4	A4	A5
B5 - B4	B4	B5
A1 - A8	A1	A8
B1 - B8	B1	B8
A3 - A6	A3	A6
B3 - B6	B3	B6
A7 - A2	A7	A2
B7 - B2	B7	B2
A5 - A4	A5	A4
B5 - B4	B5	B4

Note: Where reference is made to 'A' and 'B' banks of cylinders: 'A' bank is to the left and 'B' bank is to the right when viewed from the front of the engine, the crankshaft damper/turbocharger end.



How to equalise bridge pieces

1 Rotate the engine to the position given in "Bridge piece and valve clearance setting sequence" on page 37.

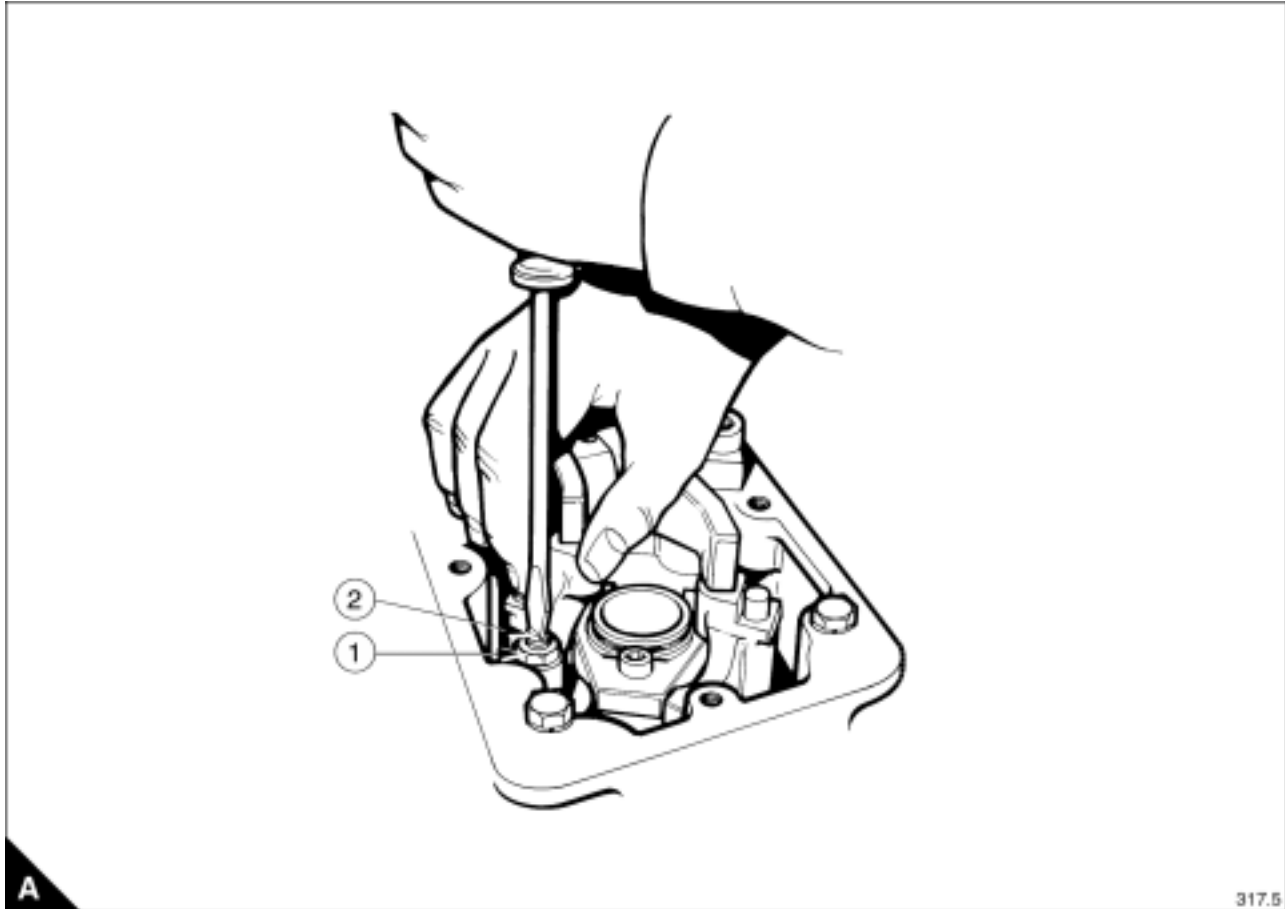
Caution: Check the inlet and exhaust rockers have clearance on the bridge piece.

2 Loosen the locknut on the bridge piece (A1).

3 Screw the adjuster (A2) out until the fixed side of the bridge piece rests on its valve.

4 Hold the top edge of the bridge piece and screw the adjuster down until it touches the valve.

5 Tighten the locknut to a torque of 35 Nm (25 lbf ft) without moving the adjuster.



How to set valve clearances

Special requirements

Special tools	
Description	Part number
Feeler gauges	UA

1 Check the clearance using a feeler gauge.

Note: The inlet and exhaust valve clearance is 0,4 mm (0.016 in).

2 To set the valve clearance loosen the locknut (A2).

3 Place the feeler gauge (A1) between the rocker and bridge piece.

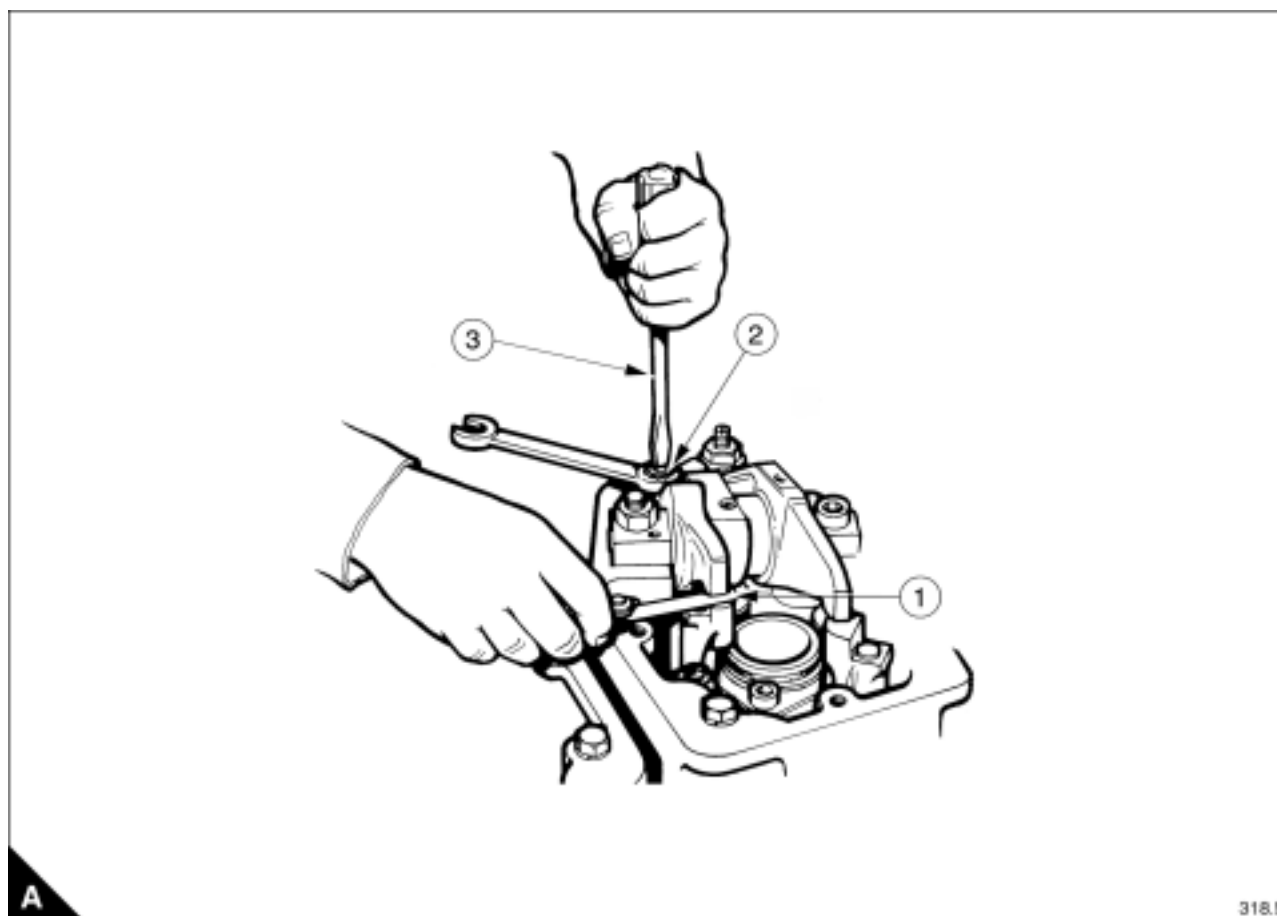
4 Screw the adjuster (A3) up or down making the feeler gauge a slide fit.

5 Tighten the locknut to a torque of 50 Nm (35 lbf ft) without moving the adjuster.

6 Refit the spark plug cover tube and rocker cover. Use a new gasket.

7 Refit the spark plug, refer to "How to clean, set and fit a spark plug" on page 35.

8 Refit the ignition coil. Tighten the retaining nuts to 19,0 Nm (14 lbf ft).



How to check valve and seat recession

Special requirements

Special tools			
Description	Part number	Description	Part number
Valve seat recession checking tool	T6253/312	Feeler gauges	UA

By the use of tool No. T6253/312, an indication of valve and seat wear (recession) can be obtained without the removal of a cylinder head.

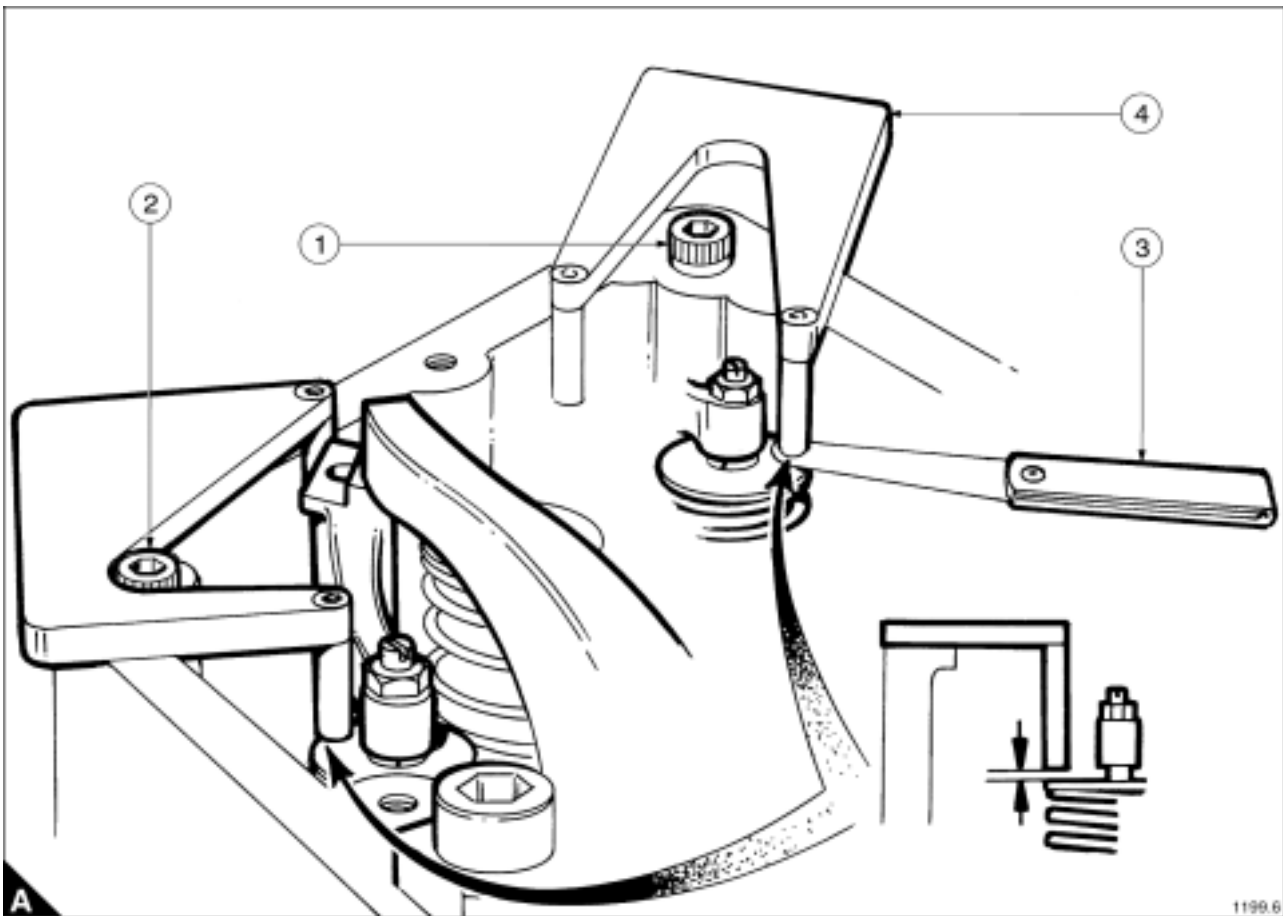
The tool is to be used as part of the bridge piece and valve clearance sequence.

Note: The inlet valves are easily checked but as there is insufficient clearance only one exhaust valve can be checked.

- 1 Place the tool on the rocker box face around the bolt (A1). Position the legs of the tool above the inlet valve spring retainers.
- 2 The clearance between the legs and valve spring retainers indicates the valve life left. A leg touching a valve spring retainer indicates the need for a cylinder head overhaul.
- 3 To check the exhaust valve, place the tool around bolt (A2).

Note: As a result of product improvements, the rocker box to cylinder head joint has been improved using a graphite material which is 0,7 mm thicker than the joint it has replaced. This change covers all 4016-E61TRS engines.

To check valve seat recession on these engines use a 0,7 mm feeler gauge (A3) in conjunction with the recession tool (A4).



5

Gas and engine fluids specification

Gas specification

A new engine will be set to operate on clean natural gas conforming to the British natural gas specifications having a lower calorific value of 34,71 MJ/Sm³ (930 BTU/Sft³).

The difference between high calorific value (HCV) and low calorific (LCV) is that (HCV) is the total amount of heat given off by the gas during combustion and the (LCV) is the high calorific value less the amount of heat used to vaporize the water content of the gas. Since the amount of heat lost in vaporizing the water is different for different gases, the lower calorific value of the gas is chosen as the basis for fuel consumption data. There must be no liquid hydrocarbon fractions in the gas.

Limiting values for British Gas	
Methane number must exceed	75
Combustible constituents must exceed	95%
Calorific value (LCV) to exceed	34 MJ/Nm ³ (912 BTU/Sft ³)
Ethane	4.5%
Hydrogen content not to exceed	0.1%
Propane must not exceed	1.0%
Isobutane content not to exceed	0.2%
Normal butane not to exceed	0.2%
Normal pentane and higher fractions (hexane, heptane, etc). The summation must not exceed	0.02%
Minimum gas pressure at inlet to regulators	15 mbar (1.5 kPa)
Gas pressure not to exceed, without additional pressure regulators	50 mbar (5 kPa)
Hydrogen sulphide not to exceed	0.01% or 100 ppm

Note: The rating may be reduced if lower calorific value of the fuel is lower than 34,71 MJ/Nm³ (930 BTU/Sft³). Also pressure must be constant to maintain emissions and stability. If any of the above parameters are not met, Perkins Engines Company Limited should be consulted for advice.

Gas safety regulations

There are legal requirements that within the U.K. gas fittings and equipment must be installed only by competent persons and in accordance with the Institution of Gas Engineers Procedures IGE UP2. Outside the U.K. anyone undertaking work on the engine or associated with the engine and its gas equipment in particular should check with local and national regulations to ensure compliance.

Lubricating oil recommendations

Approved lubricating oil

Esso Estor HPC 40

Caution: To use a lubricating oil other than that specified, it is essential that Perkins Engines Company Limited, Stafford, is consulted, failure to do so could affect the engine warranty.

Oil and filter change programme

The lubricating oil and filter life is governed by the engine load and gas quality. To determine the optimum oil and filter change period after the engine has been commissioned, use the oil analysis programme which follows.

Initiating an oil analysis programme

Caution: The oil sample must be taken from the mean level in the engine sump, never from the sump drain plug.

Note: During the engine's initial 500 hour running period, oil analysis will show higher levels of iron and copper than the acceptable contamination parameters, marked (*) in the list below. As the engine continues to run the levels will drop within the specified parameters.

Every 250 hours after the first 500 hour oil and filter change the oil should be analysed.

At 750 hours by comparing the oil analysis results a contamination trend can be established, allowing each individual operator to develop an oil and filter change policy for the operating conditions of their engine.

Caution: Irrespective of condition the lubricating oil and filters **MUST** be changed at 2000 hours.

Critical lubricating oil contamination parameters

Viscostatic at 100 °C	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	cSt max 20% above original value
Insolubles.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.5% wt.max
Total base number (TBN)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	60% less than new oil value
Nitration	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30 abs/cm max
Oxidation..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30 abs/cm max
Water ..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.2% vol max
Iron.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	less than 20 ppm*
Copper	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	less than 40 ppm*

Coolant specification

50% inhibited ethylene glycol or 50% inhibited propylene glycol and 50% clean fresh water.

For combined heat and power systems and where there is no likelihood of ambient temperatures below 10 °C, then clean 'soft' water may be used, treated with 1% by volume of Perkins inhibitor.

The inhibitor is available under Perkins part number OE45350.

Maintenance of coolant

Warning! *Always stop the engine and allow the pressurised system to cool before removing the filler cap. Avoid skin contact with the coolant mixture.*

The coolant mixture should be changed at 8,000 hours or 12 months and checked at 2,000 hour intervals for the correct alkalinity level; the pH should not be above 7.5.

Note: A hydrometer only shows the proportion of ethylene glycol. This is not a measure of protection against corrosion.

Caution: *Failure to follow the above recommendations may result in engine damage and will invalidate the engine warranty.*

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6

Fault diagnosis

Introduction

This fault diagnosis chart covers mechanical defects which may occur with the engine. It must be used in conjunction with electronic service tools (TIPSS-EST).

To locate problems within the engine and its systems, refer to the Diagnostic Manual (TSL 4233).

Caution: Do not use mobile phones within 2 meters of the engine as the transmitted signal can affect the electronic management system.

TIPSS connections (A)

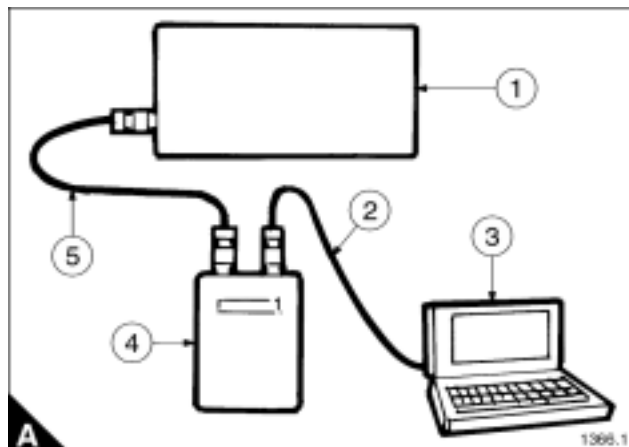
A1 Engine mounted GECM box

A2 PC adaptor harness

A3 PC

A4 Interface module

A5 Service tool harness



Problems and possible causes

Problem	Possible causes
The starter motor turns the engine too slowly	1, 2, 3, 4
The engine does not start	5, 6, 7, 8, 10, 11, 12,
The engine is difficult to start	5, 7, 8, 9, 10, 11, 12, 26, 27, 28, 29, 46, 47
The engine is losing power	8, 9, 10, 11, 12, 13, 15, 26, 27, 28, 29, 30, 44, 46
Misfire	7, 8, 9, 13, 15, 26, 27, 28, 29, 30
High gas consumption	7, 9, 12, 26, 27, 28, 29, 44, 46
The engine knocks	13, 20, 26, 27, 29, 30, 32, 33, 38
The engine runs erratically	7, 8, 9, 12, 26, 27, 28, 29, 30, 44, 46
Vibration	32, 33, 38, 39, 42
Low oil pressure	16, 18, 32, 33, 34, 37, 43, 48
High oil pressure	4, 35
High oil temperature	4, 13, 16, 48
Crankcase pressure	24, 29, 38
High coolant temperature	22, 23, 25, 26, 40, 41
Blue exhaust smoke	21, 24, 29, 38, 45

List of possible causes

- 1 Battery capacity low.
- 2 Bad electrical connections.
- 3 Fault in starter motor.
- 4 Wrong grade of lubricating oil.
- 5 Starter motor turns engine too slowly.
- 6 Ignition failed (no spark at plugs).
- 7 Dirty or worn spark plugs.
- 8 Fault in gas supply.
- 9 Drop in gas quality.
- 10 Restriction in air induction system.
- 11 Restricted movement of engine speed control.
- 12 Restriction in exhaust system.
- 13 Engine temperature is too high.
- 14 Engine temperature is too low.
- 15 Incorrect valve clearances.
- 16 Not enough lubricating oil in sump.
- 17 Spare.
- 18 Dirty lubricating oil filter element.
- 19 Fan damaged.
- 20 Fault in engine mounting or flywheel housing.
- 21 Too much lubricating oil in sump.
- 22 Restriction in air or coolant passages of radiator.
- 23 Electric coolant pump failure.
- 24 Restriction in breather.
- 25 Insufficient coolant in system.
- 26 Cylinder head flame rings leaking.
- 27 Worn cylinder bores.
- 28 Leakage between valves and seats.
- 29 Piston rings are seized in piston (rings worn or broken).
- 30 Broken valve spring.
- 31 Valve stems and/or guides are worn.
- 32 Crankshaft bearings are worn or damaged.
- 33 Lubricating oil pump is worn.
- 34 Relief valve does not close.
- 35 Relief valve does not open.
- 36 Relief valve spring is broken.
- 37 Fault in suction pipe of lubricating oil pump.
- 38 Piston is damaged.
- 39 Flywheel housing or flywheel is not aligned correctly.
- 40 Fault in thermostat or thermostat is of an incorrect type.

Continued

- 41 Restriction in coolant passages on the engine.
- 42 Spare.
- 43 Restriction in sump strainer.
- 44 Turbocharger impeller is damaged or dirty.
- 45 Lubricating oil seal of turbocharger leaks.
- 46 Faulty engine management system.
- 47 Faulty sensor.
- 48 Oil cooler tubestack blocked.