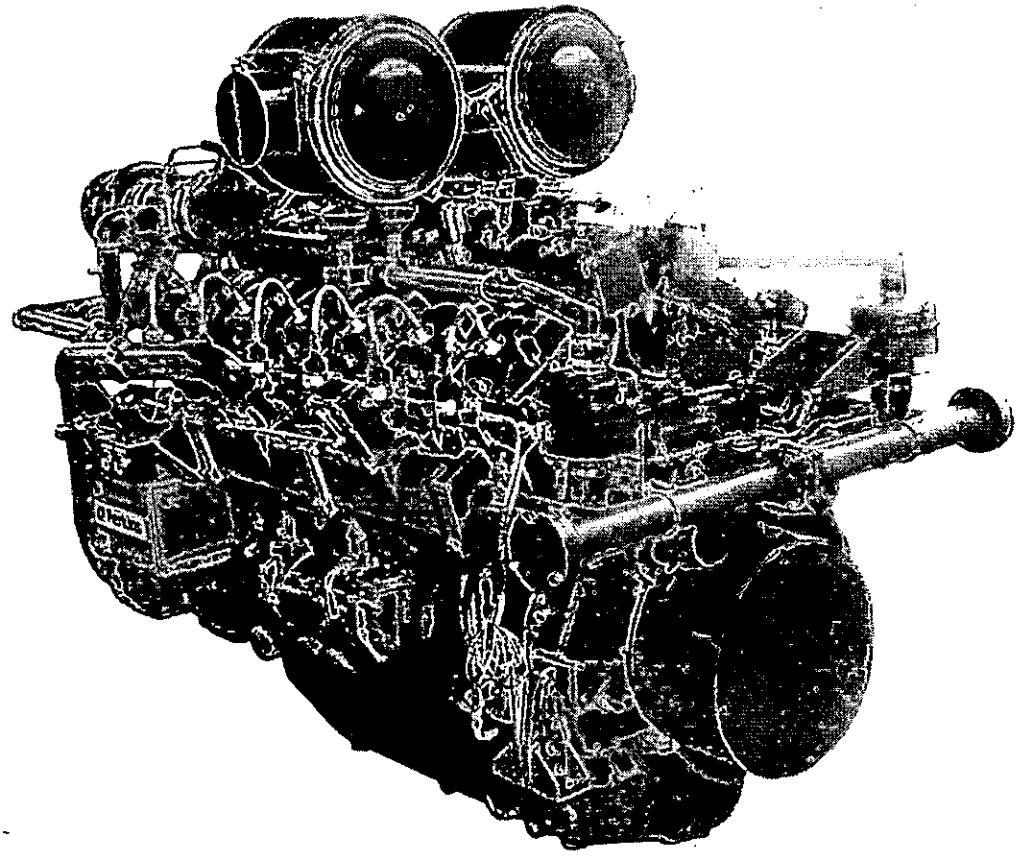
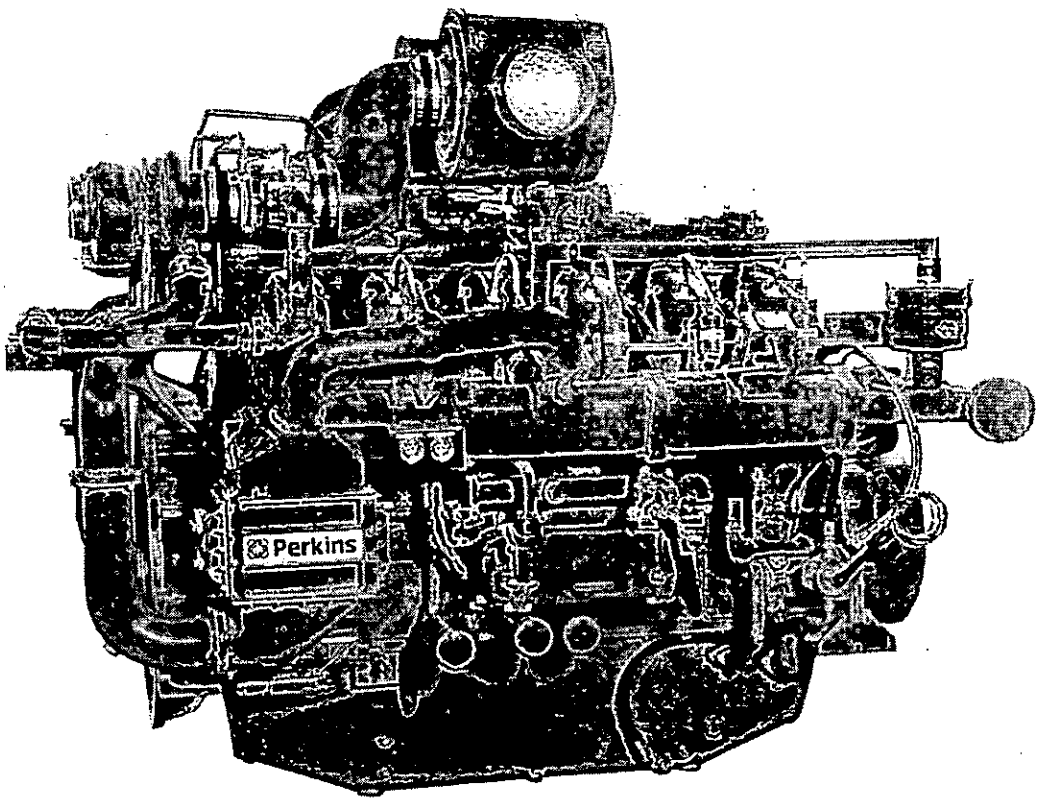
WARNING ⚠

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 TSL4200 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.

PERKINS ENGINES (STAFFORD) ENGINE DESIGNATIONS 4000 SERIES AND SE SERIES EQUIVALENT TERMS	
4000 SERIES	**SE SERIES**
4012TESI	12SETCWG
4016TESI	16SETCWG



4012TESI



4012TESI

⚠ 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 (b) over exposed hot surfaces (c) over exposed air intakes (d) over exposed belts (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 (b) (1) is worn when using anti-freeze (c) (1) is worn when taking pressure cap off radiator or heat exchanger filler (d) (5) is worn when working on or underneath engine (e) (3) is worn when using air pressure line (f) (1) is worn when changing lubricating oil/filter (g) (2) is worn when working in enclosed engine room (h) (1) is worn when changing electrolyte in battery (j) (4) is worn always when working on the engine
No smoking or naked flame 	(a) when checking battery electrolyte (b) when working in engine room (c) when operating or servicing engine
Fuel/oil pipes 	(a) check for leaks (b) check for spilt oil (clean up) (c) always use barrier cream on hands
Gas/air pipes 	(a) check for gas/air mixture leaks (b) never run gas engine with failed pressure disc (c) that gas line and valves meet local safety standards (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 (b) for heat sensors, methane and smoke detectors should be provided (if applicable) (c) test that protection system is working correctly (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 (b) never start engine with governor linkage disconnected (c) do not hold stop lever in run position when starting engine (d) always hold stop lever in stop position when cranking only
Electrical equipment 	(a) check that electrics are earthed to local safety standards (b) disconnect electrical supply to water jacket heater (if fitted) before working on engine (c) take care against electric shocks (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 (b) check for correct ventilation of engine room (c) check that guards are fitted (d) check that diesel exhaust is clear (e) check that pipework allows gas to escape upwards (f) check that pipework is supported
Stop the engine 	(a) before changing lubricating oil (b) before filling radiator or topping up with anti-freeze (c) before repairing engine (d) before adjusting belts (e) before adjusting tappets (f) before changing spark plugs/injectors (g) before changing air/oil/fuel filters (non change-over) (h) before tightening fixing bolts etc
Flammable fluids 	(a) never store near engine (b) never use near naked light
Clothing 	(a) do not wear loose clothing, ties, jewellery etc. (b) always wear steel toe cap shoes (c) always wear head, eye and ear protection (d) always wear overalls (e) always replace spillage contaminated overall immediately
Lifting heavy components 	(a) use correct lifting equipment (b) do not work alone (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 (b) always wear overalls and proper footwear
Handling/cutting gaskets and joints containing asbestos 	(a) always wear respiratory protection (b) always provide dust extract system (c) always dispose of waste in accordance with local/legislative requirement
Waste disposal 	(a) do not leave oily rags on or near the engine (b) do not leave loose items on or near the engine (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

4012TESI (MINNOX)	12 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, low NOx emission levels, 9.5:1 compression ratio
4012TESI (MINNOX) 200 L.C.	12 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, with NOx emission of less than 200 g/GJ, 9.5:1 compression ratio.
4012TESI (MINNOX) 140 L.C.	12 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, with NOx emission of less than 140 g/GJ, 9.5:1 compression ratio.
4012TESI (MINNOX) 140 H.C.	12 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, with NOx emission of less than 140 g/GJ, 11.5:1 compression ratio.
4016TESI (MINNOX) 200 L.C.	16 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, with NOx emission level of 200 g/GJ or less, 9.5:1 compression ratio.
4016TESI (MINNOX) 140 L.C.	16 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, with NOx emission of 140 g/GJ or less, 9.5:1 compression ratio.
4016TESI (MINNOX) 140 H.C.	16 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, with NOx emission of 140 g/GJ or less, 11.5:1 compression ratio.
4016TESI (MINNOX) 90 H.C.	16 cylinder, 'V' form, 4 stroke, gas engine, water cooled, turbo-charged, water cooled charge air cooler with separate water pump and cooling circuit, lean burn, with NOx emission of 90 g/GJ or less, 11.5:1 compression ratio.

The figures quoted are based on engines set to meet the ISO 3046/1 1981 Condition.
For full technical data please refer to the **Product Information Manual.**
Type (Gas) 12 cylinder and 16 cylinder (MINNOX) 'V' form, water cooled, turbocharged, wet exhaust manifolds with separate raw water cooled charge air cooler.

RANGE	**4012TESI (MINNOX)**	**4016TESI (MINNOX)**
Cycle	4 stroke	
Configuration	'V' form	
Bore	160 mm	
Stroke	190 mm	
Total swept volume	45.842 litres	61.123 litres
Compression ratio	9.5:1 or 11.5:1	
Rotation	Anti-clockwise looking on flywheel end.	
Firing order	1A,6B,5A,2B,3A,4B	1A,1B,3A,3B,7A,7B,5A,5B
	6A,1B,2A,5B,4A,3B	8A,8B,6A,6B,2A,2B,4A,4B
Cylinder numbering	Cylinder 1 furthest from flywheel	

Cylinders designated A are on the left side of the engine when viewed from opposite end to the flywheel, with cylinders designated B on the right hand side of the engine.
NOTE: This is **NOT** the same as the British Standard and ISO designation.

Valve clearances	Exhaust 0.4 mm (0.016 ")	
(Engine cold)	Inlet -As above	
Valve dia. (mm) inlet & exhaust	48	
Valve timing	See Operation Manual **Section U7**	
Valve setting	See **page 39 onwards of the Operators Handbook**	
Ignition Timing	See engine number plate	
Piston speeds	Engine r/min.	m/s (ft.min)
	1000	6.33 (1247)
	1200	7.60 (1496)
	1500	9.50 (1870)

COOLING SYSTEM

Approved coolants	See **page 22**	
Total capacity engine including charge air cooler & wet exhaust manifolds	81 litres (17.8 gals)	110 litres (24.3 gals)
Total capacity engine and radiator	239 litres (52.6 gals)	278 litres (61.3 gals)
Total capacity engine and heat exchanger	153 litres (33.7 gals)	183 litres (40.3 gals)
Engine shut down temperature	96°C	
Max. temperature into engine	To be determined from heat dissipated and water flow through each particular engine model	
Thermostat opening temp.	71°C (nat. gas) 85*C (landfill or biogas) 92*C (HC engines)	
System pressure	0.5 - 0.7 bar	
Maximum pressure at jacket coolant pump outlet	2.5 bar max	

GAS SYSTEM

	4012TESI (MINNOX)	4016TESI (MINNOX)
Approved gas	British Natural Gas	
Lower calorific value	34.71 MJ/nm^3	
Carburettor mixing unit	Deltec 200 - 11	
Carburettor throttle body	Deltec 100 - 11	Deltec 140 - 11
Gas control valve	Deltec 36 mm dia.	Deltec 45 mm dia.
	Deltec 38 mm dia. 4016TESI (minnox 140 HE) ONLY	
Gas pressure min.	15 m bar (1.5 kPa)	
Gas pressure max.	50 m bar (5 kPa)	
Regulator type (Zero pressure)	Dungs FRS 220, 5065 or 5100	
Later engines	or Kromschroder GI50 R02 or GI65 R02	
Supply pressure	If above 50 mbar (5kPa) an additional regulator should be used in order to bring the supply pressure to between the max. & min. figures given above	
Additional items to meet The Institution of Gas Engineers procedures IGE/UP/3 for 4012/16 (Minnox).		
Low pressure detector	Perkins Part no. **See Spares book** (low pressure gas supply only)	
Gas solenoid valves	Not Perkins supply	
Spit back detector	Perkins Part no. **See Spares book**	
Manual gas shut-off valve	Perkins Part no. **See Spares book** (If fitted)	

IGNITION SYSTEM

Ignition unit type	Altronic DISN 800
Ignition coil type	Altronic 501 061 (L.C. engines) Altronic 591 010 (H.C. engines)
Spark plug type	CHAMPION RN79G 14mm (earlier L.C. engines)
	CHAMPION RB77 WPC 18mm (later engines)
Spark plug gap	RN79G 0.5 mm (0.020")
	RB77WPC 0.4 mm (0.015")

GOVERNOR

Make	Heinzmann Electronic	
Type	2 x E6V	2 x E10

LUBRICATION SYSTEM

Recommended oil	See **pages 19 - 21**	
Type of system	Wet sump, external engine mounted oil pump.	
Total oil capacity (oil cooler and filter)	178 litres (39 gals)	238 litres (51 gals)
Sump capacity (dipstick) min.	136 litres (30 gals)	147 litres (32 gals)
Sump capacity (dipstick) max.	159 litres (35 gals)	214 litres (47 gals)
Min. oil pressure (rated speed) to bearings	340 kPa (49 lb/in^2)	
Crankcase pressure max	25 mm water gauge	
Max. oil temperature in sump	105°C	
Lubricating oil filter	disposable canister type	
Crankcase breather	Closed circuit	

INDUCTION SYSTEM

	4012TESI (MINNOX)	4016TESI (MINNOX)
Air cleaner	Twin	
Type (paper element)	S551A	
Max. air intake depression	543 mm H_2O (40 mmHg)(L.C. engines) 406 mm H_2O (30 mmHg)(H.C. engines)	
Air restriction Indicator setting	380 mm H_2O	
Turbocharger	Twin Garrett (4016TESI 140 H.C. only) Twin Schwitzer (all other engines)	

EXHAUST SYSTEM

Manifold type	WET
Exhaust outlet flange	Vertical (twin)
Mating flange	2 x 6" Table D
Max. exhaust back pressure	40 mm Hg
Max. exhaust temp. (°C)(after turbocharger)	See **Product Information Manual**

FLYWHEEL

SAE size	18"
No. of teeth on ring gear	156

FLYWHEEL HOUSING

SAE size	'00'

CRANKSHAFT

Max. overhung weight on rear bearing	1700 Kg	
T.V. damper	1 x 18"	2 x 20"

NOTE: Subject to torsional vibration investigation different T.V. dampers may be fitted

DRY WEIGHT

Dry weight	4380 Kg	5520 Kg
Wet weight	4680 Kg	5820 Kg

HOLDING DOWN BOLT HOLES

Bolt size (engine feet)	22 mm
No. off	8

ELECTRICAL SYSTEM

Voltage	24	
Alternator type	Prestolite LNA4024/5 with internal regulator	
Alternator output (amps)	30 at a stabilised output of 28 volts	
Starter motor type (Twin) Prestolite/Butec	MS1/108	MS7/5
No. of teeth (gear ring)	156	
No. of teeth (starter motor)	12	
Battery capacity cold cranking amps to IEC Standard at 0°C (32°F)	286 (each battery)	286 (each battery)
Battery (lead acid)	24V(2 x 12V) at 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:

High air manifold pressure switch 172 kPa (25.1 lb/in²)

Shutdown switches	Alarm	Shutdown
High oil temperature	115°C	120°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 supercede any settings specified in the engine sales contract.

Overspeed	15% (on 1500 rev/min only)
High air manifold bursting disc pressure (Early engines only)	75 lb/in² at 42°C or 58 lb/in² at 120°C

AIR STARTING

Air Starter Pressure	150 lb/in² (1034 kPa)
Compressed air supply	170 lb/in² (1172 kPa)
Type	Ingersoll-Rand Type SS815

INSTRUMENT PANEL (ENGINE MOUNTED)

	Normal operation
Oil pressure	Between 300 - 560 kPa (42.6 - 80 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**
Boost pressure	See **Test Certificate**

COOLANT JACKET HEATING

Heater	2 x 4 kW

WARNING ⚠ IT IS ESSENTIAL WHEN HANDLING INHIBITORS THAT PROTECTIVE EQUIPMENT IS WORN i.e. GOGGLES, GLOVES, RUBBER BOOTS 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 used on engine test gives satisfactory protection for 6 months after despatch from the works.
2. After test the oil is then drained from the sump.
3. The water cooling system is flushed thorough with a Shell corrosion inhibited anti-freeze at 50% dilution with water.
4. 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.)
5. All openings in the engine (including points where pipework has been removed and air cleaner inlet(s), etc.) are sealed with plugs or blank flanges, etc.

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.

1. The oil used on engine test confers satisfactory protection for 12 months after despatch from the works.
2. After test the oil is then drained from the sump.
3. The water cooling system is flushed through with a Shell corrosion inhibited anti-freeze at 50% dilution with water.
4. 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.)
5. All openings in the engine (including points where pipework has been removed and air cleaner inlet(s) etc) are sealed with plugs or blank flanges.

SPECIAL PRESERVATION LEVEL C
Available on request only.

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

1. After engine test the oil is drained from the sump, oil pump, filters and oil cooler.
2. The engine is refilled with Crodafluid PQ11 engine preserving oil.
3. The engine is started and two brief accelerations to a maximum speed (No load) are made to ensure complete circulation of the preserving oil. After stopping no further rotation of the engine takes place.
4. The preserving oil is then drained from the sump.
5. The water cooling system is flushed through with a Shell corrosion inhibited anti-freeze at 50% dilution with water.
6. The water pump impellor is sprayed with Crodafluid PM47 oil film rust preventative.
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. 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.
9. Air filters are sprayed inside with Crodafluid PQ11 preserving oil.
10. Plastic plugs are fitted to the gas inlet, water connections, spare instrument holes in panels and air filter inlets.
11. Exhaust outlet is fitted with a steel blanking plate.
12. Water hoses are treated with silicone grease and wrapped or sleeved with black polythene (silicone rubber hoses need not be treated)
13. Drive belts are removed and wrapped in wax paper, and packed into black polythene with silica gel as desiccant.
14. Starter, alternator, switches, instruments, sensors, and wiring are sprayed with Ambersil MS4 silicone grease.
15. Pulleys, flywheel, starter ring, pinion, etc are protected by dipping or painting with Crodafluid PM47 oil film rust preventative.
16. The flywheel housing is fitted with a steel blanking plate.
17. Control panels have desiccants placed inside.
18. The complete engine assembly is sprayed with Crodafluid PW10 wax film rust preventative.

(ALSO REFER TO PERKINS GAS INSTALLATION MANUAL TSL4200)

FOUNDATION

The foundation put down to accommodate a driven unit powered by a gas 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 satisfactory running of a gas 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 an engine driven water pump to force coolant through the engine oil cooler, engine water jackets, cylinder heads and, in some cases, around a water cooled exhaust manifold.

The hot water from the engine then enters the header tank of the radiator, passes through the radiator tubes and then out to the suction side of the pump. A pressure of 0.5 to 0.7 bar is maintained throughout the system. Water passing through the radiator, is cooled by pushing air through the matrix by an engine driven fan.

To obtain extra power from a turbo-charged engine the hot air delivered from the turbo compressor(s) is cooled before entering the engine cylinders.

The cooling of the charge air is achieved by directing the charge air flow from the turbocharger (via an air pipe) into a block type air cooler, where it flows over cooling tubes, before being drawn into the engine via the inlet manifold. The water is delivered from an engine driven raw water pump and passes through the cooling tubes of the block cooler, and hence to a heat exchanger/radiator.

NOTE: On Combined Heat and Power (CHP) applications fresh water and raw water pumps, thermostats and a battery charging alternator are not fitted.

Installation variations of the above include remote mounted radiators, break tanks, cooling towers, heat exchangers and special radiators.

EXHAUST SYSTEM

The primary function of the exhaust system is to pipe the exhaust gases from the engine manifold(s) and discharge them, at a controlled noise level, outside the engine room, at a height sufficient to ensure proper dispersal.

Back Pressure - Limitation

Excessive back pressure will cause a lack of complete combustion and deterioration in the scavenging of the cylinders. The result will be lower power output, high exhaust temperature and the formation of soot. The soot, if oily, can affect the turbine of a turbocharger by building up on the blades, hardening and, as pieces of carbon break off, unbalancing the turbine wheel and causing problems due to the ensuing vibration.

Perkins' gas 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.

Maximum Back Pressure

THE EXHAUST BACK PRESSURE FIGURES FOR PERKINS ENGINES CAN BE FOUND IN THE **PRODUCT INFORMATION MANUAL** AND ALSO IN **ENGINE DATA SECTION** OF THE **OEPRATOR'S HANDBOOK.**

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. (See Product Information Manual).

ii) Keep weight off the engine manifold(s) and turbocharger(s) 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 flange when the engine starts and stops. A flexible element should therefore be fitted as near to the outlet flange as is practically possible.

v) To reduce radiant heat in a closed engine room or canopy, the exhaust system and silencer must be lagged, but not the turbocharger or exhaust manifold.

vi) Ensure that the exhaust pipework allows the gas to flow in an upward direction, so as to avoid build up of gas pockets and prevent an explosion occurring.

vii) Provide each engine with a separate exhaust system.

ENGINE BREATHER

All engines are fitted with a breathing 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, they are passed through a mesh filter in order to remove as much oil as possible before the gases are returned to the atmosphere.

BREATHER INSTALLATION

Although the breather discharge is almost entirely oil free, the gases should still be ducted outside of the engine room which must 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 build up.

TORSIONAL VIBRATION

Torsional vibrations occur in any rotating shaft system it is important when fitting equipment to an engine particularly single and twin-bearing alternators that there torsional vibration characteristics are known.

CRITICAL SPEED

At certain speeds in the engine running range these vibrations may be of sufficient magnitude and frequency to fracture the engine crankshaft or 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 vibration analysis is to locate 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 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 could be judged as "safe" because the critical speed is passed through in a second or so. However, if the application is an "all speed" range then all critical speeds have to be controlled within safe limits.

GAS SYSTEM

The standard gas system as supplied on the engine is connected to the gas supply at the pressure regulator.

The engine should operate satisfactorily providing that the gas pressure is correct (see **page 23**).

Where a gas engine needs to conform to the British Gas Code of Practice IM17, the gas system as supplied on the engine is connected to the gas supply at the manual valve (see **Fig. 1**).

NOTE: 2 solenoid operated gas valves must be fitted in series to stop the gas flow, these are required for the protection equipment. They must also conform to any local regulations and are therefore supplied by the customer.

Key
(Fig. 1)

1. Gas supply (gas pressure to be constant)
2. 50 mbar max
3. Water manometer
4. Manual valve
5. Supplied loose
6. Filter
7. Low pressure detector
8. Supplied by customer
9. Gas solenoid valves
10. Engine supply
11. Pressure regulator
12. Water manometer
13. Mounted on engine
14. Spit back detector
15. Negative pressure
16. Water manometer
17. Flexible pipe

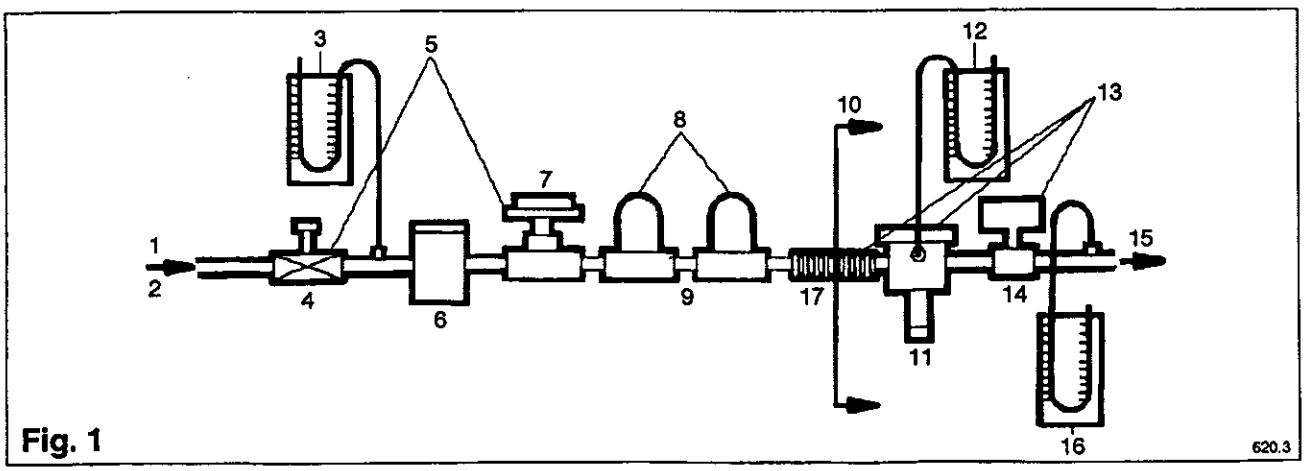


Fig. 1

SOUND INSULATION

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

NOISE LEVEL

Noise levels are measured in decibels - dB - through a frequency range of 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 outside noise levels have to be controlled, the following factors must be considered:-

i) **Building Construction**

Outside walls - should be double brick - with cavity.

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

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

ii) **Ventilation**

The air inlet(s) 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 airflow, creating excess resistance to the fans.

With the amount of cooling air required on the larger engines the splitters are of large size and the building should be adapted so that they fit correctly.

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

ENGINE ROOM VENTILATION (SEE INSTALLATION MANUAL)

The engine room should be fitted with an extraction fan to provide adequate ventilation to dissipate the heat radiated by the engine and other components, and to maintain the temperature of the engine room at a satisfactory level. The ventilation system should also allow sufficient air to be drawn into the engine room to cater for the engine combustion air requirements, and prevent engine noise being transmitted via the ducting. Refer to the **Installation Manual or the Applications Department** for any further information.

ELECTRICAL SYSTEM (STARTING AND PROTECTION)

The electrical system should be kept as simple as possible, local starting by key switch on the engine mounted instrument panel is preferred. In the case of remote starting the above facility must be isolated to prevent damage.

DERATING

WARNING ⚠ IT IS ESSENTIAL THAT FULL ACCOUNT IS TAKEN OF ALL DERATING INFLUENCES WHETHER GAS SPECIFICATION, ALTITUDE, AMBIENT TEMPERATURE OR HUMIDITY. WHERE ANY OF THESE DEVIATE FROM THE STANDARD SPECIFIED IN THIS MANUAL THE RATING OF THE GAS ENGINE MUST BE ADJUSTED AS INSTRUCTED BELOW.

SETTING ENGINE POWER TO SUIT ACTUAL SITE CONDITIONS

Derating means reducing the power output of an engine from its normal rating at normal temperature and pressure conditions to allow for adverse effects of site conditions e.g. altitude and ambient temperature.

Perkins Engines (Stafford) Ltd. may be unaware of the final destination of an engine at the time of despatch from the works. The engine will be set to give the power output at normal temperature and pressure under ISO 3046 standard conditions, using gas conforming to British Natural Gas Specification, having a lower calorific value of 34.71 MJ/Nm^3 (930 BTU/Sft^3), which when operating under the actual site conditions, could result in severe damage to the engine (refer to **page 23**).

Providing that the actual gas being used meets with the above conditions, then the engine need only be derated for altitude and ambient temperature conditions.

Any engine so supplied must be derated in accordance with the published percentage derate figure as shown in the **Product Information manual**, by the Equipment Manufacturer on his premises, or even on site.

To derate, calculate, (using the above percentage derate figure) the new reduced power output of the engine, and run the engine or generating set on this load.

Where possible this maximum load limit should be set and "locked" in the engine control panel.

QUANTITY OF OIL

	4012TESI	4016TESI
The total system capacity	178 litre (39 gallons)	238 litre (52 gallons)
The maximum sump capacity	159 litre (35 gallons)	214 litre (47 gallons)
The minimum dipstick mark indicates	136 litre (30 gallons)	147 litre (32 gallons)

CAUTION
In order to select a suitable lubricating oil for a gas engine it is necessary to consider the fuel quality.

NATURAL GAS ENGINES (NO ACIDIC PRODUCTS PRESENT)

The oil should be a grade that is specifically formulated by all the major oil companies for turbocharged and charge cooled natural gas engines. The oil should contain anti-wear and detergent/dispersant additives. The oil is to have high resistance to oxidation and have good thermal stability. Modern gas engine oils do not rely on a high total base number to achieve long life and the special additive packages that are now available from many of the major oil suppliers now meet this criteria.
Engines fitted with oxidizing catalysts (2 way) require a lubricant that is low in zinc and phosphorus, it is essential that the oil supplier confirms that the brand of oil supplied is compatible with the catalyst.

BIOGAS ENGINES (CONTAINING ACIDIC PRODUCTS AT LEVELS APPROVED BY PERKINS ENGINES (STAFFORD) LTD)

These engine require a lubricating oil that has more reserve alkalinity than the natural gas engine and therefore the TBN should be more than 8 and less than 10 with the sulphated ash in the range of 0.5 to 1.1%. The oil supplier will assist with the selection of suitable oils when presented with the gas analysis. (TBN = Total Base Number).

NATURAL GAS AND BIOGAS ENGINES

Where gas engines oils are not available, please consult Perkins Engines (Stafford) Ltd for advice.

GRADE OF OIL

The viscosity of the oil used should be either SAE 30 or SAE 40. In general SAE 30 is used at temperature less than 30°C average ambient temperature and SAE 40 more than 30°C. As these engine are generally operating continuously, it is possible to use higher viscosity oils as sluggishness in starting is not generally critical.
The use of SAE40 will give reduced oil consumption but under certain conditions it will also give reduced oil change periods.

OIL CHANGE PERIOD (NATURAL GAS ENGINES)

For normal operation of gas engines, change the oil after the first 500 hours, after which the oil change period is 800 hours or annually which ever is the sooner.
It may be possible to extend the oil change period, where an oil change programme has been approved by Perkins Engines (Stafford) Ltd, based upon the analysis of oil samples taken during the first 1000 hours of engine use. However even if an analysis is showing a satisfactory oil quality, the oil life should not be extended above 1000 hours.

The following should be regarded as critical parameters:

Viscosity at 100°C	16.5 cSt maximum
Insolubles	1.5 maximum
Total Acid Number (TAN)	less than 4 times the TAN value for new oil.
Total Base Number (TBN)	50% less than new oil value.

Total base number (TBN) and total acid number (TAN) must not cross over.

Nitration	25 maximum
Oxidation	25 maximum
Water	0.2% maximum
Iron	Less than 20ppm*
Copper	Less than 40ppm*

NB Oil samples should be taken from the mean level in the engine sump never from the sump drain plug.

Should there be a lubricating oil supply problem or a high sulphur content in the gas, Perkins Engines (Stafford) Ltd should be contacted to give advice in selecting suitable formulations.

OIL CHANGE PERIOD (BIOGAS ENGINES)

Engines that are operated on either digester gas or landfill gas are to be subjected to special conditions regarding the oil change periods.

When the engine/s are first commissioned an analysis of the site gas is to be submitted to Perkins Engines (Stafford) (this is addition to the analysis supplied at the order stage) and a description of the proposed lubricating oil that is to be used.

When the engine starts operating it is essential that oil samples are taken at intervals of every 150 hours with the result of the analysis being sent to Perkins Engines (Stafford) at the earliest opportunity.

This course of action is necessary because of the variability of the gas. If the oil is allowed to be used after it has deteriorated beyond the limits specified below then the engine may be damaged. The warranty on the engine is dependant on the oil being maintained in satisfactory condition. To meet this requirement it is necessary to continue the oil analysis programme throughout the warranty period. The frequency of the analysis can be extended but it must show that at the oil change point that the oil is still in acceptable limits.

CRITICAL PARAMETERS

Maximum viscosity at 100°C	16.5 cSt
Total acid number and total base number must not cross over	
TBN must not reduce to less than 50% the value of new oil	
Nitration must not exceed	25
Oxidation must not exceed	30
Insolubles >3 μ must not exceed	1.5
Water max %	0.2
Silicon max ppm	100
Sodium max ppm	50
Iron max ppm	35*
Copper max ppm	35*

During the early life of the engine it will be found that the parameters marked * will have higher levels as a result of the running in procedure.

UNDER NO CIRCUMSTANCES IS THE OIL TO BE USED FOR MORE THAN 900 HOURS EVEN IF THE ANALYSIS SHOWS THAT THE OIL IS IN ACCEPTABLE CONDITION.

NOTE: When operating on methane based fuels, approximately one litre of water is produced for every cubic metre of methane burnt. It is essential to ensure that the piston blow by can not condense either in the crankcase or in any pipes associated with the breather. Water has a devastating effect on oil life due to the attack on the additive package in the oil. It is essential that the engine breather is functioning effectively. Water should be drained from the sump weekly.

WARNING ⚠ FAILURE TO COMPLY WITH THESE INSTRUCTIONS MAY RESULT IN ENGINE DAMAGE.

APPROVED LUBRICATING OILS (NATURAL GAS ENGINES)
(Suitable for British and Dutch natural gas)

Oil Company	**Type**
MOBIL	Pegasus 480 (Suitable for catalyst equipped engines)
MOBIL	Pegasus 489
ESSO	Estor Supreme LA 40
ESSO	Estor Protec LA 40
TEXACO	Geotex LA or HD
SHELL	Mysella MA 40
CASTROL	NG404-408

APPROVED LUBRICATING OILS (BIOGAS AND OTHER GASES)

Oil Company	**Type**
MOBIL	Pegasus 489 + *EM/PA programme

*EM/PA = Equipment Maintenance through Progressive Analysis

CATALYST EQUIPPED GAS ENGINES
These require oils with sulphated ash limited to 0.5%, zinc limited to 0.04% and phosphorous limited to 0.09% by weight, (**see the above table**).

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

ENGINE COOLING SYSTEM

To protect the engine cooling system against corrosion it is essential that the engine coolant contains suitable additives which will give the necessary protection.

Caution: untreated water is not suitable.

WATER QUALITY

The water that is mixed with the additive must have the following characteristics:

Chloride less than 80 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 (i.e. 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 anti-freeze with water should be used at all times, even in areas where frost is unlikely.

This mixture will give frost protection down to -35°C. In areas where Shell anti-freeze is unobtainable contact Perkins Engines (Stafford) Ltd for advice.

Under no circumstances should an additive containing nitrites, borates, phosphates, chromates, nitrates or silicates be used, as these materials are not compatible with the materials used in the cooling system.

When mixing the anti-freeze with the water always follow the manufacturer's recommendation which is to add the anti-freeze to water and mix thoroughly before adding the mixture to the engine cooling system.

Mixing water to the anti-freeze can lead to the formation of gel in the mixture, due to over concentration, and this can lead to blockage of water passages and subsequent loss of water flow causing overheating.

MAINTENANCE OF COOLANT

The water/anti-freeze mixture should be replaced in operating engines at least once a year.

It is essential to maintain the coolant at the correct alkalinity level i.e. the pH should not increase above 7.5. A hydrometer only shows the proportion of ethylene glycol. **This is not a measure of protection against corrosion.**

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

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 value (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.

WARNING ⚠ IF THE ENGINE IS NOT SET TO SUIT THE SITE GAS, UNECONOMICAL RUNNING, LOSS OF POWER OR DAMAGE MAY OCCUR, WHICH COULD RESULT IN INJURY.

Where gases other than British Natural Gas are to be used, such as wellhead gas, digester gas and landfill gas, it is essential that a detailed analysis of the gas is submitted to Perkins Engines (Stafford) Ltd. as resetting or changing the standard gas equipment may be necessary.

Limiting Values for British Natural Gas:

		4012/16TESI(MINNOX)	
		200 &140 L.C.	**140 & 90 H. C.**
1)	Methane number must exceed	65	80
2)	Combustible constituents must exceed	85%	95%
3)	Calorific value (LHV) to exceed	31.7 MJ/Nm³ (850 BTU/Sft³)	34 MJ/Nm³ (912 BTU/Sft³)
4)	Ethane	6%	4.5%
5)	Hydrogen content not to exceed	0.2%	0.1%
6)	Propane must not exceed	2%	1%
7)	Isobutane content not to exceed	0.2%	0.2%
8)	Normal butane not to exceed	0.2%	0.2%
9)	Normal pentane and higher fractions (hexane, heptane, etc.). The summation must not exceed.	0.02%	0.02%
10)	Gas pressure at inlet to regulators must exceed	15 mbar (1.5 kPa)	15 mbar (1.5 kPa)
11)	Gas pressure not to exceed without additional pressure regulators	50 mbar (5 kPa)	50 mbar (5 kPa)
12)	Hydrogen sulphide not to exceed	0.01% or 100 ppm	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 (Stafford) Ltd should be consulted for advice.

GAS SAFETY REGULATIONS

There are legal requirements that within the U. K. gas fittings and equipment are installed and used in accordance with the GAS SAFETY (INSTALLATION AND USE) REGULATIONS. Only competent persons should install this equipment. Reference should be made to the BRITISH GAS CODE OF PRACTICE IM17. Outside the UK 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.

CLEANING

WARNING ⚠ THE USE OF CERTAIN CLEANERS, DEGREASANTS AND SOLVENTS ENTAILS THE OBSERVATION OF SAFETY PRECAUTIONS IN RESPECT OF PROTECTIVE CLOTHING, EYE PROTECTION AND ADEQUATE VENTILATION.

Where possible a water based solvent cleaner should be used. If a low volatile hydrocarbon solvent is used the manufacturers instructions must be adhered to.
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.

WARNING ⚠ DO NOT USE WOOL BASED CLOTHS FOR CLEANING.

Always observe scrupulous cleanliness when rebuilding an assembly, after thoroughly flushing 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 loose 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 and scrapings must be prevented from entering oilways or ports. Rough or ragged edges should be removed from all moving parts, oilways, ports, etc.
New parts should be kept in their protective coating until required.

WARNING ⚠ JOINTING COMPOUNDS AND LOCTITE PRODUCTS SHOULD NEVER 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.

SEALANTS AND JOINTING COMPOUNDS

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, such as 'Loctite', are recommended, as they are most unlikely to cause trouble of this kind, even if they are used too generously.

'LOCTITE' HYDRAULIC SEAL 542 (RED)

The above compound has been found suitable for sealing pipe fittings and threaded connectors up to 19 mm. The connections can be readily unscrewed and the old material simply removed.

No special treatment of the threads is required before assembly. The compound is applied directly to the thread.

The compound will remain liquid whilst in contact with air but will harden automatically, when confined between closely fitting metal parts.

'LOCTITE' PIPE 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.

WARNING ⚠ LOCTITE PRODUCTS MUST NOT COME INTO CONTACT WITH LIQUID OR GASEOUS OXYGEN.

'LOCTITE' SEALANT COMPOUND 518 (RED)

This compound is suitable for use on metal to metal surfaces (i.e. bell housing to crankcase faces) and 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. Yet when necessary, joints can be readily dismantled and the old sealing material simply removed.

No special treatment of the faces is required before assembly: the product is reapplied directly to one of the faces.

Any excess of the compound may be wiped away without the use of any special clean-up solvent.

'LOCTITE' SEALANT COMPOUND 510 (ORANGE)

The above compound is suitable when used with a gasket to give a gas/air tight joint on the air pipe flanges. 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. No special treatment of the faces is required before assembly: the product is re-applied directly to one of the faces.

Any excess compound may be wiped away without the use of any special clean-up solvent.

'LOCTITE' SEALANT COMPOUND 573 (GREEN)

This compound has almost identical properties to Loctite 510 (above), but it is easier to dismantle should be necessary.