Table of contents

00. Contents - Instructions - Terminology

00.1. General Remarks

This manual contains data and instructions for operating and maintaining Wärtsilä 220 SG gas engines. It is assumed that engine operation and maintenance personnel are well informed of the care to be given to GAS engines and so basic general knowledge is not covered here. Wärtsilä France reserves the right to make minor alterations and improvements resulting from further developments of the engine without revising this Manual. Engines shall be equipped as agreed in the sales documents. No claims can be made on the basis of this Manual as it describes components that are not necessarily included in every engine shipped. Exact supply details are defined by the specification number on the manufacturer's plate affixed to the engine. Remember to state clearly the engine type, engine number and specification number in all correspondence or when ordering spare parts. This Manual is supplemented by a Spare Parts Catalogue including sectional drawings or external views of components (partial assemblies).

00.2. General rules

1 **Before carrying out any operation whatsoever,** read the corresponding section(s) in this Manual.

2 **Keep a logbook** for each engine.

3 **Utmost cleanliness and order is required** during all maintenance work.

4 **Before removing any components, check** that the systems concerned have been drained and pressure released. When dismantling, immediately seal off oil, fuel and air holes with adhesive tape, suitable plugs, clean cloths, etc.

5 **When replacing a worn or damaged part** that has an identification mark indicating the cylinder or bearing number, mark the new part in the same manner at the same spot. Each replacement should be recorded in the engine logbook and the reason for the replacement clearly explained.

6 **After reassembling,** check that all screws and nuts are tightened and locked, if necessary.

00.3. Terminology

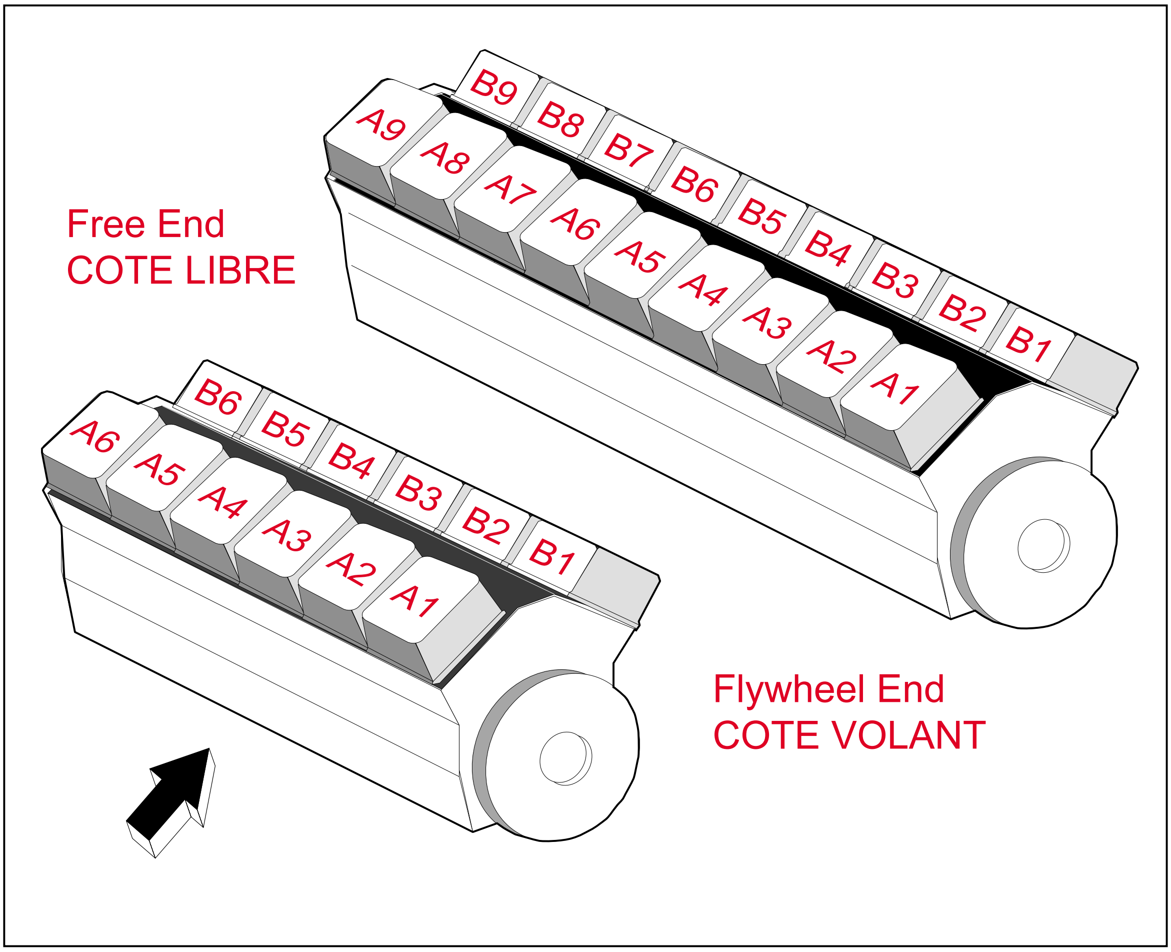


Fig. 00-1

The most important terms are defined as follows (see Fig. 00-1):

A) **Control side (side A) :** Side of the engine on which the control devices are accessible (start/stop, instrument panel, speed governor).

B) **Rear side (side B) :** Side of the engine opposite the control side.

C) **Flywheel end: :** End of the engine where the flywheel is located.

D) **Free end :** End opposite the flywheel end.

E) **Designation of cylinders :** In compliance with ISO 1204 and DIN 6265, cylinders are numbered starting at the flywheel end: bank A is on the control side and bank B is on the rear side.

00.3.1. Designation of bearings (see Fig. 00-2)

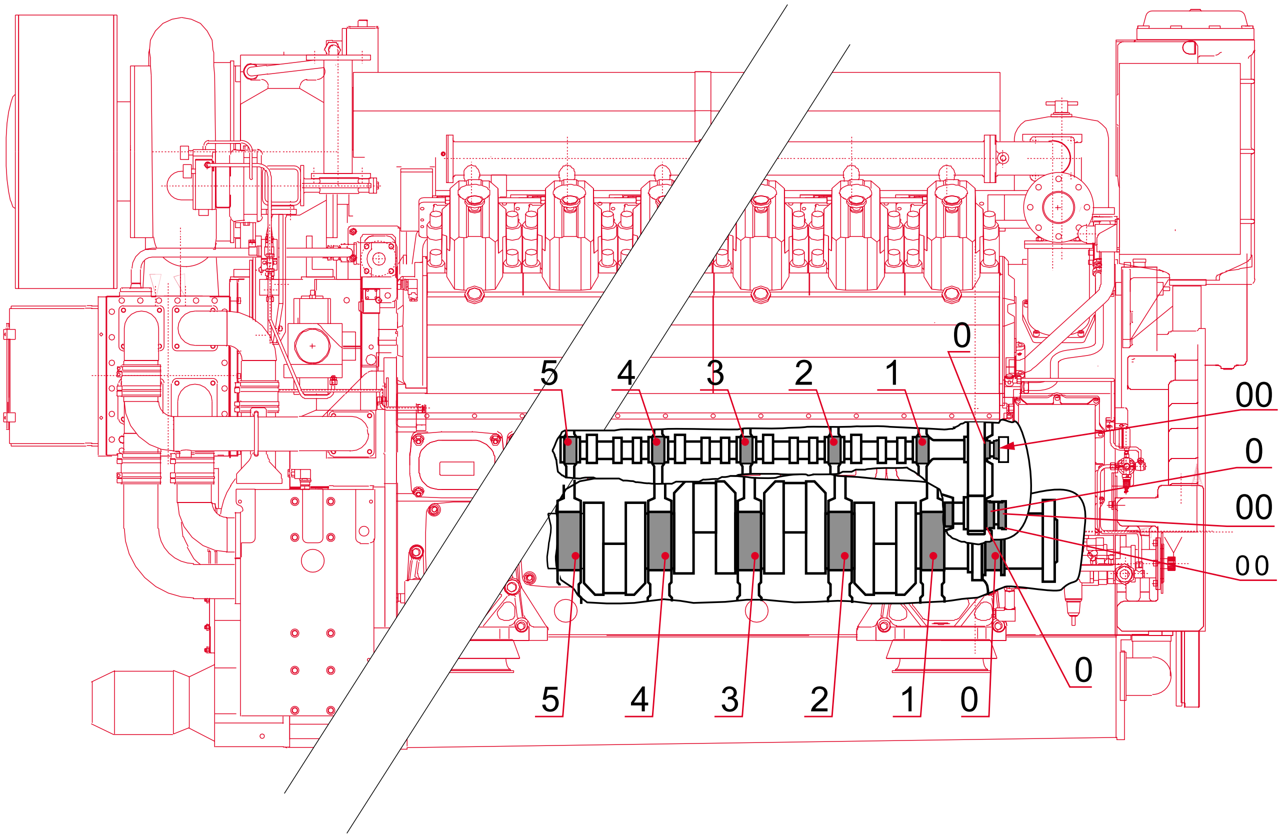


Fig. 00-2

A) **Crankshaft bearings:** The shielded bearing (closest to the flywheel) is bearing No. 0. The first standard bearing is bearing N° 1, the second N° 2, etc. Thrust bearings (N° 0) are numbered 00 (outer, closest to the flywheel) and 0 (inner, furthest from the flywheel).

B) **Camshaft bearings:**Like the crankshaft bearings, the thrust bearings are numbered 00 (outer, closest to the flywheel) and 0 (inner). The first standard bearing is N° 1, the second N° 2, etc.

C) **Camshaft bushing:** The camshaft bushing located close to the flywheel is N° 0. The second is N° 1. Thrust bearings are designated by numbers 0 (inner) and 00 (outer).

00.3.2. Other definitions

A) **Clockwise rotating engine:** when the engine is viewed from the flywheel end, the crankshaft turns clockwise.

B) **Counterclockwise rotating engine:** when the engine is viewed from the flywheel end, the crankshaft turns counterclockwise.

C) **Bottom dead centre (BDC):** Position of the piston when the turning point of the stroke is reached at the bottom of the cylinder.

D) **Top dead centre (TDC):** Position of the piston when the turning point of the stroke is reached at the top of the cylinder.
The Top Dead Centre of every cylinder is marked on the flywheel graduations. During a complete working cycle, corresponding to two revolutions of the crankshaft in a four-stroke engine, the piston passes the Top Dead Centre twice:

- The first time when the inlet and exhaust valves are open.
- A second time at the moment of ignition, when the valves are closed.

01. Main Characteristics - Operation - General Description

01.1. W 220SG Engine Main Data

Bore : .... 220 mm
Stroke : .... 240 mm
Capacity per cylinder : .... 9.12 l
Piston speed : .... 12 m/s at 1500 rpm
Valves : .... 2 intake, 2 exhaust
V angle : .... 60°
Compression ratio : 11

Firing Order			
Engine type	12V220SG	16V220SG	18V220SG
Clockwise			
Counter-Clockwise	B1-A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5		B1-A1-B5-A5-B9-A9-B3-A3-B6-A6-B8-A8-B2-A2-B4-A4-B7-A7

Engine Oil Capacity			
Engine type	12V220SG	16V220SG	18V220SG
Approximate capacity (litres) standard sump	700		900
Approximate top-up capacity between min. to max. dipstick marks. (litres)	170		120

Approximate Engine Coolant Capacity (litres)			
Engine type	12V220SG	16V220SG	18V220SG
Engine only	350		550
Engine and cooling system	1500		2200

01.2. Recommended Operating Data

See test reports.

01.3. Reference Conditions

Meets ISO 3046/1 (1986)

Air pressure: . . . . 100 kPa 1 bar

Air charge temperature: . . . . 308 K (35° C)

Relative humidity : . . . . 30 %

Supercharger cooler water temperature: . . . . 323 K (50°C)

Exhaust back-pressure: . . . . 5 kPa (500 mmH2O)

Gas net calorific value (LCF): 33440 kJ/N/m3

01.3.1. De-rating factors = (a + b + c) %

- a = 0.5% of power output for each degree of charge air temperature above 35°C (max. 50°C)
- b = 1% of power output for each 100 meters altitude above 500 m (max. 2000 m)
- c = 0.4%of power output for each degree of LT coolant temperature above 50°C

Methane index less than 80 - please, consult Wärtsilä France.

01.4. General Engine Design

01.4.1. General Information

The Wärtsilä 220 SG is a supercharged gas engine (4 stroke pre-chamber ignition) available in 12, 16 and 18 cylinder V versions. It is designed for 140 bars maximum combustion pressure. It has been designed with a view to maximizing component integration and keeping the number of components down.

01.4.2. Engine Block

The engine block (cylinder block and crankcase) is a single piece of SG cast iron. The crankshaft is underslung and maintained by main bearing caps which are secured by two hydraulically tightened studs and two side screws. The main bearing caps are SG castings and are guided laterally by the engine block. There are large covered inspection ports for access to the crankshaft and camshafts on both sides of the engine block.

01.4.3. Crankshaft

The crankshaft is forged from a single piece of high tensile steel and is entirely nitrogen case-hardened. Each counterweight is secured by three screws. There are two counterweights for each crankpin.

01.4.4. Connecting Rods

Each connecting rod is forged from a single piece of metal; the big-end is in two parts with stepped mating surfaces; the big-end cap is hydraulically clamped on two tie-studs. The connecting rods are mounted side by side in the engine. Oil is channelled along an oilway bored in the connecting rod to cool the piston and lubricate the gudgeon pin bush and piston skirt.

01.4.5. Main Bearings and Big End Bearings

The main bearings are fitted with upper and lower half-shells which are both precision machined. The upper half-shell is positioned in the lubricating groove by a pin at each end. The lower half-shell is positioned by a pin in a slot of the main bearing cap. The two half-shells are slightly longer than the main bearing body so they can be tightened. The main bearing closest to the flywheel provides extra support for the flywheel and coupling. It is fitted with four thrust washers to provide axial positioning of the crankshaft.

01.4.6. Cylinder Liner

The "wet" type cylinder liner is made of centrifugally cast iron. Two O-rings around the lower part seal off the coolant from the oil around the cylinder liner. The liner is fitted with an anti-glazing ring so as not to glaze the cylinder.

01.4.7. Piston

The piston is an assembly composed of a steel head and an aluminium skirt fastened together by four screws. Lubrication between piston and liner is by pressurised oil from two openings in a groove of the skirt. The piston ring grooves are hardened. The gudgeon pin bores are reinforced by bushes made of higher strength alloy and the gudgeon pin is held by two circlips inside the bushes.

01.4.8. Piston Rings

A piston ring set comprises a fire ring, a sealing ring and a spring-action oil scraper ring. The three rings are fitted in grooves in the piston head.

01.4.9. Cylinder Head

The cylinder head is made of grey cast iron. The areas exposed to combustion and subjected to high temperatures are effectively cooled by the coolant. An intermediate deck enhances cooling and also absorbs the mechanical stress forces to which the cylinder head is subjected. The robust, raised design of the cylinder head means only four hydraulically tightened tie-rods (studs) are required. The cylinder head includes two intake valves and two exhaust valves per cylinder. The intake valves are slightly larger in diameter so as to improve scavenging of spent gasses. The intake and exhaust ducts open up on the same side of the cylinder head in the V. The intake and exhaust valve seats are made of special, wear-resistant alloy. The exhaust valve seat is water-cooled. The valve stems are chrome-plated and the seat faces are stellite-coated. Rotators (ROTOCAP) are used to ensure even wear of the valves and seats.

01.4.10. Camshaft and Valve Control Mechanism

The camshafts are composed of an assembly of two (for 12V engines) or three (for 16V and 18V engines) cylindrical sections arranged end-to-end. The cams and journal surfaces are case-hardened. The sections are assembled end-to-end by flanges. The camshaft rotates in anti-friction bushings fitted in the engine block; these bushings are liquid nitrogen-mounted and dismantled using a hydraulic tool. The camshaft can be removed or fitted from either end of the engine. Axial thrust stops are provided at the flywheel end either by the governor control box (side A) or by the thrust bearing housing (side B).

The valve tappets are of the piston-roller type. Both ends of the push rods are machined to be convex. The valve mechanism also includes rocker arms and drive columns (yokes) mounted on the cylinder head.

01.4.11. Camshaft Drive

The camshaft drive is entirely integrated in the engine block. The drive components are identical for each of the two camshafts. The crankshaft pinion is expansion fitted on the shaft. It drives the camshafts via an intermediate shaft on which two cog wheels are mounted and fastened by five screws. These pinions can be adjusted relative to one another through 360°. The camshaft pinion is screw fitted.

The camshaft drive gear train is lubricated by oil from sprays fitted inside the flywheel cover.

01.4.12. Flywheel Cover

The flywheel cover serves several purposes: it protects the flywheel and supports the alternator flange for generating sets. It is used for mounting the starter motors, the turning gear and the flywheel indexing device. It incorporates several coolant passages and oilways. It is bored with oilways supplying the camshaft drive system lubrication sprays.

01.4.13. Free-End Cover

The cover completely shrouds the torsion vibration damper. All the pumps are fitted on this cover:

- Standard equipment consists of the twin-wheel coolant pump for the high- and low-temperature circuits, the direct-drive oil pump, and the electric pre-lubrication pump.

The cover includes all the coolant channels.

The coolant temperature control module is fitted to side B of the cover. The coolant manifold is fitted to side A of the cover to supply the supercharge air cooler.

01.4.14. Oil Sump

The “wet-type” oil sump is made of welded steel sheet and fixed under the engine block. It includes a suction pipe and a supply pipe running from the free end to the flywheel end. The drain plug is located near the free end. The oil sump is equipped with a dipstick.

01.4.15. Gas Supply System

This includes a pressure regulating valve unit ahead of the engine to regulate gas pressure via the Wärtsilä Engine Control System (WECS 3000) installed on the engine. Two gas supply systems are used on the engine: one to supply the pre-chambers and the other to supply the main chambers. Two gas intake solenoid valves are fitted to each cylinder, one to admit gas into the pre-chamber and the other to admit gas into the main combustion chamber of the cylinder.

01.4.16. Lubrication System

The lubrication system includes the oil sump, the lubricating pumps, the centrifugal filter and the oil module. The oil is drawn along the feed line inside the oil sump to an oilway in the free-end cover. The pump module, which comprises the direct-driven oil pump and the electric pre-lubrication pump, is mounted directly on the outside of the cover. The oil travels from the oil pump along an integrated duct to the free end cover and then along a welded tube in the sump to the flywheel end. Then it enters a duct integrated in the flywheel cover. From there it is piped to the oil module. The oil module is made up of four thermostatic valves, the cooling unit and oil filter unit. It is composed of several aluminium castings and is mounted above the flywheel. The full-flow filters are of the paper cartridge type and are placed horizontally inside the module. A three-way valve can be used to stop oil flow to one of the filter chambers. The filter chamber is emptied by a valve. From the module, some of the oil is piped along to lubricate the camshaft drive gear and bearings, tappets and valve gear on the cylinder head. The remainder of the oil is fed to the main gallery machined in the cylinder block. It lubricates the main bearings, big-end bearing shells and gudgeon pin bushes and also cools the pistons. A small amount of the pressurised oil is used to lubricate the piston skirts. A pipe from the main gallery carries lubricating / cooling oil to the supercharge turbocharger(s). The lubrication system also includes a centrifugal filter mounted in a by-pass arrangement.

01.4.17. Starter System

The starter system is pneumatic. It uses a turbine-type pneumatic starter. An electric starter may be mounted as an option.

01.4.18. Exhaust Gasses and Turbocharger System

The exhaust gasses are swept from the cylinder heads via a water-cooled manifold. This multi-tube, multi-purpose component is known as the “multiduct” and is made of a special heat-resistant SG cast iron alloy. It transfers air from the air manifold, incorporated in the engine block, to the cylinder heads. In addition it transfers the exhaust gases from the cylinder heads to the exhaust pipes and the coolant from the cylinder heads to the return ducts in the engine block. It also supports the exhaust pipes and heat insulation. The exhaust piping is made of special heat-resistant SG cast iron alloy. The parts forming the exhaust piping are separated by metal expansion joints. Metal expansion joints are also fitted between the exhaust pipes and the turbocharger. All of the exhaust piping is contained in an insulating casing with a low external surface temperature. The heat insulation is formed from steel sheets separated by a layer of insulating material. Two types of air supercharging can be used: a single turbocharger system for improved performance under full load, or a constant pressure system with one turbo per bank of cylinders. The supercharge air cooler is fitted at the free end and operates as a two-stage cooler.

01.4.19. Automatic Control Systems

The Wärtsilä 220 SG engine is fitted with the “WECS 3000" WÄRTSILÄ ENGINE CONTROL SYSTEM for engine command and control. This is a recent BUSCAN computerised communication technology. All the engine parameters are picked up by sensors linked to connection units distributed around the engine. These feed information back to the main control unit (MCU) along multiconductor cables. Engine parameters are controlled and adjusted by a PC. System operation is described in Section 23.

01.5. 12V220SG Engine views

01.5.1. Side A

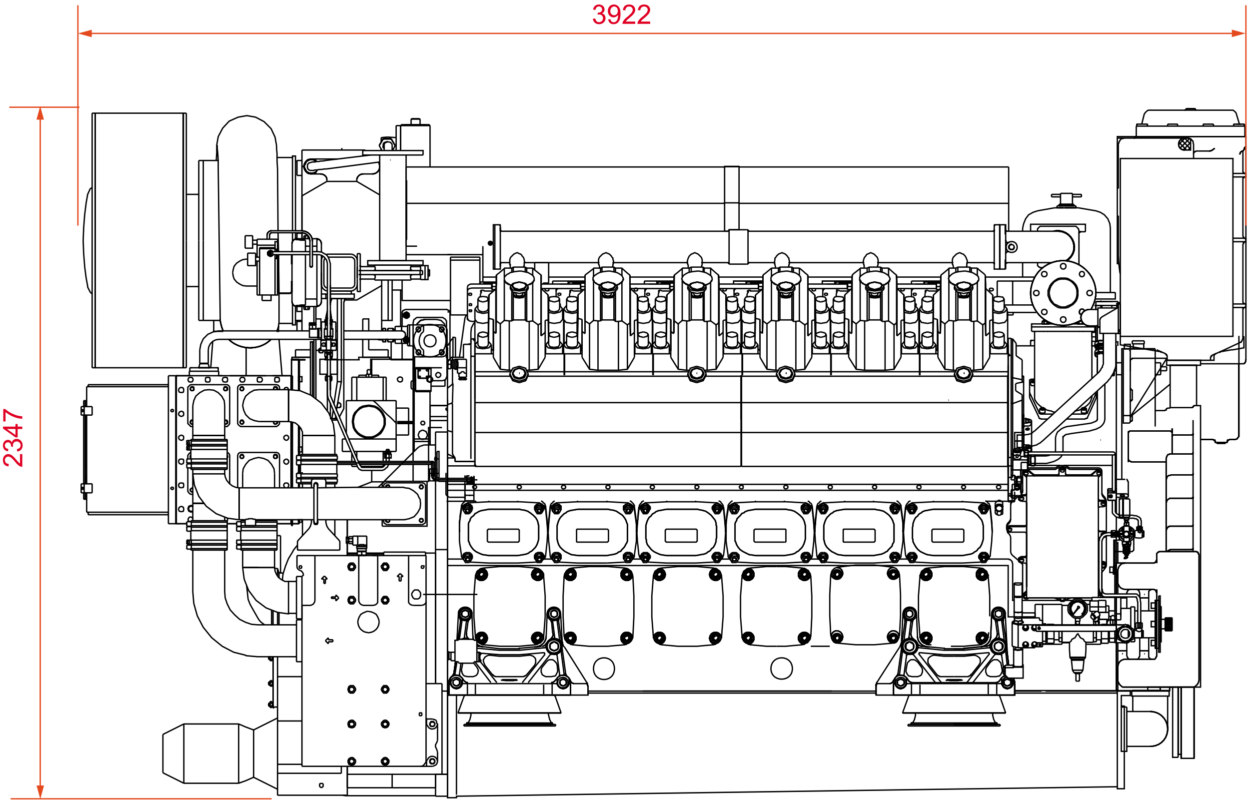


Fig. 01-1

01.5.2. Side B

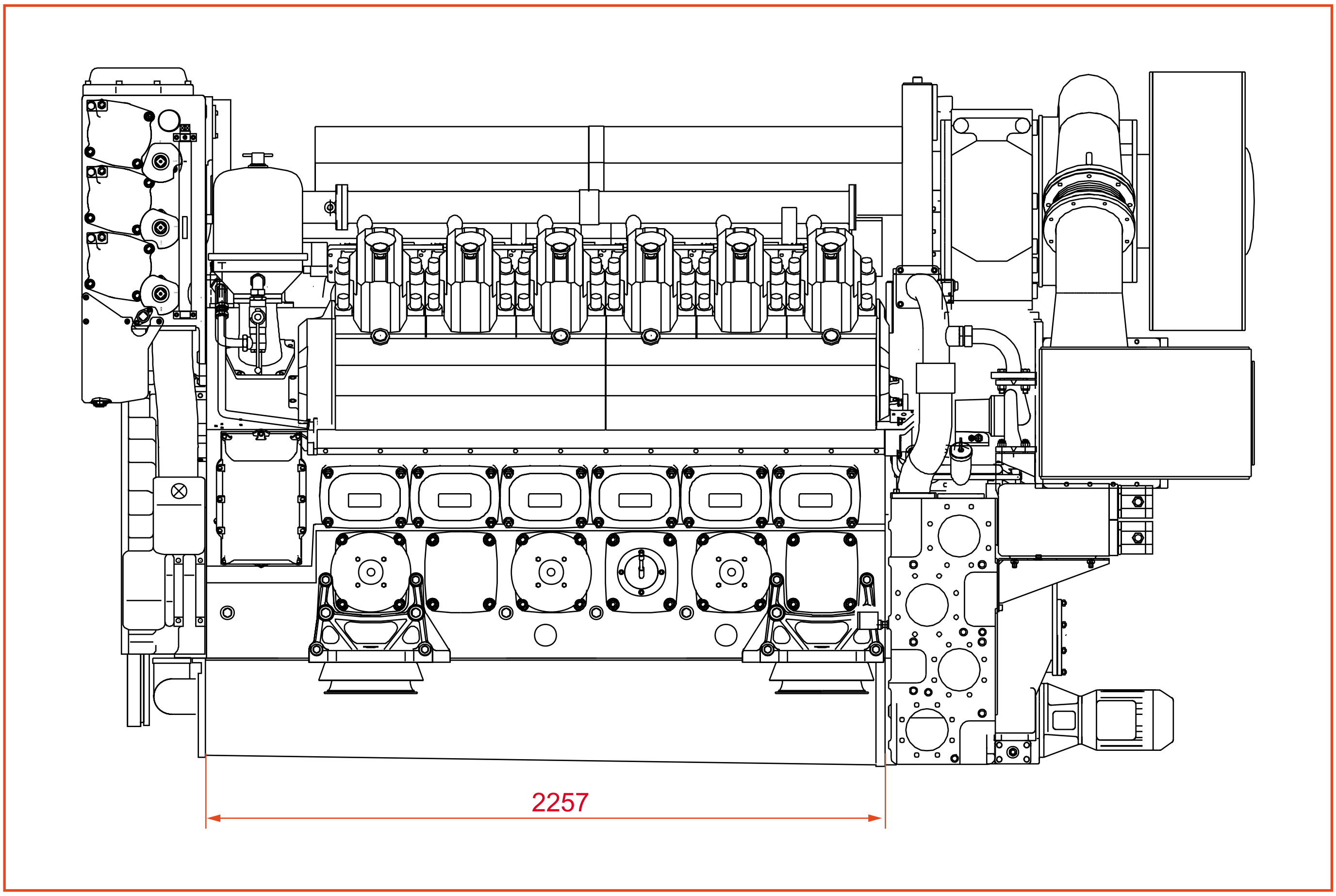


Fig. 01-2

01.5.3. Free End

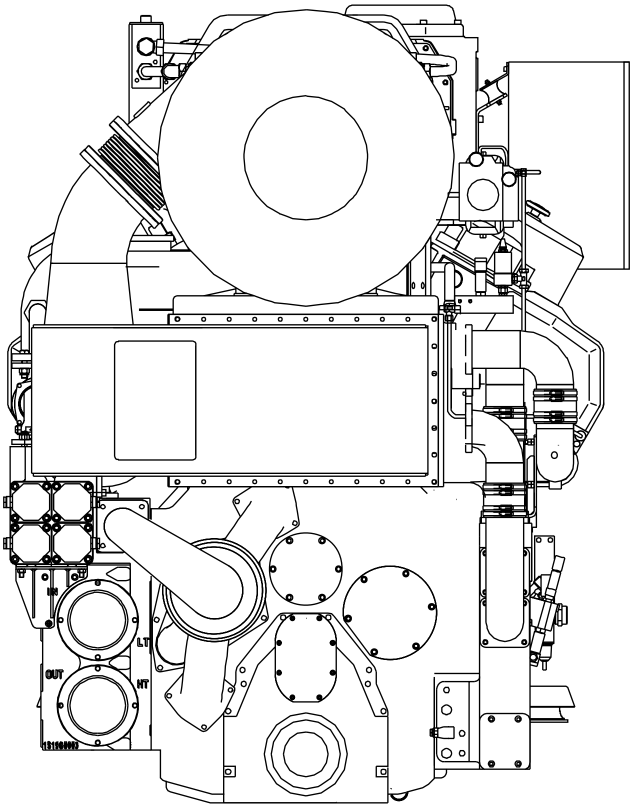


Fig. 01-3

01.5.4. Flywheel End

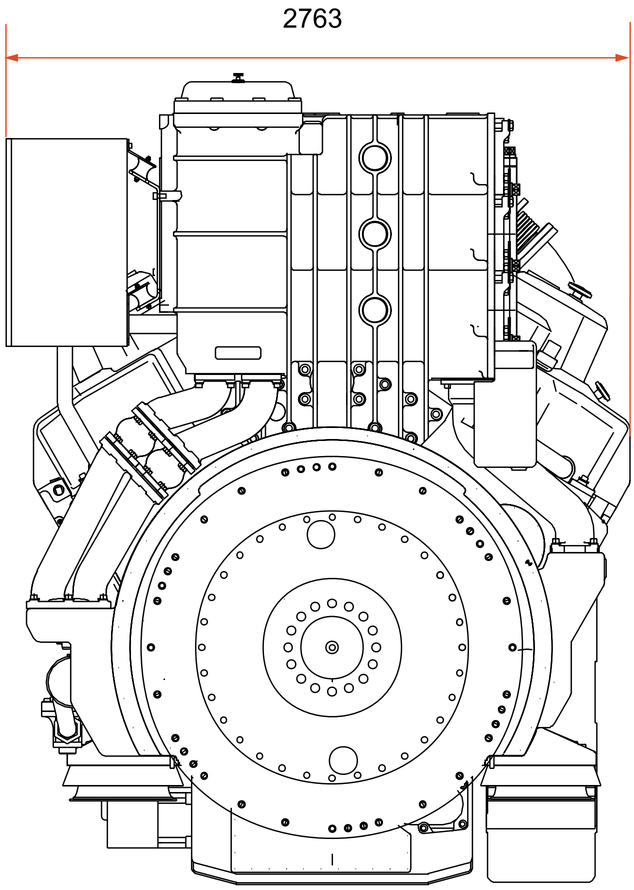


Fig. 01-4

01.5.5. Top View

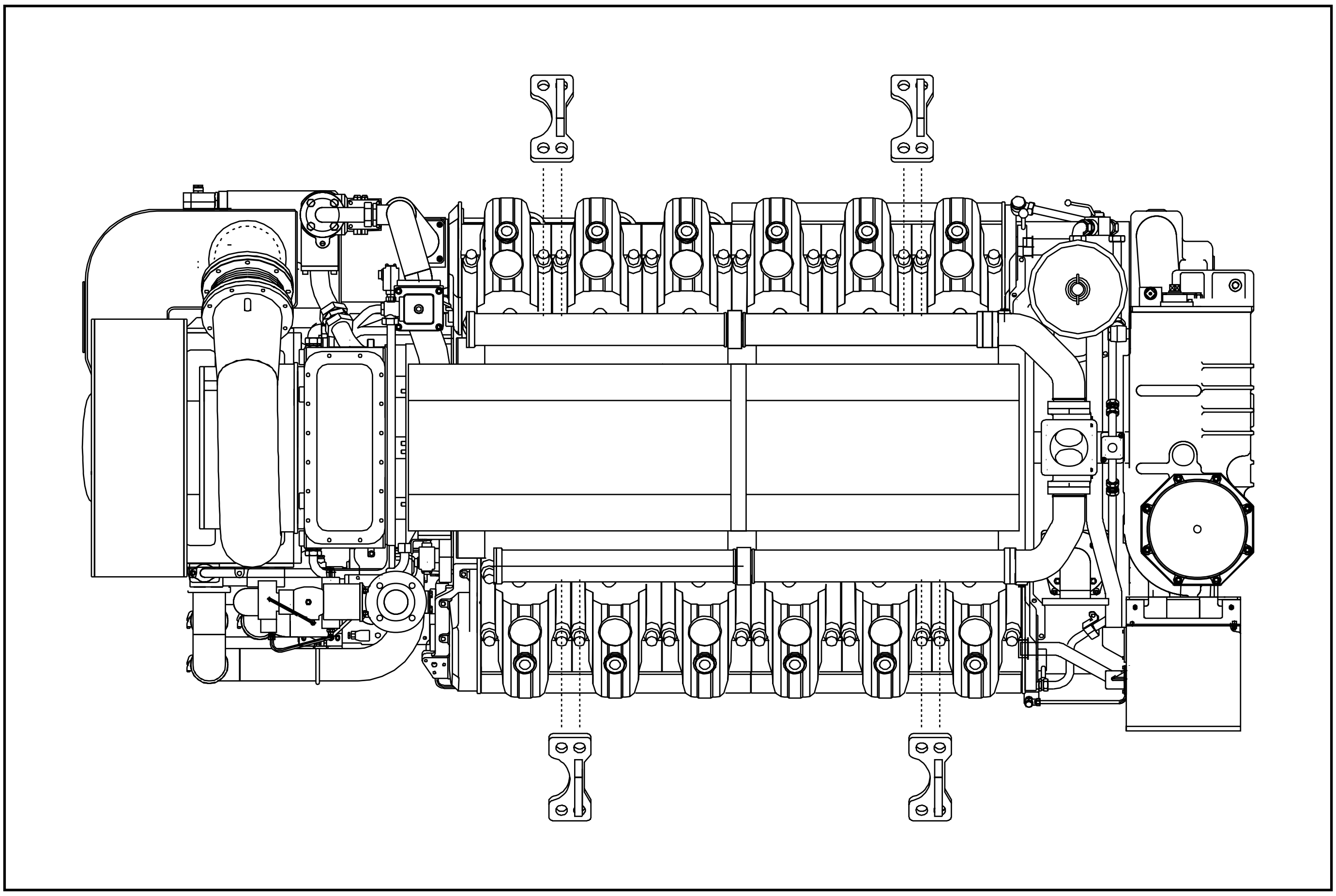


Fig. 01-5

01.6. 18V220SG Engine views

01.6.1. Side A

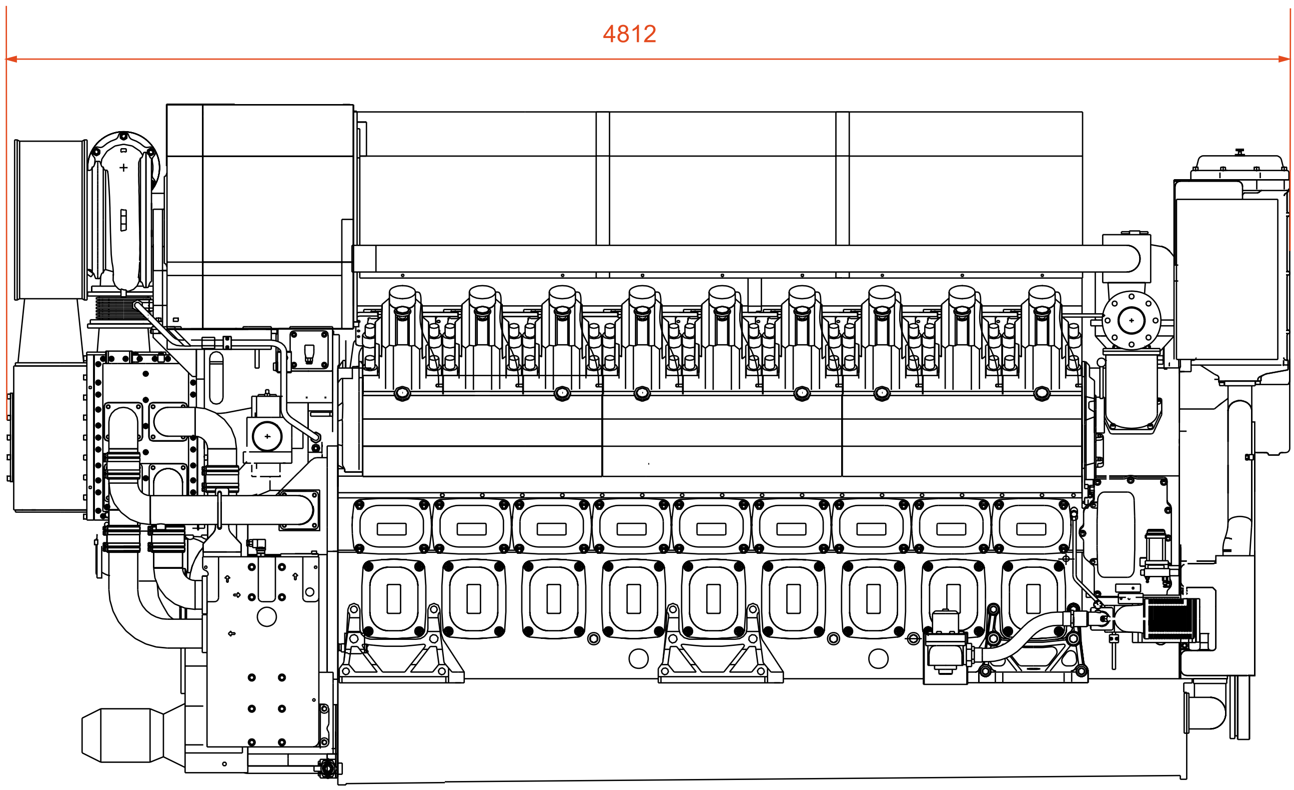


Fig. 01-6

01.6.2. Side B

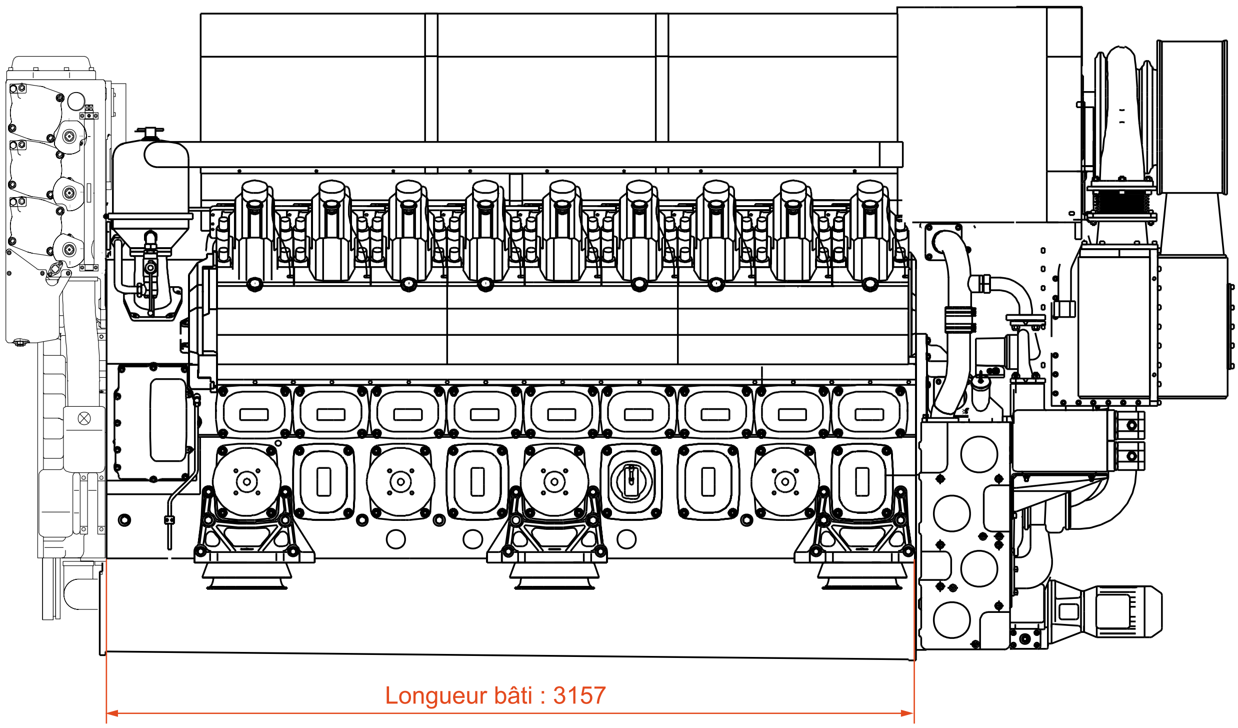


Fig. 01-7

01.6.3. Free side

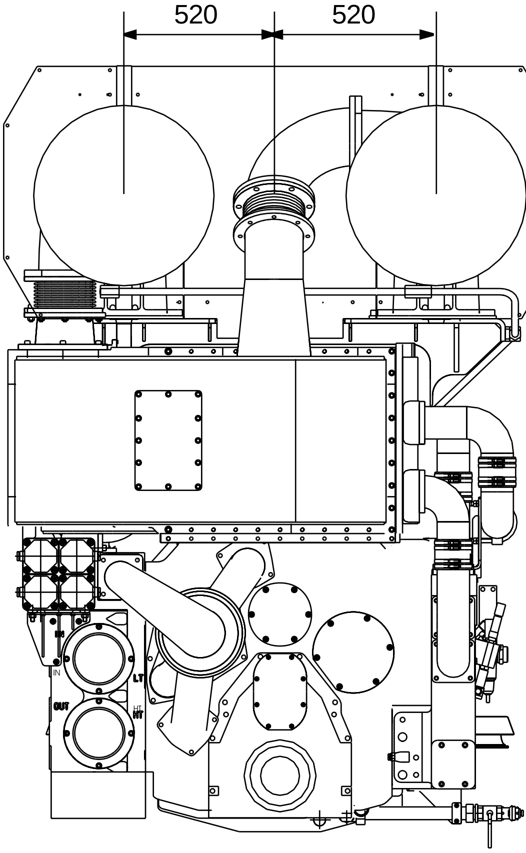


Fig. 01-8

01.6.4. Flywheel side

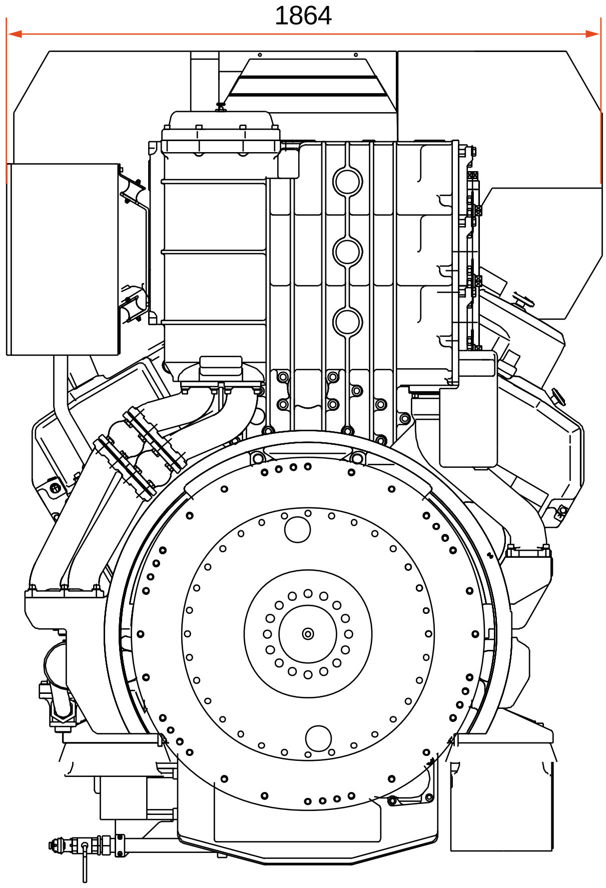


Fig. 01-9

01.6.5. Top view

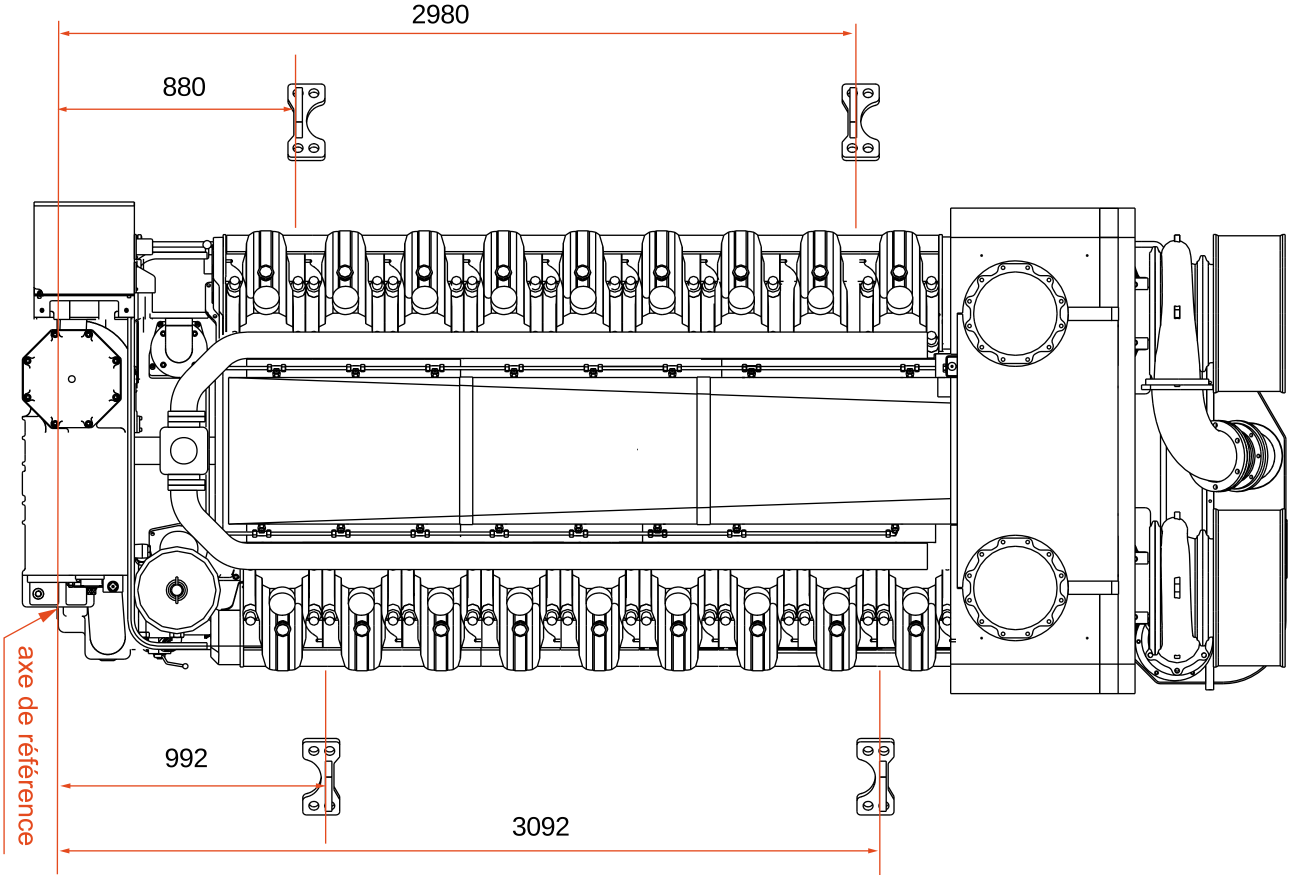


Fig. 01-10

02. Fuel, Lubricating Oil, Coolant

02.1. Gas

02.1.1. General Information

The engine is designed to operate on natural gas complying with the following specifications:

Gas quality	
Methane index	> 80
Methane (CH4)	> 75%
Hydrogen sulphide (H2S)	< 0.01 %
Net calorific value	> 33 MJ/Nm^3
Solid deposits and particles	< 5 µm

The methane index is a number evaluating resistance to gas knock. A high methane index indicates higher resistance to knocking. The methane index can be calculated if the constituents of the gas are known. Heavy hydrocarbons such as strongly concentrated ethane, propane and butane tend to lower the methane index significantly . This lowers resistance to knocking and the engine performance must be down-graded. (see Fig. 02-1).

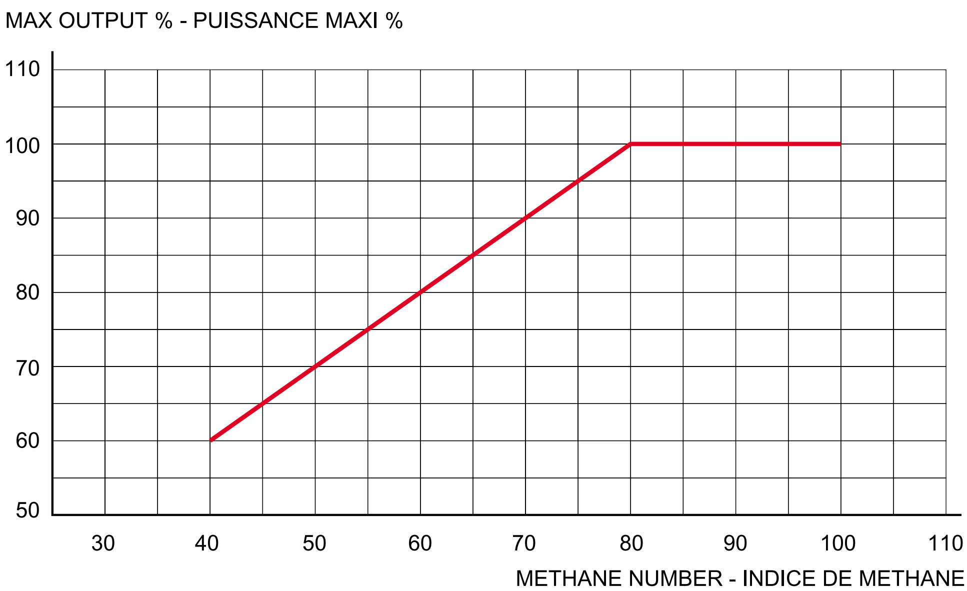


Fig. 02-1

Hydrogen sulphide (H_2S) causes serious damage to engine components. It is therefore essential to check the percentage does not exceed the indicated value.

02.2. Lubricating oil

02.2.1. Characteristics

Viscosity :

Viscosity, class SAE 40.

Alkalinity :

Oil alkalinity depends on the type of gas used in the engine.

Additives :

The oils should contain additives for good oxidation stability, corrosion protection, and loading capacity and also to prevent deposits from forming on internal engine components (piston rings and bearings in particular).

02.2.2. Lubricating oil qualities

VISCOSITY	12.5 to 15.0 centistokes at 100 °C SAE 40
TBN	5 - 6.5
Sulphate ash	0.4 - 0.6

APPROVED OILS	
Supplier	**Brand Name**
SHELL	Mysella LA 40
ELF	Nateria Mh 40
MOBIL	Pegasus 705
MOBIL	Pegasus 805
ESSO	SHPC 40

Caution!

Contact Wärtsilä France before using a lubricating oil not listed in this table. Lubricating oils that are not approved have to be tested in compliance with Wärtsilä France procedures.

Never mix different oil brands unless approved by the oil supplier and, while under warranty, by Wärtsilä France.

02.2.3. Inspection and maintenance

a) **As an efficient method** of defining the oil change frequency and a way of obtaining the engine manufacturer's opinion as to the condition of your engine, we recommend that you send us oil samples, taken at regular intervals, indicating the corresponding number of operating hours.
To be representative of the oil circulating, the sample should be taken with the engine running and put in a clean 0.75 l container. Take samples before and not after topping up with fresh oil. Before filling the container, rinse it with oil from which the sample is to be taken.

In order to make a complete assessment of the condition of the oil in service, the following details should be supplied with the sample: installation, engine number, oil brand name, engine operating hours, number of hours the oil has been used, location from where the sample was taken, type of fuel and any other relevant remarks.

Oil samples with no information except for the installation and engine number are virtually useless.

When appraising the condition of the oil used, the following properties should be observed. Compare with typical values (type analysis) for fresh oil of the brand used.

Viscosity:

Viscosity shall not be more than 25% above the guidance value indicated at 100°C. The maximum permissible viscosity for an SAE 40 grade oil is 212 cSt at 40°C and 19 cSt at 100°C. The minimum permissible viscosity for an SAE 40 grade oil is 70 cSt at 40°C and 9 cSt at 100°C.

Water content :

The water content should not exceed 0.1% -0.3%. Otherwise water has got into the oil because of defective seals on items such as the coolant pump, cylinder liners, etc. The oil must be drained and the problem investigated.

Total Acid Number (TAN) :

The TAN value must not be >3. A higher value indicates high acidity. The oil must be changed.

Total Base Number (TBN) :

A maximum decrease of 40% compared with the fresh oil value is acceptable.

Oxidation - Nitration :

Oil oxidation is caused primarily by gas from the crankcase (blow by) and is proportionally greater at high engine temperatures. Maximum permissible value: 15 ABS/cm.
Nitration is essentially caused by NOx formed during combustion: maximum permissible value: 20 ABS/cm.

b) **Topping up.** Measure and record the quantity of oil added. Attention to lubricating oil consumption may give valuable information about engine condition. A continuous increase may indicate wear of the piston rings, pistons and cylinder liners. A sudden increase may require the removal of the pistons if no other reason is found.

c) **Guidance values for oil change intervals** are to be found in Section 04.

It is advisable to observe the following oil change procedure:

1 **Drain the lubricating system** while the oil is still hot. Make sure that the oil filters and coolers are drained too.

2 **Clean spaces where oil is held,** including the filters and the camshaft compartment. Fit new oil filter cartridges.

3 **Fill the oil sump with the required quantity of oil,** see Chapter 01, Section 01.1.

02.2.4. Oil sampling procedure

The oil sample shall be sufficient to ensure good reproducibility of measurements.

02.2.4.1. Recommendations

The oil sample shall be taken from the engine when hot and stopped (after running). Take the sample through the drain port or through the dipstick tube using a flexible pipe and a syringe, fixed to the container. The flexible pipe shall be long enough for the sample to be taken from the middle of the sump oil.

Always use clean containers to avoid any risk of contamination due to traces of sediment when taking the sample (cleanliness precautions to be taken before and after sampling).

(Make sure the container is properly sealed by turning it over and tapping it.)

The oil sample must be as representative as possible of the oil in the engine. For this reason, when taking a sample from the drain port, it is recommended to run off part of the oil before filling the container. This prevents any impurities deposited at the bottom of the sump from contaminating the sample.

If the sample is taken at the oil filter, make sure that the plug is tightened with a wrench to prevent any possible leaks.

02.2.4.2. Oil sampling kit

Container with a syringe and flexible pipe, plug to close the container after sampling and an identification label. Kit reference: 180001.

02.2.4.3. Information to be recorded on the identification label for engine monitoring

Remember to attach the duly completed sample form to the sample container. Put identical stickers on the sample form and the sample container.

02.2.4.4. Identification

Engine mark
Engine type
Engine No.
Number of engine operating hours
Sample date
Ampling conditions (oil change or intermediate)
Fuel type
Number of operating hours of the oil
Type of use
Oil brand name
Oil name
Lubricant SAE grade
Amount of oil added since last oil change

Equipment identification: the results of the analysis must be correctly cross-referenced to the engines from which samples were taken.

02.3. Coolant

02.3.1. General information

To prevent corrosion, scale deposits or other deposits in closed circuits, the water has to be treated with additives.
Before treatment, the water must be as limpid and as soft as possible (maximum 10 d°H). The chloride content must be less than 80 mg/l and the pH greater than 7. The best results are obtained with fully de-mineralised water, for example from a soft water generator, to which additives are added.

Caution! **Distilled water without any additives absorbs the carbon dioxide in the air, which greatly promotes corrosion.**

Sea water is very corrosive and forms deposits, even if only small amounts get into the system.
Rainwater has a high oxygen and carbon dioxide content. Accordingly it is corrosive and cannot be used as coolant.

02.3.2. Additives

Use only products from well-known and reliable suppliers, with major distribution networks. Follow their instructions to the letter.

Caution! **The use of emulsion oils, phosphates and borates is not recommended.**

The following table lists the qualities of certain additives.

Summary table of the most usual coolant additives			
Additive	**Advantages**	**Drawbacks**	**Suitable use**
Sodium chromate or potassium chromate	- highly effective - small quantities active, 0.5% by weight - reasonably priced - easy to test concentration (by comparing colour against a test solution) - available everywhere	- increased risk of corrosion at too low concentrations: localised corrosion - harmful for the skin - toxic: lethal dose - prohibited for use in soft water generators intended for domestic appliances	- suitable as additive for objects where the toxic effect could be accepted - precaution for use and meticulous control are necessary
Sodium molybdate	- non-toxic - not dangerous to handle	- more expensive than toxic products - increased risks of corrosion sensitive to correct dosage	

02.3.3. Treatment

02.3.3.1. General information

When changing additives or when putting an additive into a system where untreated water has been used, the entire system must be chemically cleaned and rinsed before adding treated water. If, contrary to our recommendations, an emulsion oil has been used, the entire system must absolutely be cleaned and all grease deposits removed. Evaporated water shall be made up for by untreated water since, if treated water is used, the additive content may gradually reach an excessively high concentration. To make up for leakage and other losses, the system must be topped up with treated water. When performing maintenance work requiring the system to be drained, save the treated water for re-use.

Products approved for water treatment				
Supplier	**Name**	**Packaging**	**Reference**	**Test Kit**
Rohm & Haas	RD25 DIAMIGEL DIAGEL DIAGEL	Jerrican 25 kg Barrel 225 kg Barrel 225 kg Jerrican 25 kg	DLT612163 DLT612166 DLT612168 DLT612167	DLT612505
ELF	COOLELF SUPRA GLACELF SUPRA GLACELF SUPRA	Drum 215 litres Drum 215 litres Drum 25 litres	WFE 000090 WFE 000091 WFE 000092	

02.3.3.2. Preparation

DIAMIGEL and COOLELF SUPRA are ready-to-use products. However, for RD25, DIAGEL and GLACELF SUPRA, de-mineralised water or drinking water with the following characteristics must be used to prepare the treatment product.

a) Water characteristics before treatment:

The water must be clear. Water loaded with suspended matter results in deposits accumulating at low points where the flow rate is low.

The water before treatment must have the minimum characteristics defined for use at normal doses of the recommended treatment products.

b) Hardness:

Hardness must be as low as possible to prevent precipitation and encrustation, responsible for furring. Hardness less than 12° is advisable.

c) Hydrogen potential pH:

In principle, the pH must be greater than 7. If necessary, add sodium bicarbonate to acid water to bring the pH to 7.

d) Chloride and sulphate content:

The concentration must be less than 50 mg/l of NaCl and 40 mg/l of SO4Ca equivalent.

However, we recommend consulting the product manufacturer or Wärtsilä France when:

- the hardness is greater than 30

- the chloride content is greater than 300 (even though the possibility of treating up to 1000 is found in certain manuals)
- the sulphate content is greater than 100

Product	Protection up to	Quantity of product to use to obtain 1000 litres of treated water
RD25	Approx.- 4°C (1)	Initial treatment: 91 l Subsequent treatment: 48 l
DIAGEL	- 13°C - 17°C - 22°C - 25°C(2)	250 l 300 l 350 l 400 l
GLACELF	- 3°C - 9°C - 18°C - 25°C - 37°C(2)	100 l 200 l 300 l 400 l 500 l
COOLELF SUPRA	- 25°C	Ready-to-use
DIAMIGEL	- 35°C	DIAMIGEL is the ready-to-use version of DIAGEL

Caution: **(1) Caution: do not mix RD25 with anti-freeze and anti-corrosion products.**
(2) The cooling capacity of water decreases when the ratio of the mixture increases.

If you change the treatment product, it is necessary to drain the water circuit and clean it with running water before filling the engine with the new treated water.

Caution: **Never use soda to clean the engine.**

Note: **To ensure the mixture is well mixed, run it through the circuit using the preheating water pump for one hour.**

Otherwise, start the engine and allow it to run for 10 minutes.

02.3.4. Checking treated water quality

See the maintenance table in Section 04.

Test kits are available for monitoring the quality of treated water yourself (pH-value, concentration). These kits are inexpensive, very simple to use and warn you if a problem occurs or if you have to change your treatment.

We recommend that you send samples of the treated water to Wärtsilä France in order to optimise monitoring of your treated water.

We will determine the chemical characteristics of your treated water (composition, contamination).

You will then know :

- when next to replace your treated water,
- the condition of the coolant system,
- the causes and sources of possible damage.

03. Starting - Stopping- Running

03.1. Starting

Before starting the engine, check that:

1 **The lubricating oil level** is correct.

2 **The gas circuit is in working order**
- Pressure relief unit in service (correct pressure)
- Gas circuit main valve open

3 **The low-temperature and high-temperature coolant circuits** are in working order (correct pressure, preheating and pre-circulation of water sufficient to warm up the engine).

4 **The starting air pressure is supplied** (10 bars minimum).

5 **The coolant circuits** are appropriately de-aerated.

Caution: **The shaft driven water pump must be degassed (manual bleed on pump body), otherwise, the air pocket in the pump will stop the coolant from circulating.**

6 **The control system** is energised and ready to perform alarm functions.

Note: **All covers and protective panels must be fitted before starting the engine. These covers may be occasionally removed for measurement and checking purposes, but must be re-fitted immediately afterwards.**

Caution: **Never leave the engine running with the inspection panels open.**

03.1.1. Manual starting

1 **Crank the crankshaft through two revolutions.**

2 **Disconnect the cranking gear from the flywheel.**

3 **Check that the automatic alarm** and stopping devices are in the starting position (Section 23).

4 **Bleed the starting air circuit,** close the blow-off valve when no more condensates are released.

5 **Start the pre-lubricating oil pump.**

6 **When start-up authorisation is given,** press the START push-button until the engine fires. If it does not fire after two or three seconds, look for the cause.

Warning: **Never attempt to re-start the engine until the flywheel has come to a complete stop.**

7 **After starting,** check that pressures and temperatures are normal.

8 **Check that the alarm** and stop devices are in the working position.

03.1.2. Automatic and/or remote starting

If the engine has not been run for more than one week, perform the first start-up by hand as in Section 03.1.1.

Note: **The automatic starting system must be tested at least once a week.**

1 **When starting the engine remotely:**
First of all, start the pre-lubricating oil pump. Operation of this pump is usually indicated by a signal light. The engine can be started when the turbocharger front float detects oil flow. In automatic mode, the pre-lubricating oil pump operates alternately, keeping the engine ready for starting. It is necessary to check that this pump is in working order at least once every two days.

2 **Press the remote START push-button.**The solenoid valve installed on the engine is then energised and opens the air supply to the starter. Then press the START push-button long enough (1 to 2 seconds) to start the engine. Start up is indicated by the remote tachometer or by the lighting of an indicator. In certain cases, with automatic remote control, when the button is pressed, the pre-lubricating oil pump starts and, after supply of oil to the turbocharger is detected plus a lapse of time of about 15 seconds, the engine starts automatically, as indicated below.

3 For engines with automatic starting,
the air solenoid valve is controlled by a programming relay. Normal programming is as follows : as soon as the programming relay receives a start signal, the solenoid valve is energised for 2 to 4 seconds and opens, thus starting the engine. If engine fails to start, a second starting attempt is made after 20 seconds, energising the solenoid valve for 10 seconds. If the engine still does not start, the programming relay energises the alarm circuit. The period of time between two starting attempts must be sufficient to ensure that the flywheel has come to a complete stop.

4 When the engine has reached a predetermined speed,
an auxiliary relay, energised by the remote tachometer transmitter, turns off the starter and closes the air solenoid valve. At the same time, the power to the pre-lubricating oil pump is cut, stopping it from operating when the engine is turning. After a set period of time (from 10 to 30 seconds), the alarm, stopping and speed remote control systems are automatically connected.

03.2. Stopping

03.2.1. General information

Caution: **When overhauling the engine, make sure that the automatic starting system and the pre-lubricating oil pump are properly disconnected.**

1 **Engines with shaft driven water circulating pump:** run the engine under no load for 3 to 5 minutes before stopping.

2 **Engines with separate water circulating pump:**2 to 3 minutes under no load is sufficient, but run the pump 5 minutes more.

3 **Close the indicator instrument valves and cocks**if the engine is to remain idle for a relatively long period of time. It is also recommended to close the turbocharger air inlet and exhaust.

4 **Every two days,** the oil circuits of an engine that is stopped for a relatively long period of time must be filled using the pre-lubricating oil pump. At the same time, crank the crankshaft to a new position. This reduces the risk of corrosion to journals and bearings when the engine is exposed to vibrations.

03.2.2. Remote stopping

1 **Engines with shaft driven water circulating pump:** run the engine under no load for 3 to 5 minutes before stopping.

2 **Engines with separate water circulation pump:** 2 to 3 minutes under no load is sufficient, but run the pump 5 minutes more.

3 **Press the remote STOP push-button.** The speed governor stop coil is energised. The time of the solenoid is set - 20 to 50 seconds - so that it remains energised until the engine stops. During this period of time, the engine cannot be re-started. After the set period of time, the solenoid returns to its normal condition (de-energised).

4 **During stopping,** when engine speed drops below a certain threshold, the alarm, stopping and remote speed control system is disconnected and the signal light indicating that the engine was running goes out. At the same time, the automatic pre-lubricating oil pump starts up.

03.2.3. Automatic stopping

When the stopping solenoid is energised by the automatic stopping system, when an incident occurs, the engine stops as indicated in Section 03.2.2. Previously, an alarm device normally sent a signal indicating the reason for stopping. For example, the electro-pneumatic overspeed device may have caused the stoppage.

03.3. Normal supervision of operation

03.3.1. Every two days or after 50 hours’ running

1 **Record the readouts** from all thermometers and pressure gauges, as well as the engine load. Compare these readouts with the corresponding values at the same loads and the same speeds in the acceptance tests and curves. Guidance values are given in Section 0.1.

- If the temperature difference between the exhaust gases of the various cylinders exceeds 60°C at loads greater than 25% of the nominal power, it is necessary to find out the reason.
- At loads greater than 60% of the nominal power, the turbo-charging air temperature should, in principle, be as low as possible. However, not low enough to cause condensation. See Figure 03-1). At loads less than 40% of the nominal power, it is better to have the highest possible supercharging air temperature.

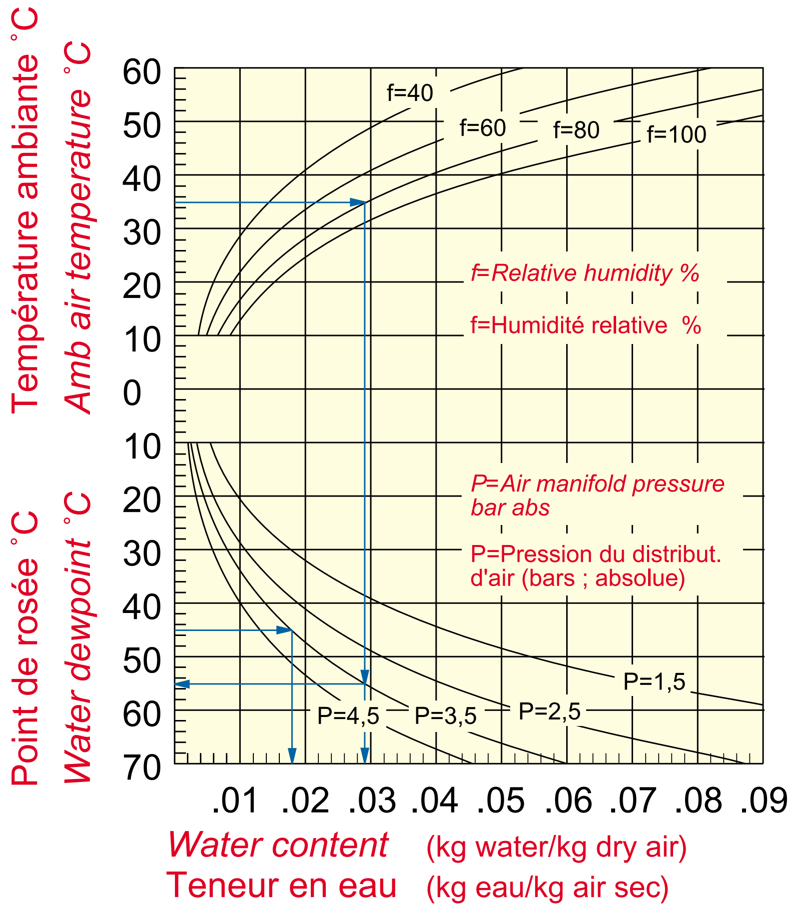


Fig. 03-1

2 **Check the oil filter clogging indicator.** An excessive loss of head due to clogging of cartridges may cause less efficient filtration because the bypass valve opens. Less efficient filtration causes increased wear.

3 **Check the oil level in the sump.** Assess the appearance and the consistency of the oil. Water in the oil may be checked for by simply letting a drop of oil fall on a hot surface (above 150°C): if the drop does not sizzle, it is not contaminated by the water; if it sizzles, it contains water.

4 **Check that coolant circuit de-gassing** (at the expansion sump) is working correctly. Check there is no excessive leakage from the tell-tale hole in the coolant circulation pumps.

5 **Check that the air cooler drainage pipes** are open.

6 **Check that the water cooler and oil cooler tell-tale holes** are open.

7 **If the option is mounted,** clean the compressor side of the turbocharger with the integrated water injector. See the turbocharger instruction manual.

8 **Drain any accumulated water and sediments from the fuel day tank** and drain the water from the starting air intermediate tank.

03.3.2. General remarks

1 **No automatic supervision system** nor checking device can replace an experienced engine technician. Carefully LOOK AT and LISTEN TO the engine!

2 **One of the most dangerous phenomena** for a gas engine is leakage or blow by of gases (fuel + air) from the piston chamber at maximum compression. If this is suspected, for example by finding a sudden increase in oil consumption, check the pressure in the crankcase sump. If the pressure exceeds 65 mm H2O , check the crankcase venting system and if no anomalies are found, remove the pistons!

3 **Operation at loads between 0 and 20% of the nominal power rate** should be limited to 100 hours maximum continuous operation. It is then necessary to increase the load to between 70% and 100% of the nominal power rating for one hour, then continue operation at low-load or completely stop the engine. Operation under no load, i.e. engine unclutched and alternator disconnected, should be avoided as far as possible.

03.4. Starting after prolonged stoppage (more than 8 hours)

03.4.1. Manual starting

1 **Check:**
- the lubricating oil level,
- the level of the water in the expansion tank,
- the water supply to the heat exchangers,
- the supply of gas to the pressure regulating unit.

2 **Comply with all mandatory requirements** stipulated in Section03.1. and mainly with the instructions in section 03.1.1., which are all the more important when the engine has been stopped for long periods of time.

3 **Bleed the air** from the gas and oil filters.

4 **After starting,** check that the temperatures and pressures reach their normal levels.

03.5. Re-starting after overhaul

1 **Check that the gas system is properly gas-tight.**

2 **Check the coolant circuit** to detect possible leaks and especially:
- the bottom part of cylinder liners,
- the oil cooler,
- the turbocharging air cooler.

3 **Check and adjust** valve clearance (See Section 06 for settings).

4 **Start the pre-lubricating oil pump.**

5 **Bleed the oil filters.**

6 **Check that oil comes out of each lubricating hole** and at each journal bearing, as well as from each piston and rocker cooling nozzle.

7 **Check** that there are no leaks from piping connections, both on the inside and on the outside of the engine.

Note : **Crank the crankshaft to feed oil to all connecting rods and valve rockers.**

Caution : **Rags or tools left in the engine block, incorrectly tightened screws or nuts, and worn self-locking nuts may cause total breakdown. The service life of pumps and filters is extended if the oil containers and spaces where the oil flows (sump, camshaft spaces) are kept clean.**

8 **See the instructions** in Sections 03.1. and 03.4. for information on starting.

03.6. Supervising engine operation after overhaul

1 **When the engine is started for the first time,** listen carefully for any unusual noises.
If a problem is suspected, stop the engine immediately or stop it after 5 minutes running without load at normal speed.
Check at least the temperature of the crankshaft bearings and of the connecting rod big ends, as well as any other bearings which may have been undone during the overhaul.
Re-start the engine if everything is OK.

2 **Check** that there are no gas, coolant or oil leaks. Pay special attention to the gas circuit, the prechamber and the main gas valves.

Note : **The instructions given below are of prime importance after an overhaul:**

3 **Check:**

- temperature indicators and pressure gauges,
- automatic alarm and stopping devices,
- the loss of head through the oil filters,
- the level of the oil in the sump,
- the coolant circuit de-aeration,
- crankcase pressure,
- bleed the filters.

03.7. Running-in

1 **After the pistons have been overhauled,** follow the program in , as closely as possible. If the program cannot be scrupulously followed, it is necessary to avoid running under full load for at least 4 hours.

2 **After replacement of piston rings,** pistons and liners, follow the program in Fig. 03-2 as carefully as possible.

Caution! **If the program cannot be followed, avoid running the engine at full load for at least 10 hours.**

Note: **Avoid running-in under low load at continuous engine speed.**

The engine may be run-in with the normal lubricating oil specified for the engine.

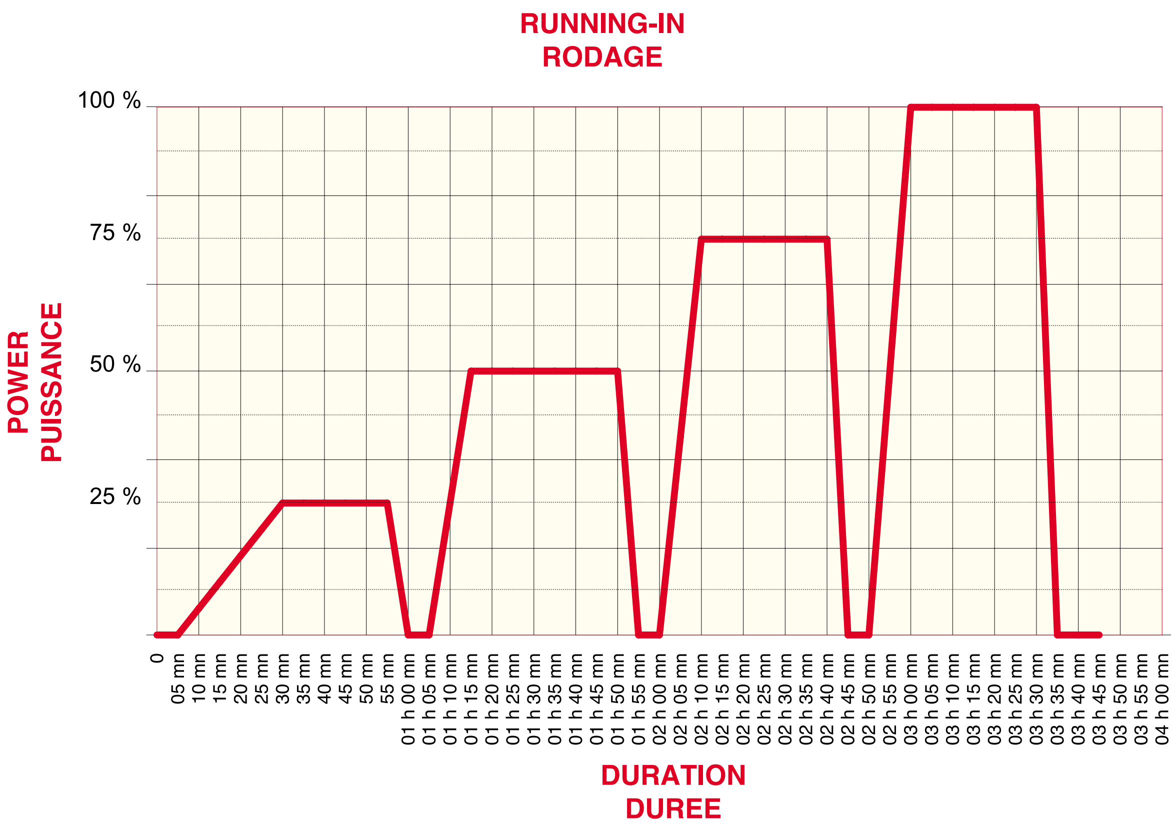


Fig. 03-2

04. Maintenance Schedule

04.1. General Remarks

The maintenance of your engine depends largely on the operating conditions. The intervals of time shown in this schedule are only guidelines; however, they should not be exceeded during the warranty period. Time between maintenance operations can be considerably extended, depending which application are being considered; for that you must refer back to Wärtsilä France Service Department to know the best adaptation between the Maintenance Schedule and your application.

1 **Before you do anything,** read carefully through the paragraphs in this Manual relating to one or more specific questions.

2 **When doing maintenance work,** keep the working area perfectly clean and tidy.

3 **Before removing any items,** check that the systems concerned have been drained and are not under pressure. After removal, immediately stop up the oil, gas and air inlets and outlets with tape, plugs, clean rags, etc.

4 **When replacing a damaged component** that has an identifying mark for a cylinder or bearing number, note down each replacement in the engine log book and state the reasons for replacement.

5 **After refitting,** make sure that all nuts and bolts are properly tightened and locked where necessary.

Note: **The maintenance schedules below are for normal operating conditions:**

- Back-pressure: 5 kPa
- Gas specification: (see chapter 02)
or
- Fuel specification : (see chapter 02)
- Oil: use approved oils only (see chapter 02).

04.2. Maintenance Schedules

04.2.1. Application: Power (Generating Set - Cogeneration)

Engine use: continuous duty	Engine type	Speed : 1200 rpm	Speed : 1500 rpm	General overhaul : 48 000 hours
	12V220	1700 kWe	2100 kWe	
	18V220	2520 kW	3200 kWe	

Servicing checks and maintenance operations	Daily	Wee-kly	Mon-thly	Code M 1	M 2	M 3	M 4	M 5	M 6	Chapter/ Function
				Every (hours): 1000	2 000	6 000	12000	24000	48000	
Clean engine	X									General Description
Look for leaks and other faults	X									
Record all operating parameters	X									
Replace cylinder liners								X	X	10.5 Chemise de cylindre
Replace antipolishing ring							X	X	X	
Check crankshaft alignment				XX			X	X	X	11.1 Crankshaft
Replace main bearing shells								X	X	
Take silicone samples for analysis						X***	X***	X***	X***	11.2 Amortisseur vibrations
Replace vibration damper								X***	X***	
Replace big-end bearing shells							X	X	X	11.6 Bielles et pistons
Replace conrod bushings								X	X	
Replace piston rings								X	X	
Check con-rods, pistons and cylinder liners								X	X	
Check rotocaps						X				Cylinder Head Maintenance
Cylinder heads overhaul or standard exchange							X	X	X	
Replace cover gaskets							X	X	X	
Check and adjust valve clearance					X	X	X	X	X	12.3.3 Valve Clearances
Check camshafts, push rods and gears							X	X	X	Rocker Gear and Camshaft + Camshaft Maintenance
Check roller tappets							X	X		
Replace roller tappets									X	

Servicing checks and maintenance operations	Daily	Wee-kly	Mon-thly	Code M 1	M 2	M 3	M 4	M 5	M 6	Chapter/ Function
				Every (hours): 1000	2 000	6 000	12000	24000	48000	
Check air filters cleanless		X								15.1 Turbo
Check turbocharger clearance(s) and clean compressor					X	X	X	X	X	
Clean charge air cooler						X	X	X	X	
Clean air filters (replace if necessary)				X	X	X				
Replace filtering elements of air filters						X(*)	X	X	X	
Replace turbocharger bearing(s)						X(*)	X	X	X	
Replace air filters							X	X	X	
Waste gate overhaul							X	X	X	
Check the HV connections					X	X	X	X	X	16. Ignition System
Replace the prechamber							X	X	X	
Check the prechamber						X				
Clean the prechamber check valve				X						
Replace wear pieces of prechamber check valve					X					
Replace the prechamber check valve						X	X	X	X	
Replace the spark plugs				X	X	X	X	X	X	
Replace ignition coils								X	X	
Replace the spark plug extenders								X	X	
Clean the gas filter (°)					X	X	X	X	X	17. Gas System
Replace the gas filter (°)							X	X	X	
Replace the gas line seals(°)							X	X	X	
Standard exchange of the main gas inlet valves							X	X	X	
Standard exchange of the prechamber valves							X	X	X	
Check and clean the solenoid gas valves						X	X	X	X	
Gas pressure regulating valves overhaul (°)							X	X	X	

Servicing checks and maintenance operations	Daily	Wee-kly	Mon-thly	Code M 1 Every (hours): 1000	M 2 2 000	M 3 6 000	M 4 12000	M 5 24000	M 6 48000	Chapter/ Function
Check the oil level	X									Lubrication circuit
Clean the centrifugal filter				X	X	X	X	X	X	
Take engine oil samples for analysis.			X							
Replace hoses and other flexible lines (if necessary)							X	X	X	
Oil draining					X	X	X	X	X	
Replace oil filter cartridges				X	X	X	X	X	X	
Oil pump overhaul or standard exchange							X	X		
Replace oil pump									X	
Overhaul of oil module								X	X	
Replace oil thermostatic valves								X	X	
Clean oil cooler						X	X	X	X	
Replace oil cartridge on turbo					X(*)	X(*)	X(*)	X(*)	X(*)	
Check additive content of engine cooling water (treatment)					X	X	X	X	X	19. Coolant System
Check coolant level	X									
Clean oil, air and water coolers						X	X	X	X	
Replace thermostatic valves								X	X	
Cooling water pumps overhaul or standard exchange							X	X		
Replace water pump									X	
Check flexible lines							X	X	X	
Replace exhaust bellows									X	20. Exhaust system
Check starting system		X		X	X	X	X	X	X	21. Starting System
Check starting system oil level			X(**)	X(**)	X(**)	X(**)	X(**)	X(**)	X(**)	
Check sensors							X	X	X	23. Automatic Control Instrumentation
Check safety devices							X	X	X	
Check batteries	X									
Check WECS system electrical connections thightening			X		X	X	X	X	X	
WECS 3000 overhaul								X	X	
Check correct tightening of main sub assemblies				X	X	X	X	X	X	General

XX after first 1000 hours only

X(*) For 12V engines only with EGT turbo equipped

X(**) For 18V engines only

X(***) For 12V engines only

(°) Fitted on gas line

General Overhaul

Note : **Wärtsilä France may change the quantities, parts and periodicity depending on product development or engine operating conditions.**

05. Maintenance Tools

05.1. General information

Gas engine maintenance requires special tools developed during engine design. Certain tools are supplied with the engine while others are available from the Wärtsilä network or can be purchased directly by the engine operator.

Tool requirements may differ from one installation to another, depending upon the type of operation and the services available in the site area. Consequently, standard sets of tools are chosen to meet basic requirements.

The list given here is a selection of the tools required for a W220 gas engine.

Tool sets are grouped in order to facilitate selection for specific service operations, making maintenance work much easier.

05.1.1. How to use this list

1 **Read the corresponding paragraphs** in this manual before undertaking any maintenance operation.

2 **Check from the list,** that all consumables and spare parts are also available.

3 **Check** that all consumables and spare parts are also available.

05.1.2. Maintenance tool ordering

1 **Find the parts**you need in the following pages.

2 **Select the tools or the parts needed.** Remember that all standard tools are not necessarily included in a standard delivery of the engine.
In your order, indicate the part number shown on the figure.

3 **Note the specifications** and other information on your order.

4 **Send the order** to our local service agency. As far as possible, indicate the name of the installation.

05.2. Instructions for using and maintaining hydraulic clamping tools

05.2.1. Foreword

Hydraulic clamping tools greatly facilitate heavy and physically tiring assembly work. The technique consists in applying hydraulic pressure to the surface of a ram in a cylinder, also known as a hydraulic tensioner, and in transforming this pressure into a tensile force on the stud (e.g. cylinder head stud). Nonetheless, the use of these tools requires strict adherence to a number of safety instructions for the prevention of accidents.

In exceptional cases, unexpected problems may arise because of very frequent use, ageing of materials or material homogeneity, damage during transport or set-up, ingress of impurities or other foreign matter, unsuitable hydraulic fluid or improper operation and overloading.

05.2.2. Types of problems

With highly loaded components, such as hydraulically pre-stressed screwed assemblies or dynamic tools using high pressures and forces during the clamping operation, three types of problem in particular may cause accidents, injury or damage to the machine if these jobs are performed without regard for the safety instructions.

a) **Breaking of highly loaded components** when the pressure is increased (tightening or loosening, inspection) e.g. with engine bolts, tie rod nuts, press rams. As pressure builds up, the elastic energy resulting from the applied load is abruptly released in such a manner that the broken parts are driven in the direction of the force, therefore along the line of the bolt or press axis. These problems only occur when the pressure is increased, therefore during pumping or when the tightening device subjected to the full pressure is additionally stressed by strong juddering.

b) **Needle-like or fan-like hydraulic oil leakages** which can cause eye or skin injuries up to a distance of one metre. These streams of hydraulic oil are caused by leaks due to torn sealing devices, burst hoses or broken valves.

c) **Breakage of piston and connecting rod bolts** while the engine is running may cause major damage to the engine.
The causes may be tightening without regard to the corresponding instructions, application of incorrect pressure, failure to connect a hose, failure to click a hose coupling in place, failure to tighten a nut fully, incorrect press mounting, omitting to check the torque value at the end of an operation (number of turns of nut not recorded).

05.2.3. Reminder of rules for use and safe practice

a) **Prior to any use**

1 **Clean the working area** so that the tool and engine component mating surfaces are free from foreign matter.

2 **Check the oil level of the pump,** make sure that the right type of oil is used and top up if necessary.

3 **Check the condition of hoses and hose couplers:**

- Tightening of end fittings
- Cleanliness of couplers
- External appearance of the hose

Scrap the equipment if doubtful.

4 **Check that tensioner rams** are returned to their lowest position (top surface of the ram lower than that of the cylinder head jack body surface or flush with that of the connecting rod jack body surface). Otherwise, the rams may be re-aligned when the hydraulic line assembly is connected, with the discharge valve open.

5 **Check that the external surface of the ram,** in zone A where there is the greatest fatigue is in perfect condition. Scrap the hydraulic tensioner if the slightest deformation is found in zone A of the ram.

6 **Check validity** of the manometer calibration

b) **During use**

1 **Precisely position jacks, hoses, etc.,** making sure that the nut is centred and moves freely.

2 **Check that the circuit has been bled,** and if not bleed it (see Section 07).

3 **Check if the hydraulic circuit is sealed.**
No leaks are allowed. If leaks are found, recondition the defective parts, then bleed the circuit.

4 **Do not exceed recommended pressures.**

5 **Check the pressure gauge works correctly.** Remove the gauge if a malfunction is found, then have it appraised and reconditioned, if necessary, by the relevant departments.

6 **Check that couplers are properly connected.** The safety sleeves return to their initial position when couplers are perfectly connected.

Caution! **During pumping (pressure increase phase), no-one must not stand in line with the bolt or the press. Remain at a safe distance from high-pressure presses and hoses (turn your face away, do not touch parts with your hands) until the full pressure is reached.**

7 **Gradually increase the pressure** to the required value with the pressure regulating valve of the pump.

Caution! **Never exceed the indicated pressure!**

8 **When loosening,** a loosening pressure 5% max. above the tightening pressure may be needed. If the nut still cannot be loosened, there is another cause (for example, seized due to rust) that has to be corrected.

9 **Do not strike** loaded presses, nuts, bolts, etc. forcefully.

10 **The effect of the tightening operation** has to be checked (nut rotation).

11 **High-pressure hoses must not be bent** nor guided in excessively tight curves around edges.

12 **Damaged components** must not be re-used nor repaired.

13 **After tightening,** pump rams must be returned to their lowest position. To this end, fully open the discharge valve of the pump (to prevent a high flow-back resistance).

05.2.4. Bleeding

Bleed each unit of the hydraulic line in turn, up to the end of the line (pressure gauge).

05.2.5. Tool storage and maintenance

Correct maintenance and storage is necessary to keep hydraulic tools in good working order and to ensure they are safe to use. The following requirements must be observed.

a) **10 to 30°C ambient temperatures** are the most suitable so that plastic parts (seals, HP hoses) do not age prematurely and the hydraulic fluid is maintained at the right viscosity.

b) **Keep tools away from dust, foreign matter, chemicals** or fluids to prevent corrosion and chemical or mechanical damage to precision finished surfaces and parting planes.

c) **High-pressure hoses must not be excessively bent.**

d) **When overhauling,** use only original spare parts as correct operation often depends on seemingly trivial things (e.g. correct hardness of rings-seals).

e) **At regular intervals, check** the accuracy of pump pressure gauge readouts.

05.2.6. Maintenance instructions for hydraulic jacks

05.2.6.1. Introduction

Any leakage around a ram requires the assembly to be removed and then reconditioned. This work entails bleeding of all tooling involved .

05.2.6.2. Removal procedure

1 **Separate the spacer from the jack** and put the jack in a pan to collect the oil from the jack.

2 **Connect the jack to a hydraulic pump.**

3 **Pressurise** until the ram is fully extended (major visible leaks).

4 **Disconnect the jack** and disassemble the ram and the body. Hold the body and hit the ram on the bottom of the pan to separate the assembly.

5 **Remove the O-rings** and the anti-extrusion rings.

6 **Visually check working surfaces.** Remove:
- any burrs using an oilstone
- signs of wear by rubbing down in a circular movement (use fine emery cloth).

Note: **The jack shall be scrapped if the working surfaces are deeply scored.**

05.2.6.3. Reassembly procedure

a) **Assembly of the sealing kit:**

1 **Anti-extrusion rings** are always installed opposite the pressure side (outer side).

2 **First of all, install the anti-extrusion rings.** Make sure that they are perfectly seated in their grooves.

3 **Make sure that O-rings** are not twisted when fitted.

Note: **Smear the friction surfaces with hydraulic fluid.**

b) Jack re-assembly :

1 **Put the jack body on the spacer.**

2 **Fit the ram and push it fully home** into the body using the hydraulic press.

3 **Make sure that the valve of one of the two couplings is open** so that the air in the jack can escape.

4 **Use a 3 mm rod.**

05.3. Hydraulic tightening tools (Section 07)

Part No.	Description	Quantity
861019	Hydraulic pump	1

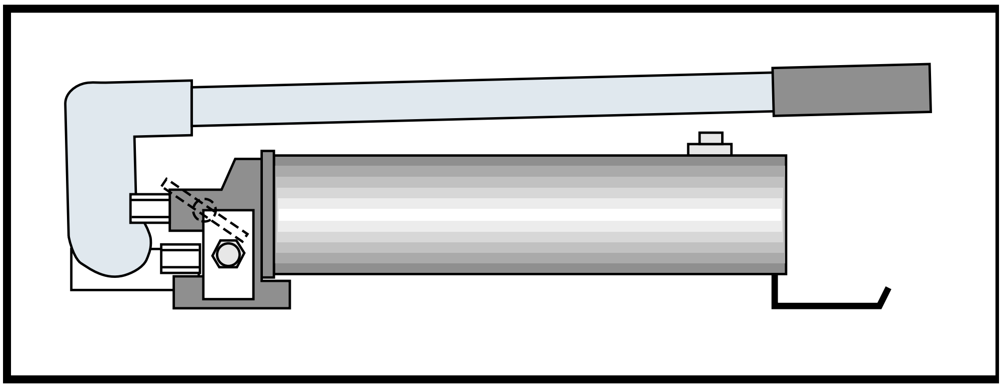


Fig. 05-1

861033	M36 type cylinders	4

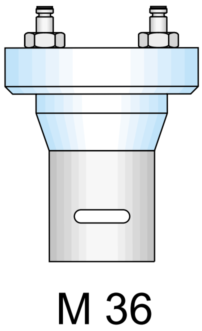


Fig. 05-2

861027	M30 type cylinders	2

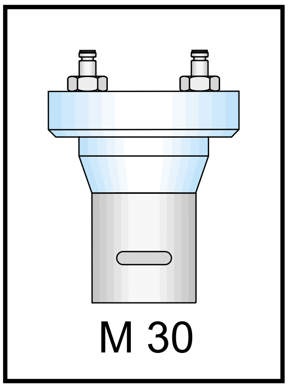


Fig. 05-3

861024 600 mm long hoses 3

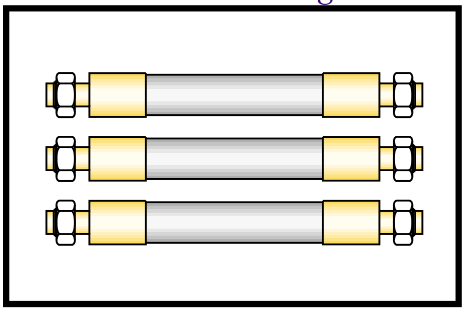


Fig. 05-6

861025 3000 mm long hoses 2

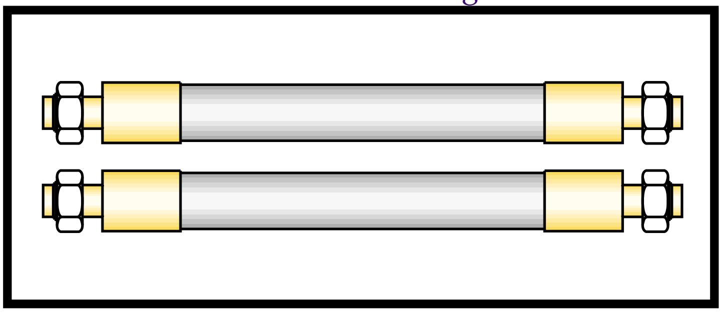


Fig. 05-4

861026 Cylinder rod. 1

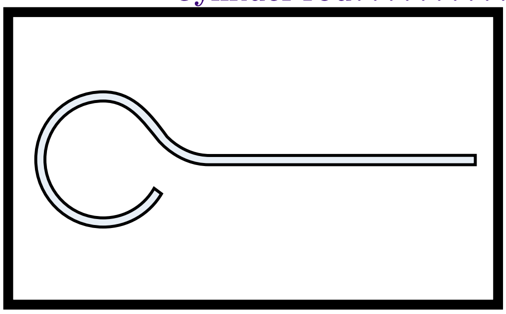


Fig. 05-5

861023 Pressure gauge + fitting 1

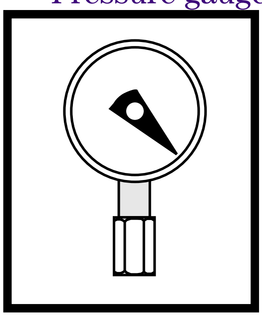


Fig. 05-7

05.4. Crankshaft bearings (Section 10)

Part Number	Description	Quantity
803001	Male socket wrench with No. 22 bit for hexagonal socket cap screws 1-inch square drive	1

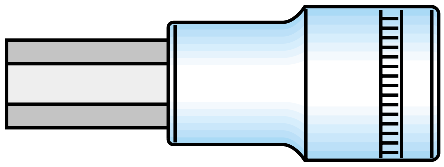


Fig. 05-8

Part Number	Description	Quantity
822001	X 4 torque multiplier	1

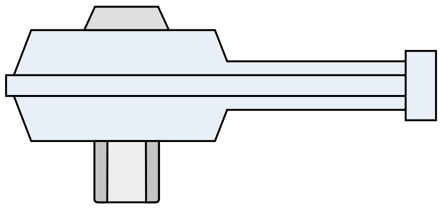


Fig. 05-10

05.5. Cylinder liners (Section 10)

Part Number	Description	Quantity
836001	Extractor and. lifting device	1

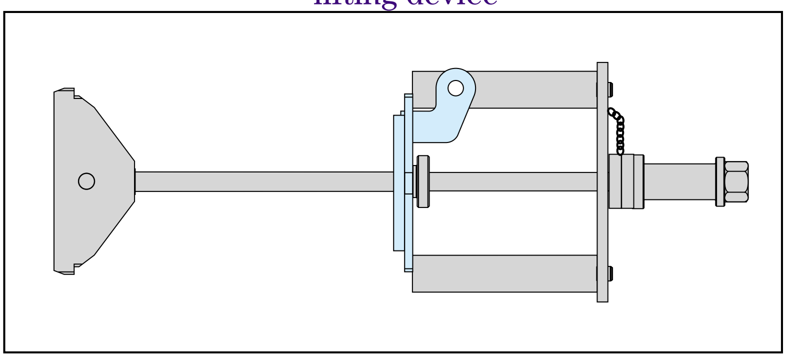


Fig. 05-9

05.6. Pistons (Section. 11)

Part Number	Description	Quantity
832002	Lifting yoke	1

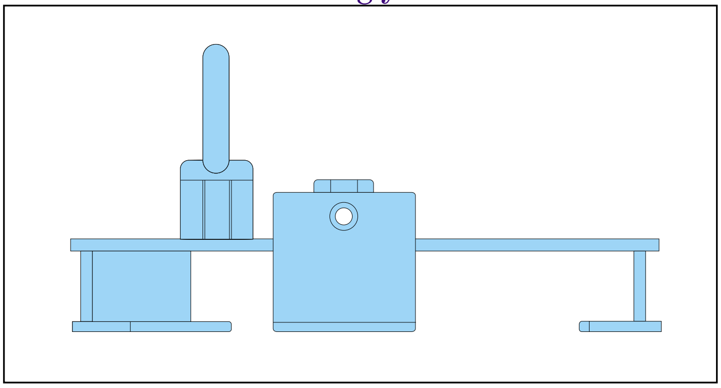


Fig. 05-11

836039	Piston-connecting rod assembly lever	1

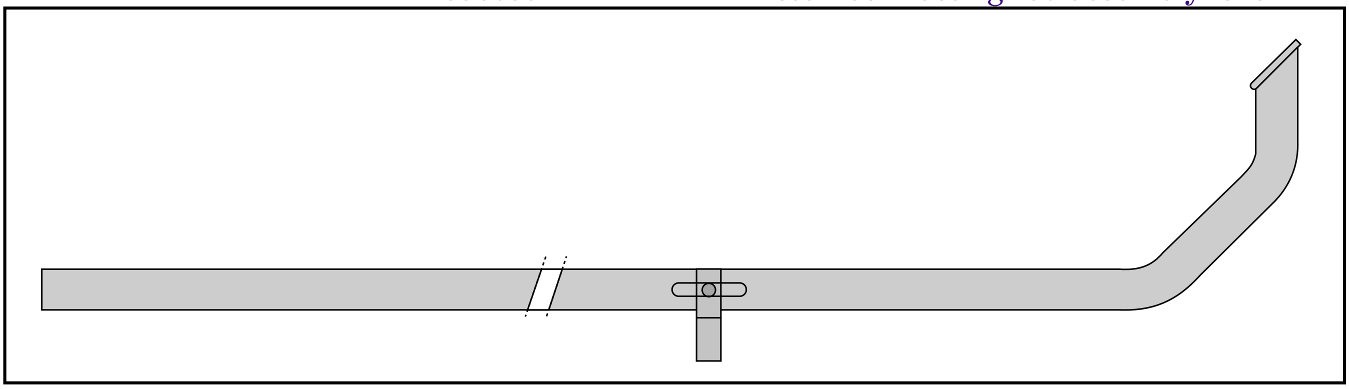


Fig. 05-12

843002	Piston ring clamping device	1

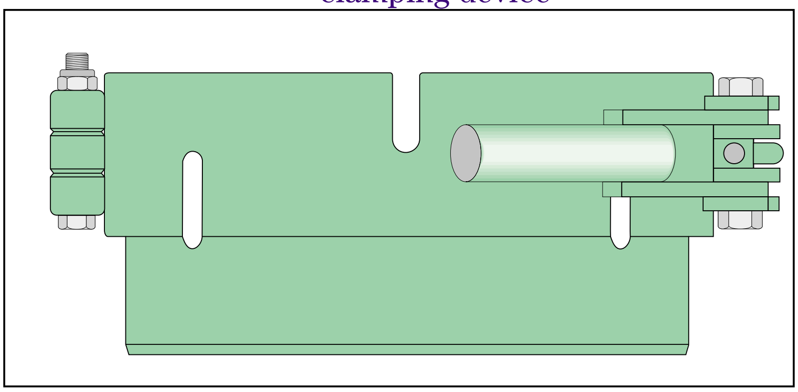


Fig. 05-13

843004 Circlip pliers 1

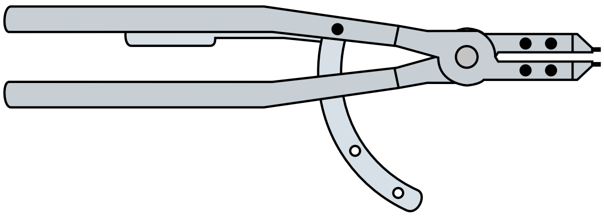


Fig. 05-14

843003 Piston ring pliers. 1

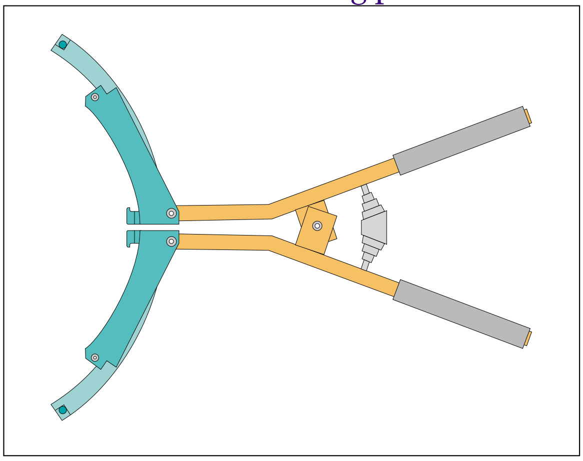


Fig. 05-15

05.7. Connecting rods (Section 11)

Part Number	Description	Quantity
803011	M30 stud fitting and removal tool	1

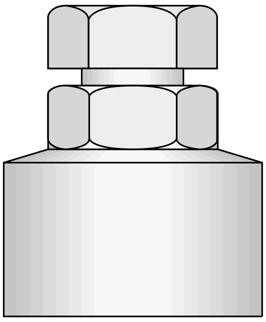


Fig. 05-16

05.8. Cylinder head (Section 12)

Part Number	Description	Quantity
832004	Cylinder head lifting tool	1

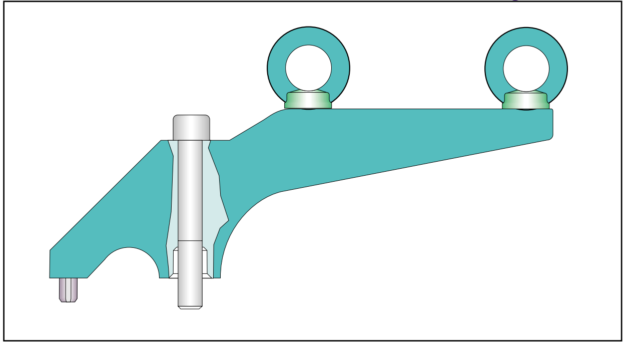


Fig. 05-19

846010	Valve removal tool.	1

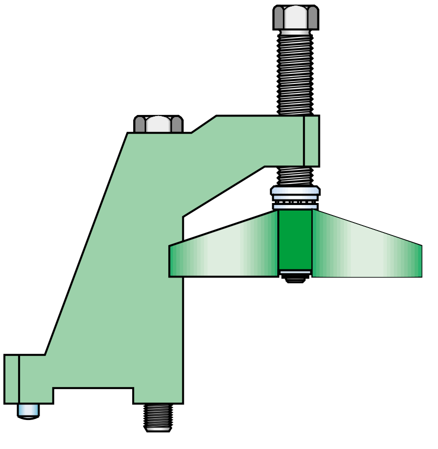


Fig. 05-17

848003	Valve clearance feeler gauge	1

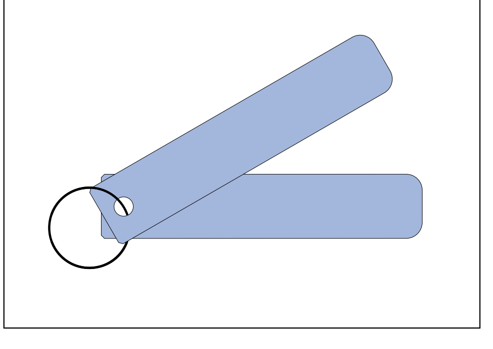


Fig. 05-18

05.9. Miscellaneous tools

Part Number	Description	Quantity
848002	Crankshaft deflection inspection tool	1
808011	3/4" ratchet square drive wrench	1
820008	Torque wrench 20-100 Nm	1
820014	Torque wrench 40-200 Nm	1
803016	M36 stud fitting/removal tool	1
820003	Torque wrench 180-900 Nm	1
800001	Hand tool set	1

05.10. Turbocharger (Section 15)

Part Number	Description	Quantity
866001	Turbocharger tools	1
comprising		
866002	Screw jack	1

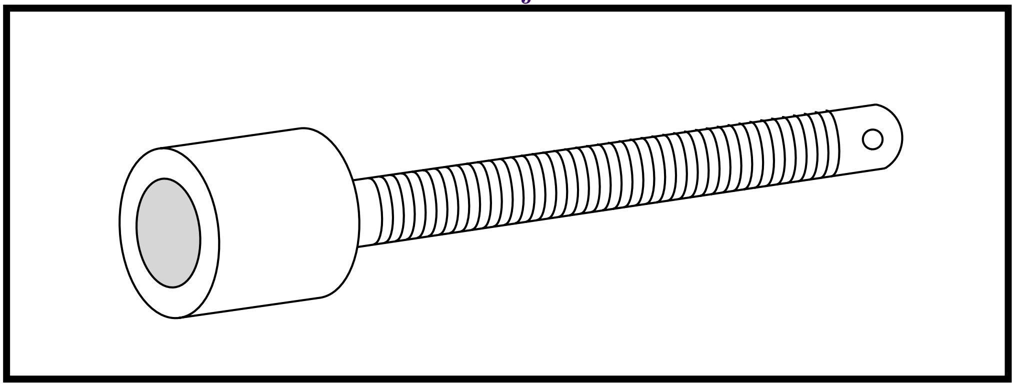


Fig. 05-20

866003	Screw jack nut	1

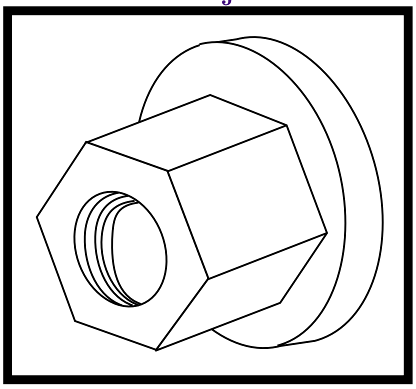


Fig. 05-21

866004	Handle	1

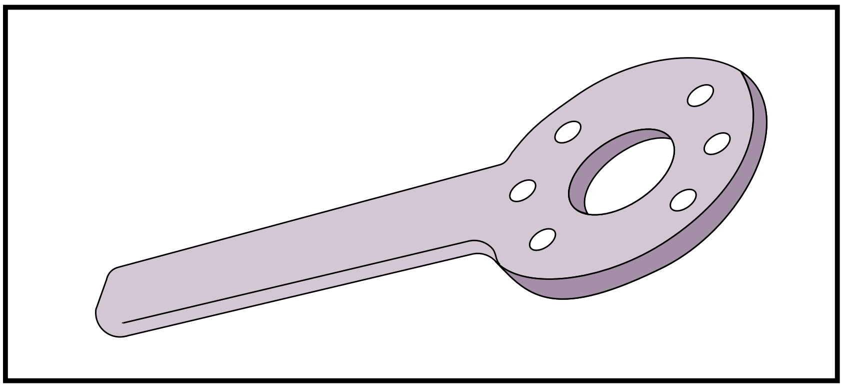


Fig. 05-22

866005 Nut 1

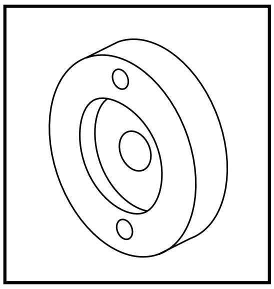


Fig. 05-26

866006 Extension tube 1

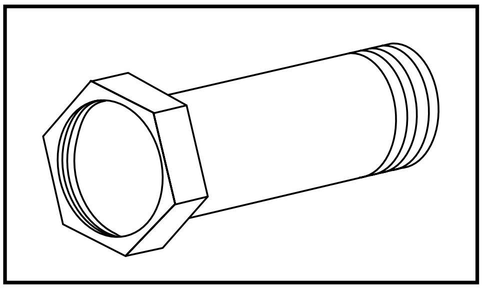


Fig. 05-23

866007 Pin 1

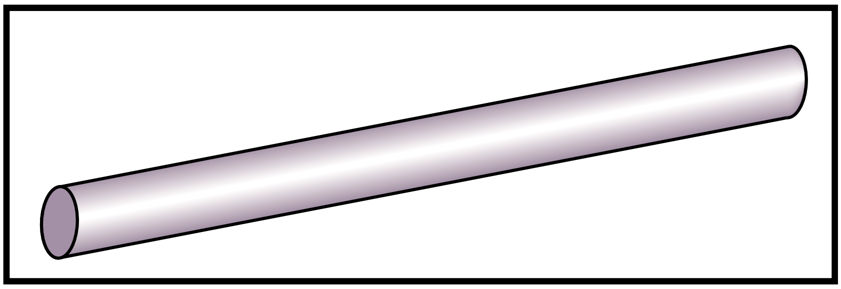


Fig. 05-24

866008 Adapter 1

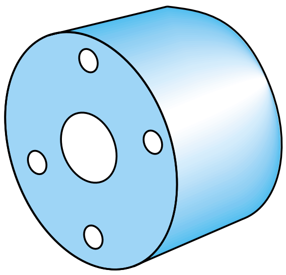


Fig. 05-25

866009 Adapter 1

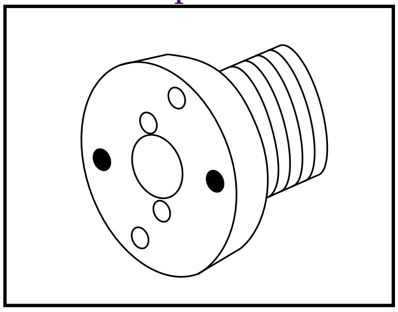


Fig. 05-27

866011 Claw 1

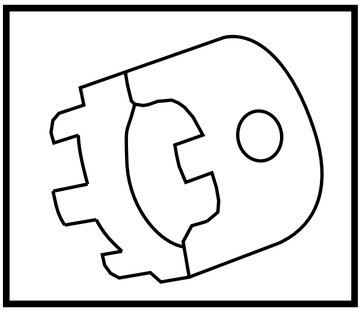


Fig. 05-28

866012 Pin 1

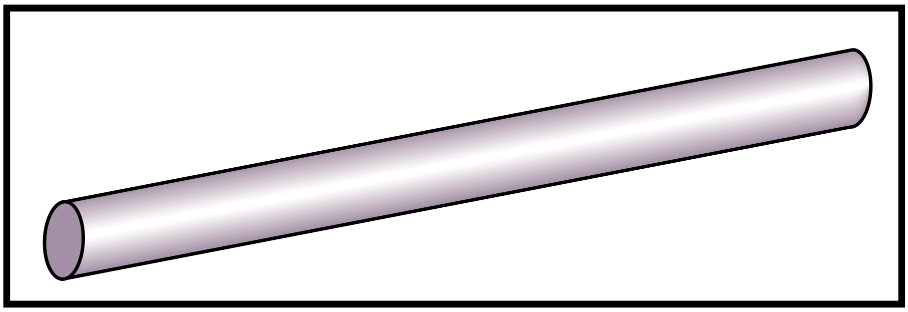


Fig. 05-29

866013 Guide sleeve 1

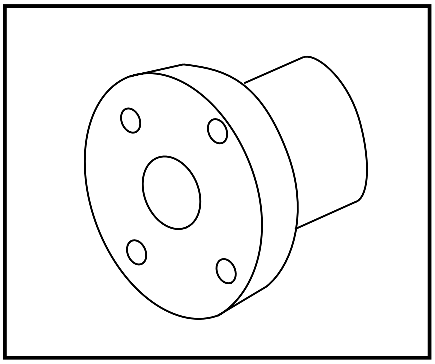


Fig. 05-30

866014	10 mm combination wrench.	1
866015	13 mm combination wrench.	1
866016	17 mm combination wrench.	1
866017	19 mm combination wrench.	1
866018	30 mm combination wrench.	1

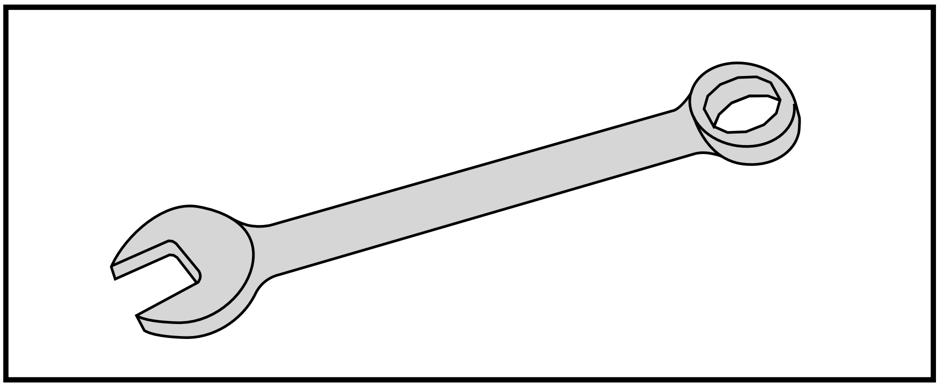


Fig. 05-31

866021	Socket	1

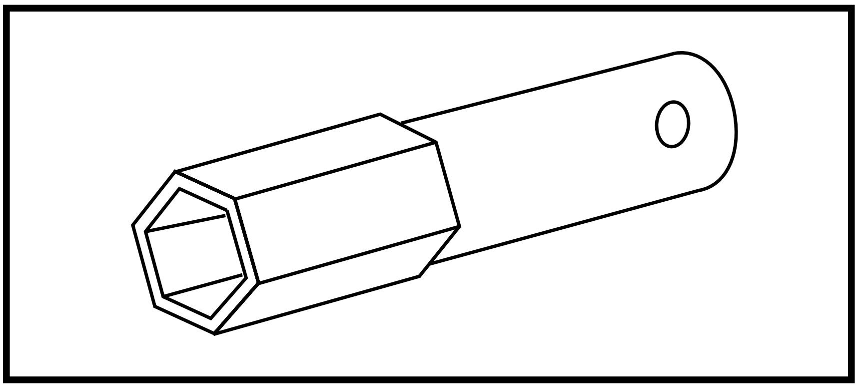


Fig. 05-32

866022	Pin	1

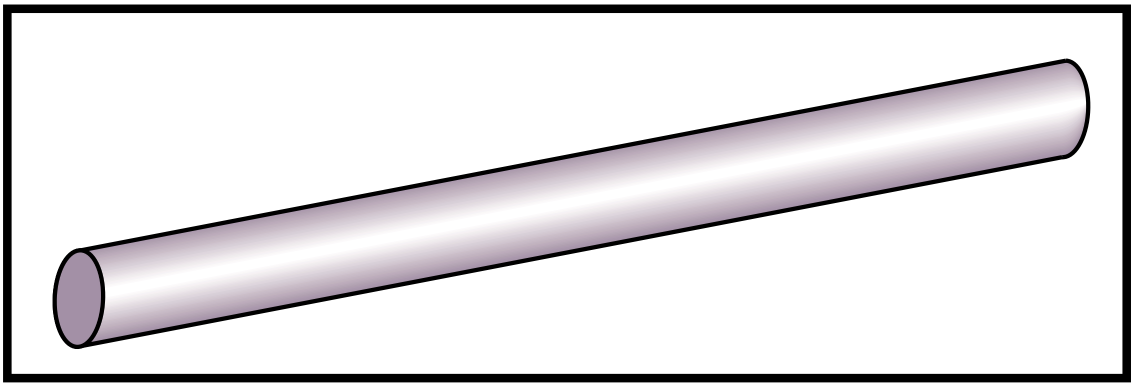


Fig. 05-33

866023	8 x 25 Screw jack	1
866024	8 x 35 Screw jack	1
866025	8 x 40 Screw jack	1
866026	12 x 40 Screw jack	1

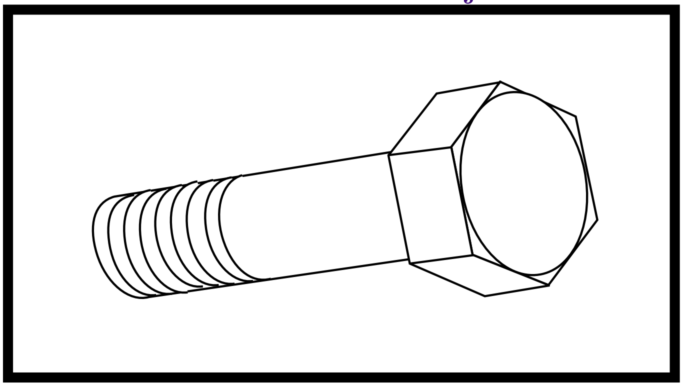


Fig. 05-34

866027	17 mm Socket	1
866028	19 mm Socket	1

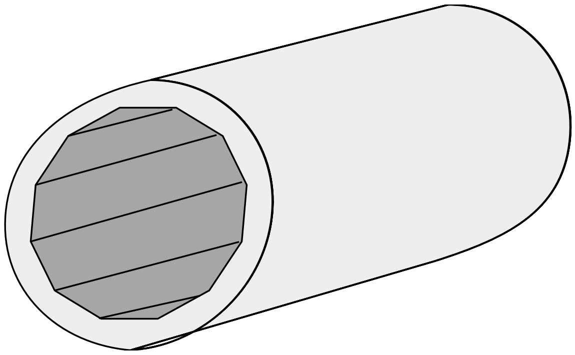


Fig. 05-35

866032	4 mm Allen wrench	1
866033	6 mm Allen wrench	1

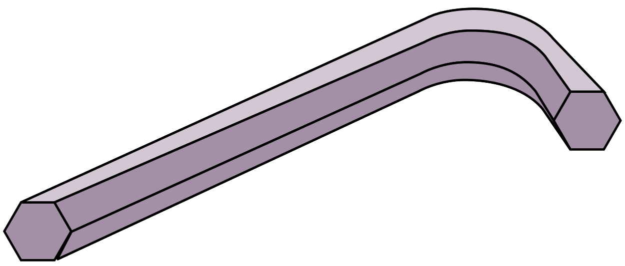


Fig. 05-36

05.11. Prechamber / Ignition (Section 16)

837001 Prechamber extractor 1

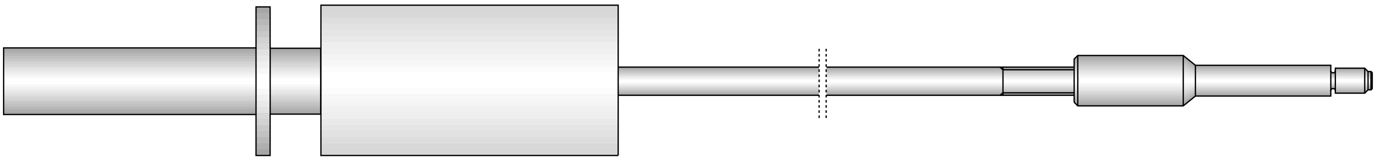


Fig. 05-37

842001 Prechamber shaft tool 1

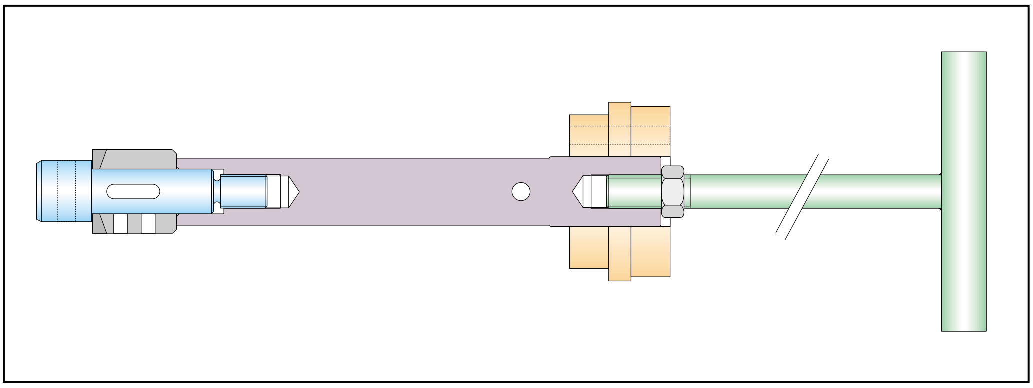


Fig. 05-38

806002 Spark plug wrench 1

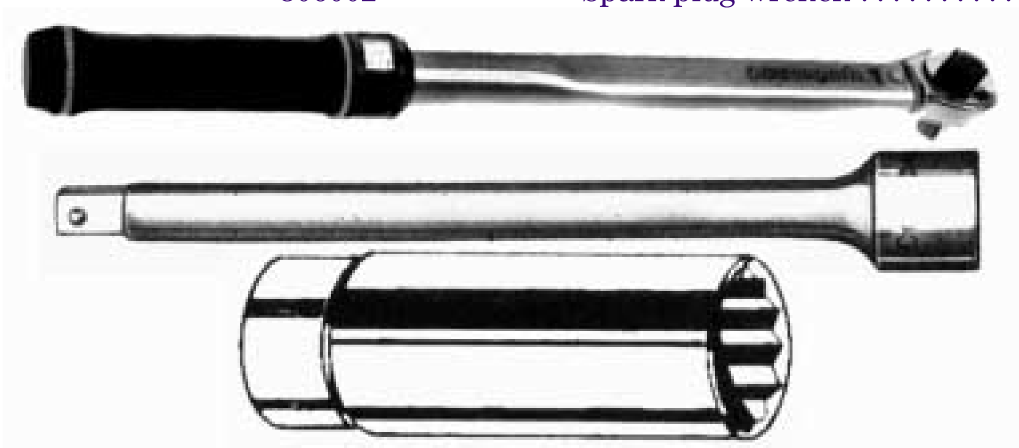


Fig. 05-39

06. Settings, Clearances and Wear Limits

06.1. Finding cylinder Top Dead Centres

06.1.1. General information

The Top Dead Centre (TDC) must be defined to correctly set the various timing positions of an engine:

- valve timing,
- positioning of the pointer on the flywheel cover,
- positioning on the flywheel of the ring graduated in angular degrees.

The TDC of a cylinder is found by measuring the movement of the piston in the cylinder.

We are going to study a general case in which the cylinder head and the rocker assembly are already installed on the engine. A1 and B1 cylinder prechambers must be removed.

Piston movement is measured with a rod inserted through the cylinder head prechamber location, and resting on the bottom of the piston combustion chamber.

06.1.2. Tools

TDC test rod (supplied on request), part No. 843004

Finding Top Dead Centres

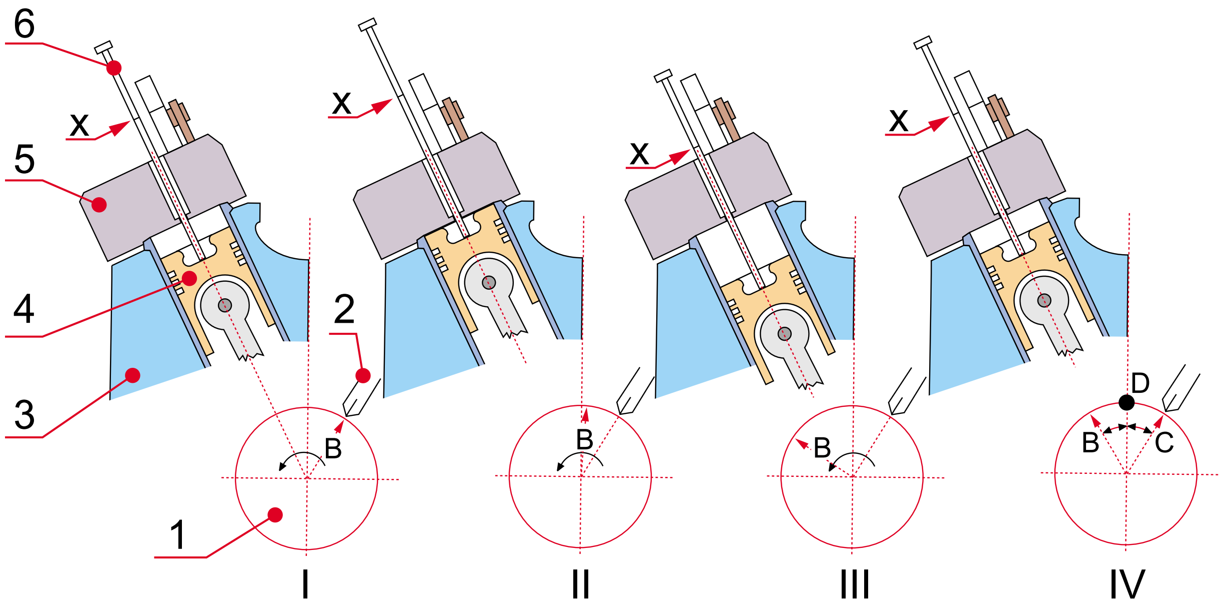


Fig. 06-1

Reference

1 . . . . Flywheel
2 . . . . Index secured to engine frame
3 . . . . Engine frame
4 . . . . Piston
5 . . . . Cylinder head
6 . . . . Piston movement
. . . . measurement tool

06.1.3. Finding the TDC

1 **Set up the tool** in place of the prechamber.

2 **Turn the crankshaft** in the normal operating direction of the engine until the moving mark is aligned with the fixed mark on the tool.

3 **Make a mark (B)** on the flywheel (1), opposite the index (2).

4 **Continue to crank the engine** in the operating direction (see fig. 6-1). The mark (X) moves upwards, then downwards.

5 **Move mark " X " well below the fixed index.**

6 **Crank the engine in the reverse direction**to bring the two tooling marks opposite each other.

7 **Make a new mark (C)** on the flywheel opposite the index (2). The corresponding mark on the flywheel at the TDC of the cylinder involved is (D), which is midway between the 2 marks (B) and (C).

8 **Remove the test rod.**

9 **When the TDC of a side-A cylinder is marked,** it is easy to find the TDC of the cylinder on the opposite side on the engine (e.g., B2 using A2) as follows:

- In the normal operating direction, measure 60° of rotation after the side-A TDC mark (Figure 6-2).

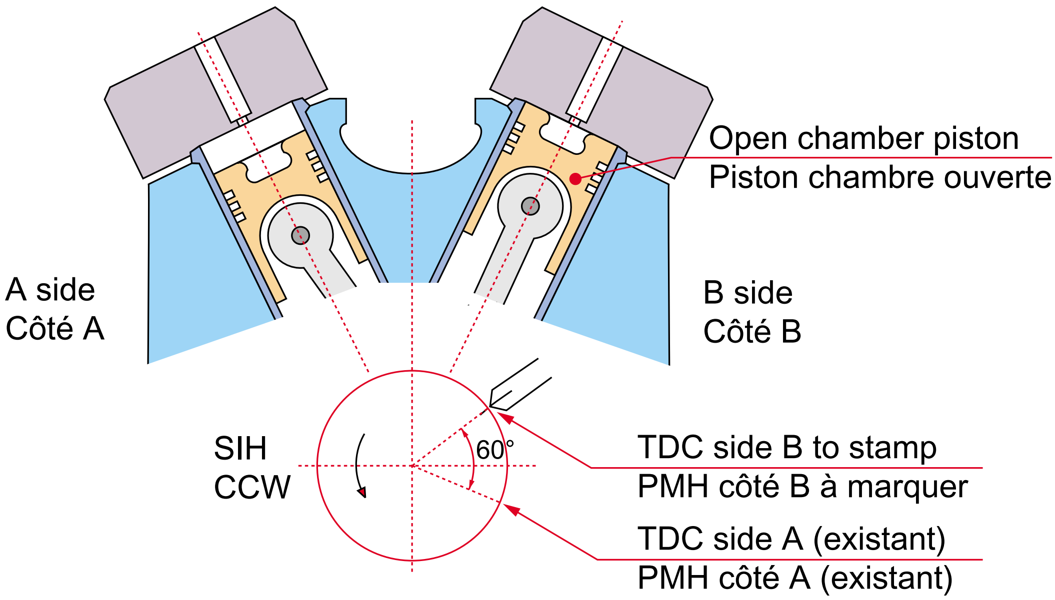


Fig. 06-2

06.1.4. Position of TDCs on the flywheels

Where the TDCs of 2 cylinders of the same bank of an engine coincide, flywheel marking is easier. Once the TDC of a cylinder is marked, it is possible, by scribing on the flywheel, to find the TDCs of all the other cylinders. The table below gives the relationships between the TDCs.

	12V220	18V220
No. of the cylinders with the same marking (cylinder numbering complies with the standard in force)	A6 and A1	1 mark per cylinder
	A5 and A2	
	A4 and A3	
	B6 and B1	
	B5 and B2	
	B4 and B3	
Deviation between the marks of the cylinders of a given bank.	120°	40°
Deviation between one mark for side A and side B of a given crank pin	60° before TDC, connec-ting rod side (in crankshaft operating direction)	20° - 60°

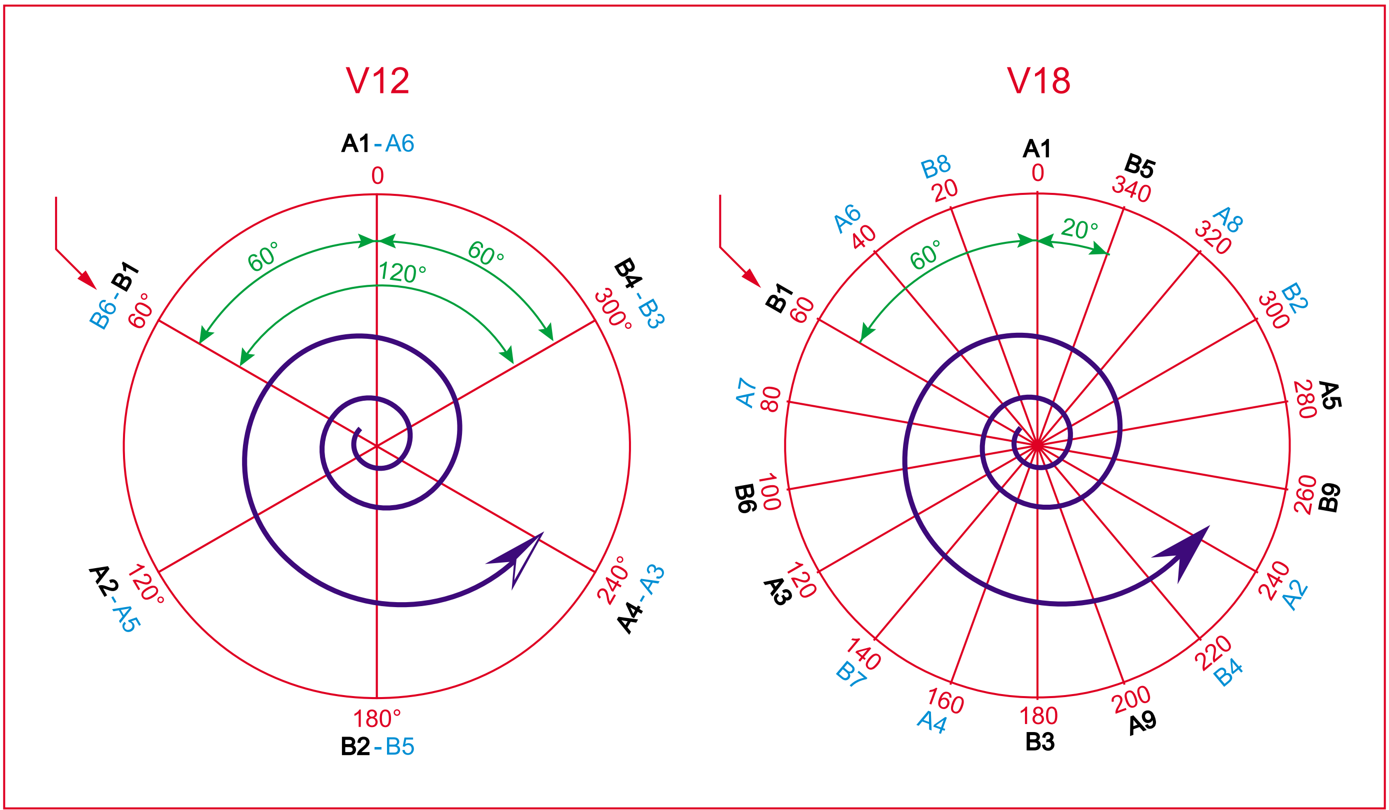


Fig. 06-3

06.2. Settings

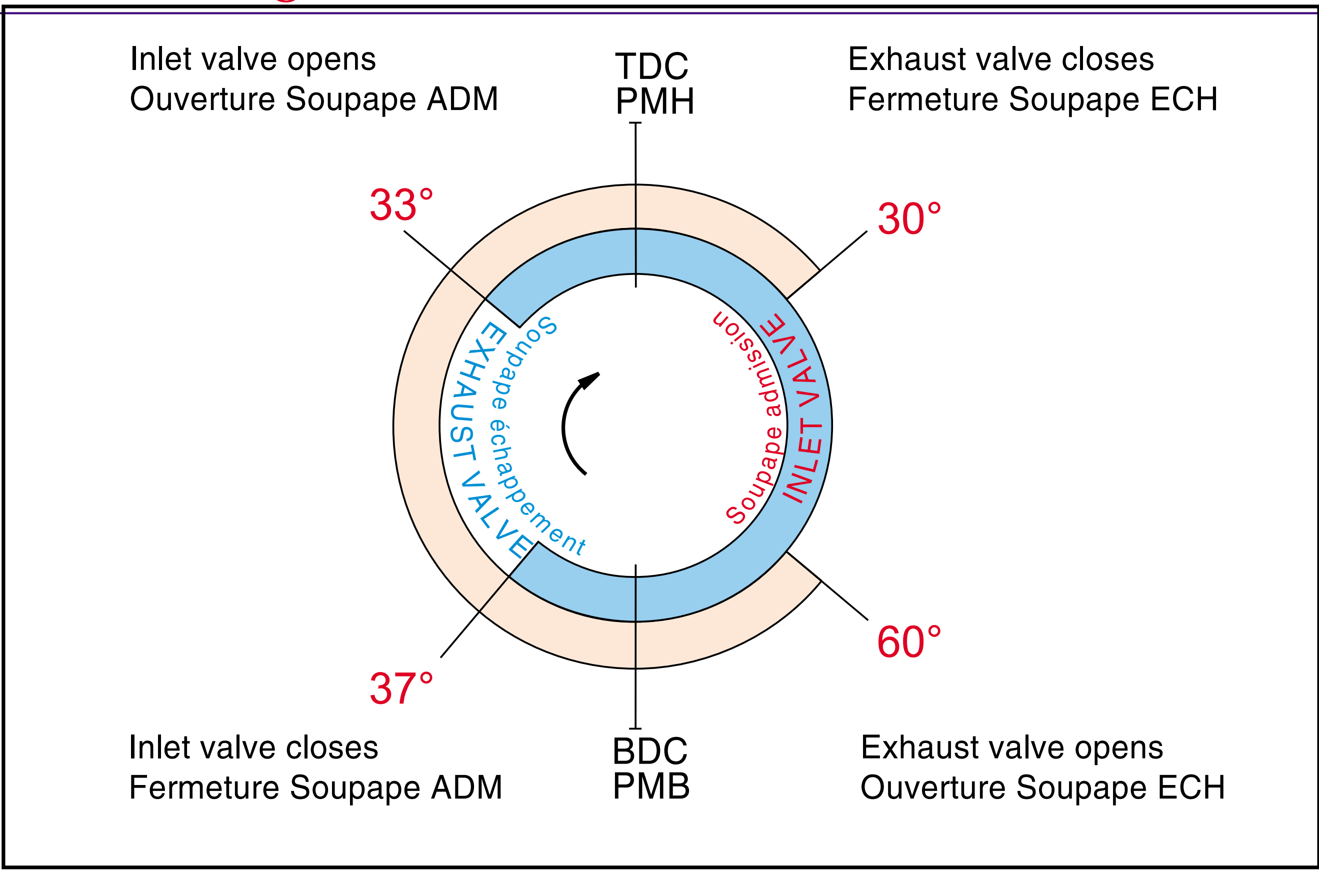


Fig 06-4

Other setting values :

- Valve clearance, engine cold :
  - intake : 0.4 mm,
  - exhaust : 0.8 mm.

06.3. Clearances and wear limits at 20°C

Part and location of measurements		Dimensions (mm) Max.	Min.	Normal clearance (mm)	Wear limit (mm)
10	Crankshaft bearing clearance (and flywheel bearing)			0,213 - 0,316	
	Crankshaft diameter	220,00	219,971		
	Crankshaft concentricity error	0,015			
	Crankshaft taper	0,02/100			
	Crankshaft bearing liner thickness				
	Crankshaft bearing housing bore	235,046	235,000		
	Assembled bearing bore				
	Axial clearance, thrust bearing			0,270 - 0,405	
	Thrust bearing thickness	13,850	13,830		
	Camshaft bearing clearance			0,125 - 0,215	
	Camshaft bearing diameter				
	Camshaft bearing bush thickness				
	Camshaft bearing housing bore				
	Camshaft bearing housing bore				
	Camshaft diameter				
	Camshaft thrust bearing bore				
	Camshaft thrust bearing clearance (radial)				
	Cylinder liner diameter	220,046	220,000	Top: Bottom:	+0,120 +0,120
	Liner concentricity error, TDC				
	Anti-glazing piston ring thickness	3,20	3,15		
11	Big end bearing clearance				
	Crankpin diameter	180,000	179,975		
	Big end bore diameter	190,029	190,000		
	Crankpin parallelism	0,03/100			
	Big end bearing liner thickness	4,970	4,955		
	Big end bore out-of-round	0,015			
	Big end bearing bore, assembled				
	Small end pin bush clearance	0,068	0,130		
	Small end pin diameter	90,000	89,990		
	Small end bore	100,006	99,984		
	Small end bore (with bushing)	90,068	90,120		
	Connecting rod axial clearance in piston			0,015	

	Part and location of measurements	Dimensions (mm)		Normal clearance (mm)	Wear limit (mm)
		Max.	Min.		
	Small end pin bush thickness				
	Piston pin clearance				
	Diameter of bore in piston	90,025	90,012		
	Big end bore diameter				
	Crankshaft gear wheel axial clearance			0,175 - 0,350	
	Camshaft drive gear axial clearance			0,25 - 0,55	
	Piston ring clearance (height): No. 1 compressing ring No. 2 compressing ring Scraper ring	 4,990 4,990 5,990	 4,975 4,975 5,975		
	Piston ring groove width: Groove No. I Groove No. II Groove No. III	 5,12 5,12 6,06	 5,09 5,09 6,04		
12	Valve stem guide diameter	14,095	14,075		
	Valve stem diameter	14,000	13,982		
	Valve stem clearance				
	Valve seat deviation - relative guide (maximum)				
	Inlet valve seat bore in cylinder head	78,094	78,075		
	Exhaust valve seat bore in cylinder head Outer Inner	 78,078 67,078	 78,059 67,059		
	Inlet valve bearing surface angle	20°	19,5 °		
	Exhaust valve bearing surface angle	30°	29,5°		
	Minimum permissible thickness of valve tulip after reconditioning: Inlet valve Exhaust valve	 4,7 mm 5,2 mm			
	Inlet valve seat bearing surface angle	20,25°	20°		
	Exhaust valve seat bearing surface angle	30,20°	30°		
13	Camshaft drive intermediate gear bearing clearance (radial) axial clearance				
	Bearing diameter in situ				
	Journal diameter				
	Gearing backlash between:: Camshaft gear and large intermediate gear Small intermediate gear and camshaft gear				

Part and location of measurements		Dimensions (mm) Max.	Min.	Normal clearance (mm)	Wear limit (mm)
	Pitch circle tangential length: - crankshaft gear assembled - large intermediate gear assembled - small intermediate gear assembled - camshaft gear				
14	Valve tappet diameter	54,970	54,940		
	Clearance on tappet and body diameter			max 0,09 min 0,03	
	Tappet roller bore diameter	30,021	30,000		
	Roller pin diameter			max 0,048	
	Roller pin clearance				
	Rocker arm bearing diameter				
	Journal diameter				
	Bearing clearance				
	Yoke stud diameter	19,935	19,922		
	Yoke bore diameter	25,021	25,000		
	Clearance on diameter				
16					
18	Lubricating pump shaft diameter				
	Anti-friction bush bore diameter				
	Bearing clearance				
	Axial clearance				
	Base tangent length over 6 teeth				
19	Backlash between water pump gear and crankshaft gear			0.235 à 0.473	
	Base tangent length over 8 teeth	115.747	115.383		
21	Starter motor drive gearing backlash				

06.4. Engine acceptance criteria

At nominal power and speed, with glcyol-free, anti-corrosion coolant:

Parameters	Parameters	Units	Criteria values	Tolerances
SETTINGS	TA LUFT emission standards	gNOx/Nm3	0.5	max
	Throttle valve setpoint	°	60	0
	Ignition advance all cylinders	DV	19	0
	Knock value all cylinders	none	300	max
	Mechanical output or spec. gas consumption	% kJ/kWh	40.0 9000	± 0.2 ± 200
OIL (new filter)	Oil temperature at cooler outlet	°C	70	max
	Oil pres. at filter inlet	bar	5.2	± 0.2
	Oil pres. at filter outlet	bar	5	± 0.2
	Oil pres. at turbo inlet	bar	3	± 0.2
CRANKCASE	Crankcase pressure	mmH2O	42	± 4
	Crankcase gas flow rate	m3/h	30	± 5
HT WATER	Water T° SAC inlet	°C	85	± 2
	Water T° engine frame outlet	°C	95	-2 to +1
	Water P at pump outlet	bar	3.3	± 0.4
LT WATER	Water T° at pump outlet	°C	40	-1 to +2
	Water P at pump outlet	bar	3.4	± 0.4
AIR	Air P after butterfly	bar (abs)	2.65	± 0.1
	Air T° after butterfly	°C	52	± 2
	Turbo speed	rpm	24100	± 300
EXHAUST	Cylinder T°	°C	455	± 20
	Gas pres. after turbine	bar	1	± 0.1
	Gas T° after turbine	°C	390	± 10
	Deviation cylinder T° / mean cylinder T°	°C	Mean cylinder T°	± 15
GAS	Main gas pressure	bar	2.4	± 0.15
	Prechamber gas pres.	bar	2.6	± 0.15
	Injection time	µs	16000	± 1500
	Gas injection time adjustment	% deviation / reference	± 5% inject. time	± 5%

The values shown above are valid for the following reference conditions: intake air temperature = 25°C and atmospheric pressure = 100 kPa. These values are those normally obtained on a standard motor with natural gas available at the Mulhouse site (methane index: 88-90). As a reference, the mean net calorific value (NCF) is 35800 kJ/Nm3.

07. Torque settings and use of hydraulic tools

Note: **When using products such as Loctite, threads must be degreased carefully with a solvent and left until completely dry before threadlocker is applied.**

07.1. Torque settings for bolts, screws, nuts and FBO fittings

07.1.1. Conventional bolts and screws

Unless otherwise stated, lubricate the threads and contact surfaces of nuts, screws and bolts. Threadlocker is required in some cases.

Do not use Molykote or other similar lubricants that reduce the friction coefficient on the screw fittings which may consequently be subjected to excessive tensile stress.

Nm = 0.102 kpm

Diameter	Hex head	Hex socket head	Torque value (Nm) *	
			Class 8.8	Class 10.9
M 6	10	5	10	14
M 8	13	6	25	34
M 10	16	8	48	70
M 12	18	10	80	120
M 16	24	14	200	300
M 20	30	17	400	570
M 24	36	19	700	980

* lubricated with oil or coated with Loctite.

It is advisable to tighten screws and bolts with a torque wrench.

07.1.2. Fitting FBO couplings

To avoid any risk of leakage from FBO couplings working loose on the W 220 engine, it is essential to follow a few basic assembly rules.

a) **The pipe ends must be cylindrical** and free from burrs.

b) **The distance** between the two pipe ends or unions:

- double union
- reducer union

must be less than 5 mm.

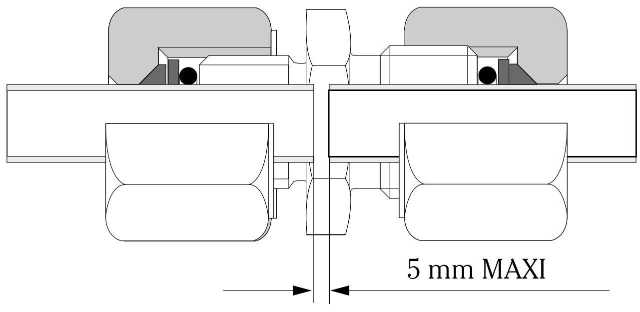


Fig. 07-1

c) **The distance** between the pipe end and the union coupling:

- male union adapter
- female union adapter
- T-joint
- elbow
- banjo

must be less than 5 mm.

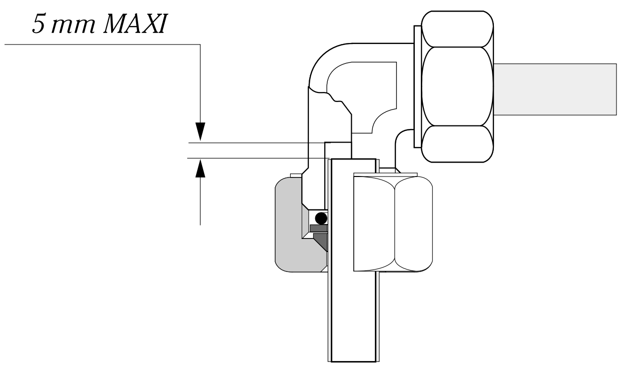


Fig. 07-2

d) **When fitting the union coupling on the pipe,** lightly smear the contact faces between the conical seal and the nut only with BR 2 grease.

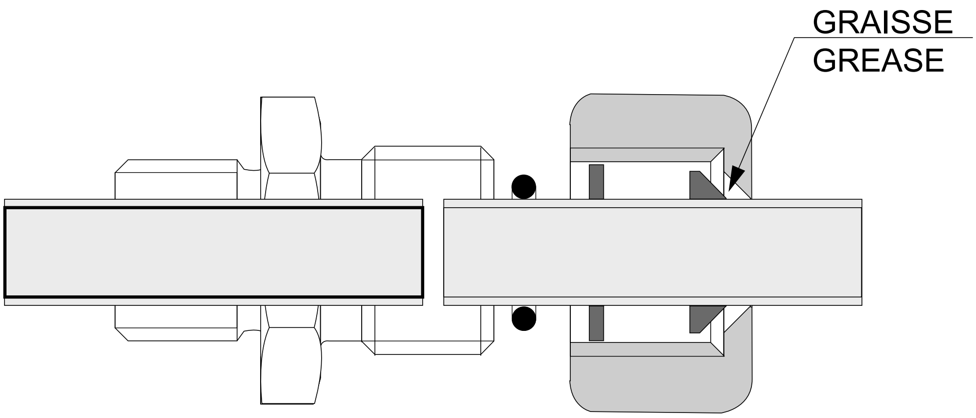


Fig. 07-3

Caution: **It is strictly prohibited to grease the nut thread or the contact face between the conical seal and the pipe.**

e) **It is necessary to use a torque wrench** to tighten the nut of the union coupling. The torque settings for the different pipe diameters are shown in the table below.

f) **Torque settings**

Pipe outer diameter (mm)	6	8	10,2 1/8	12	14	16	17,2 3/8	18 19	20
Torque Nm	32	40	47	50	60	70	80	95	95

Pipe outer diameter (mm)	21,3 22 1/2	25	26,9 3/4	28 30	33,7 32 1"	35	38	40 42,4 1"1/4	44,5 45	48,3 1"1/2
Torque Nm	100	125	140	160	180	220	220	250	300	300

Caution: **Incorrect tightening may lead to the pipes working loose and breaking.**

07.1.3. Specific torque settings

Letters A, B, C etc. of Fig. 07-4 et Fig. 07-5 correspond to letters a), b), c) etc. of the heading in pages 95 à 109 of this section.

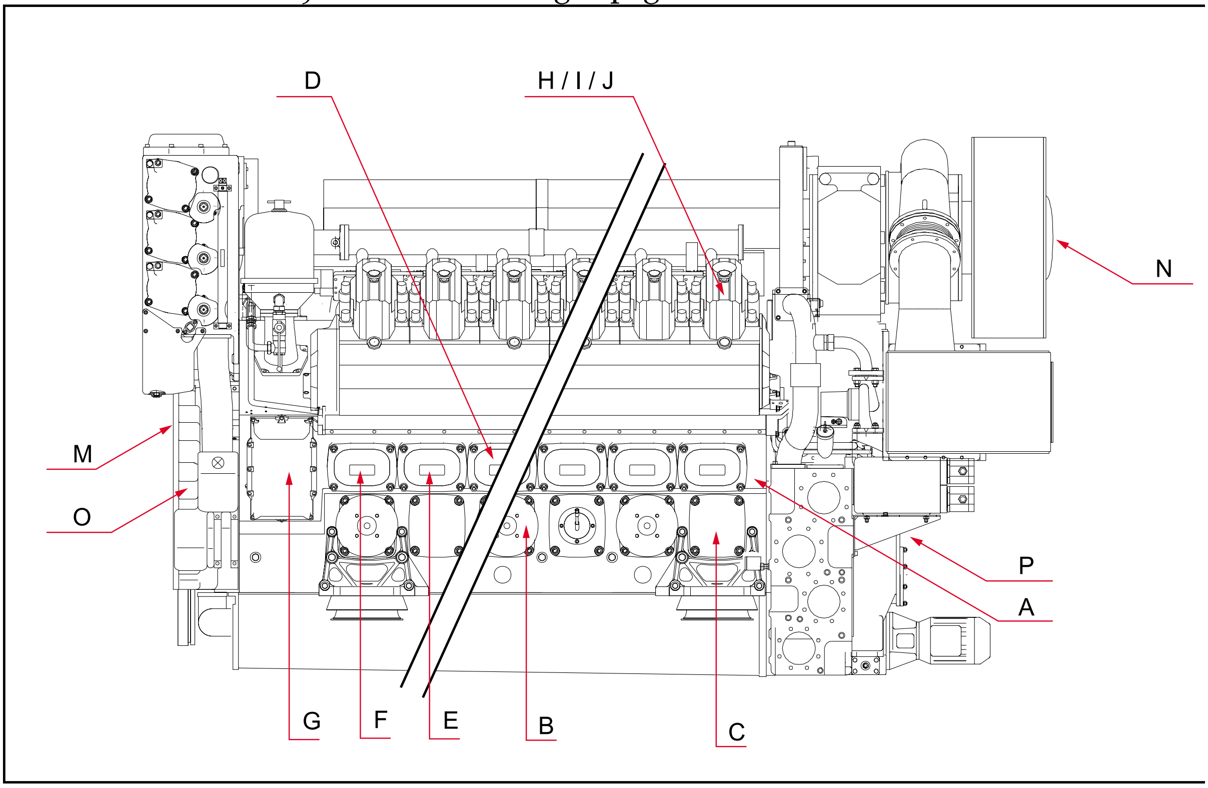


Fig. 07-4

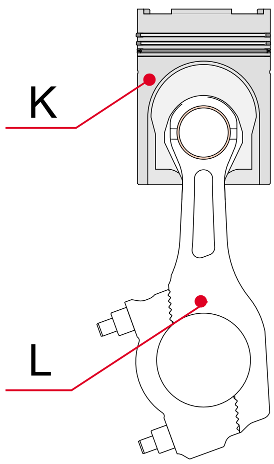


Fig. 07-5

a) **Engine block** for W12V220 see Fig. 07-6, for W18V220 see Fig. 07-7

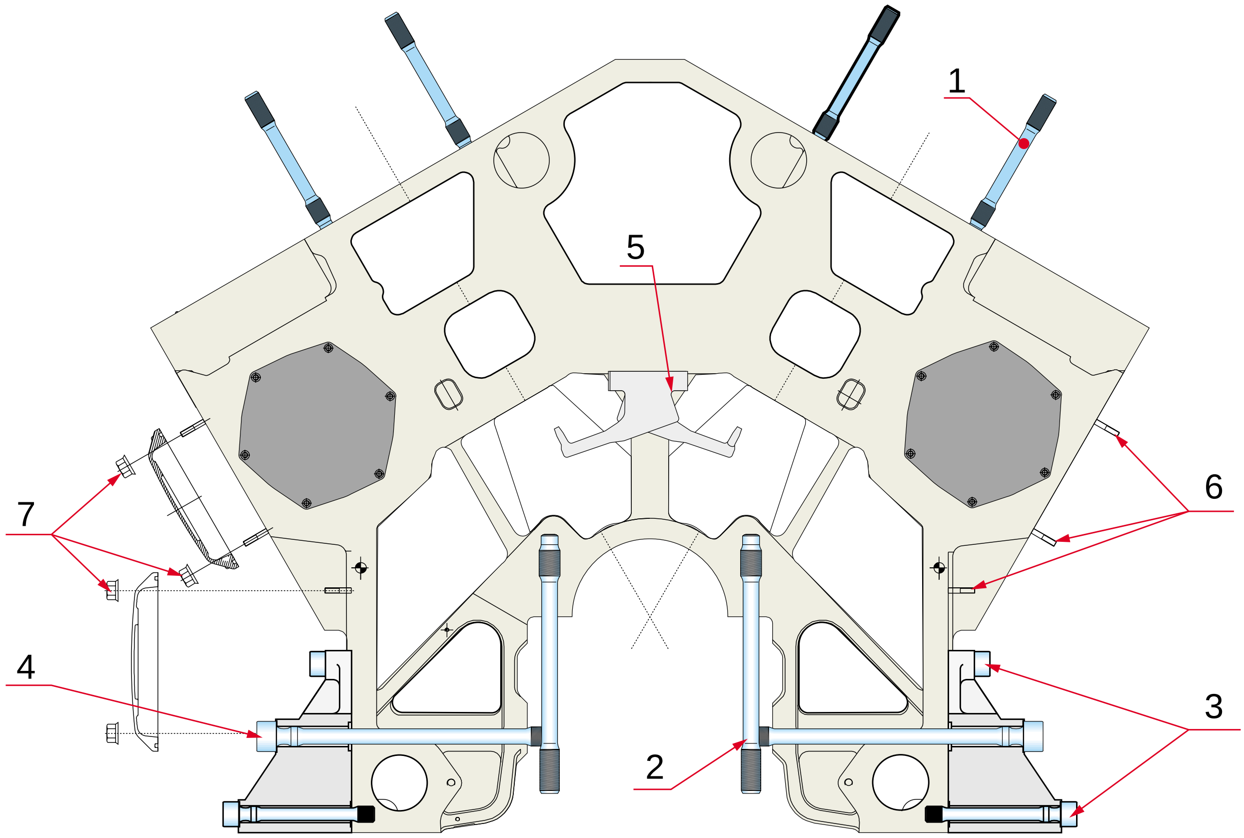


Fig. 07-6

Pos.	Designation	Torque (Nm)
1.	Cylinder head stud. (Use tool no. 803016)	150
2.	Main bearing stud. (Use tool no. 803016)	150
3.	Hex socket screws. Lubricate threads with oil.	700
4.	Main bearing side screws	See Section 10
5.	Oil spray screws Apply Loctite 270 to threads.	25
6.	Inspection door studs. Apply Loctite 243 to threads.	10
7.	Crankshaft and camshaft cover nuts	100

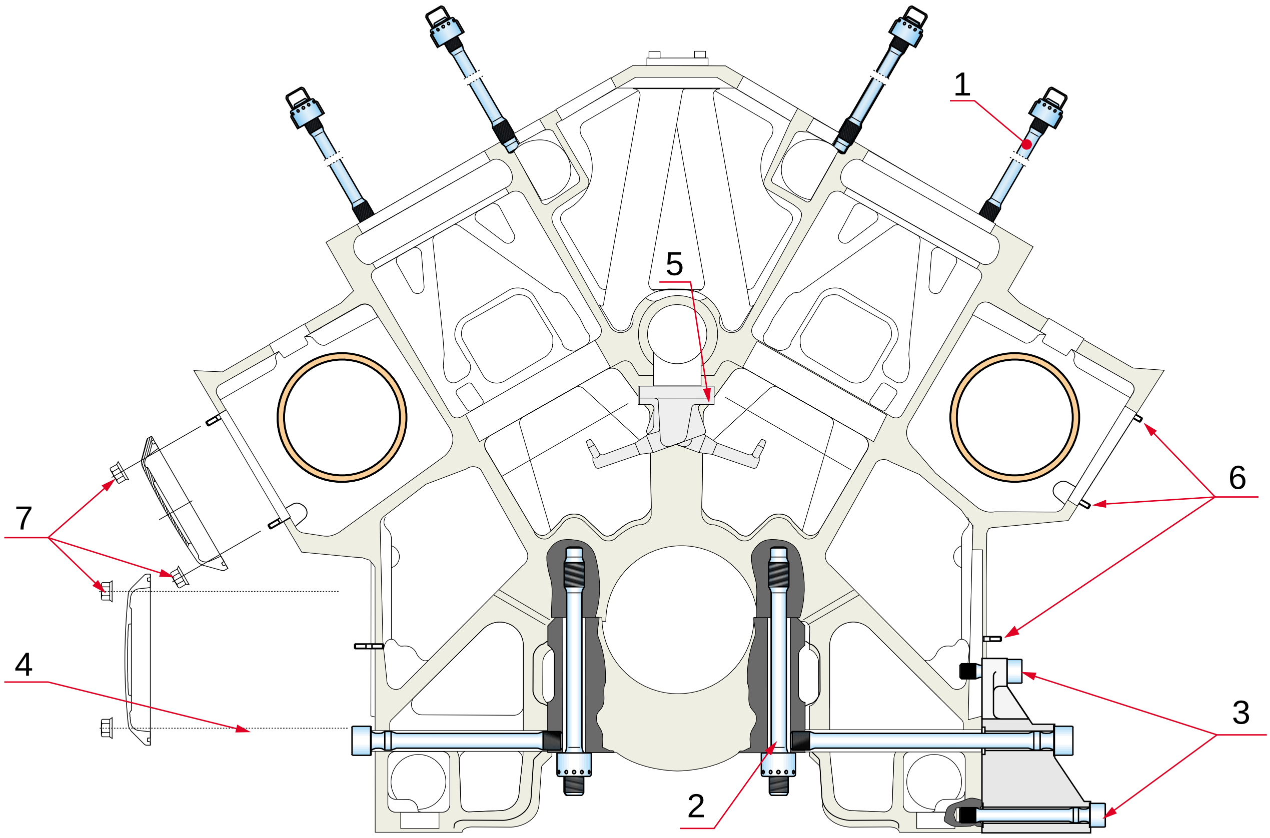


Fig. 07-7

Pos.	Designation	Torque (Nm)
1.	Cylinder head stud. (Use tool no. 803016)	150
2.	Main bearing stud. (Use tool no. 803016)	150
3.	Hex socket screws. Lubricate threads with oil.	700
4.	Main bearing side screws	See Section 10
5.	Oil spray screws Apply Loctite 270 to threads.	25
6.	Inspection door studs. Apply Loctite 243 to threads.	10
7.	Crankshaft and camshaft cover nuts	100

b) Crankshaft and flywheel

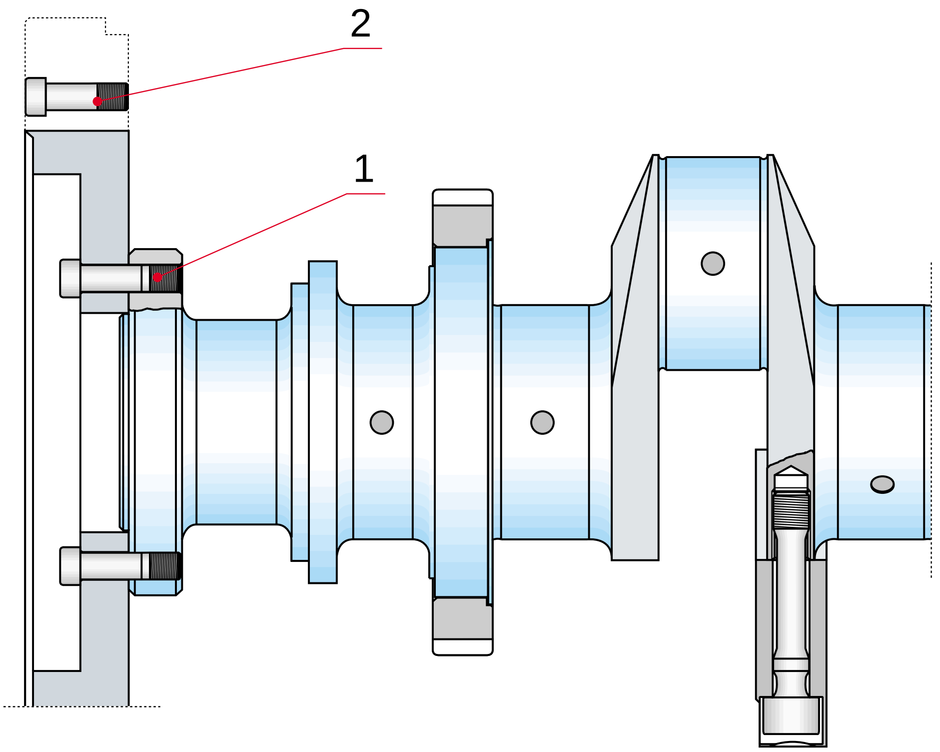


FIG. 07-8

Pos.	Designation	Torque (Nm)
1.	Crankshaft flange screw. Lubricate contact surfaces and threads with Molykote G-n Plus. Use torque x4 multiplier tool.	780 ± 20 195
2.	Starter ring gear screw Apply Loctite 242 to threads	80

c) **Crankshaft free end** for W12V220 see FIG. 07-9, for W18V220 see FIG. 07-10

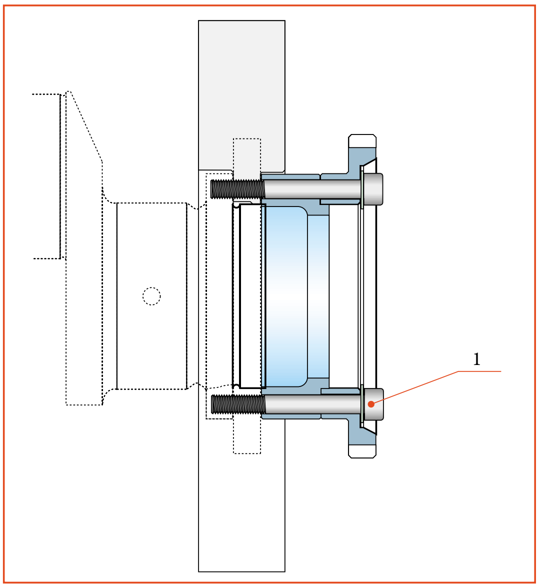


FIG. 07-9

Pos.	Designation	Torque (Nm)
1.	Pump drive pinion screw at crankshaft free end. Use torque x4 multiplier tool	500 + 20 125

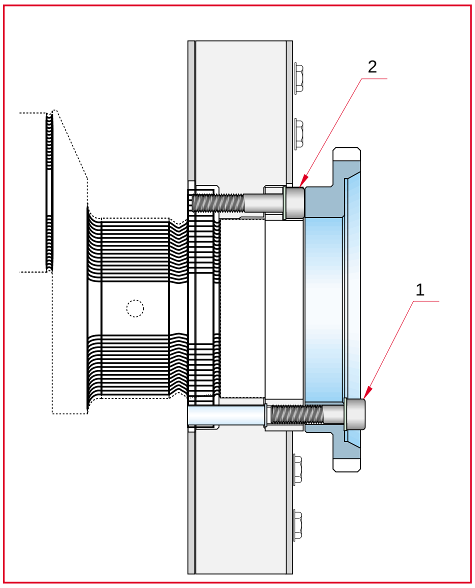


FIG. 07-10

Pos.	Designation	Torque (Nm)
1.	Pump drive pinion screw at rear of crankshaft.	See chap 11
2.	Intermediate piece screw at rear of crankshaft.	See chap 11

d) Camshaft

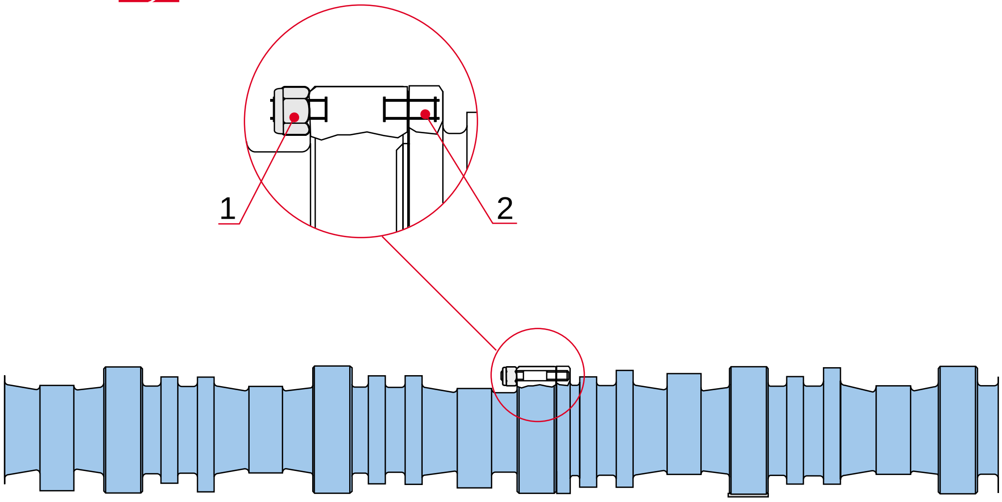


FIG. 07-11

Pos.	Designation	Torque (Nm)	
		Ph2	Ph1c
1.	Nut	182	110
2.	Screw (Loctite 270)	50	

e) Camshaft A

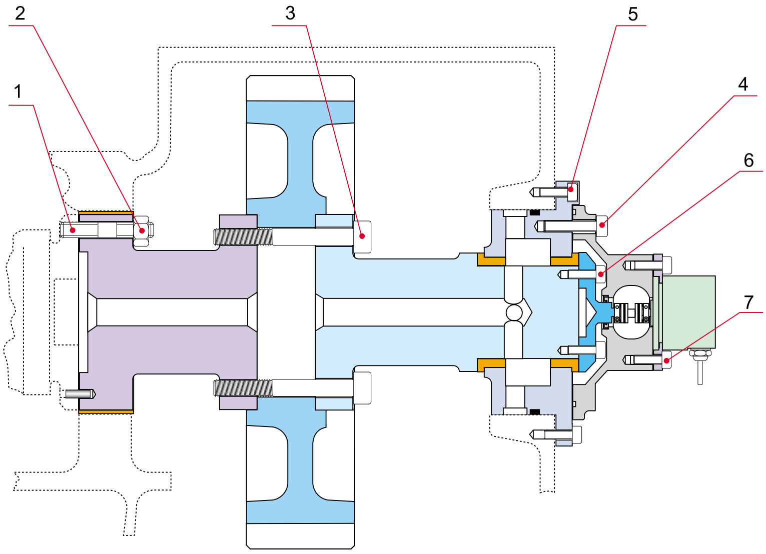


FIG. 07-12

Pos.	Designation	Torque (Nm)	
		Ph2	Ph1c
1	Screw	50	
2	Nut	182	110
3	Screw	282	110
4	Screw	80	
5	Screw	25	
6	Screw	25	
7	Screw	25	

f) Camshaft B

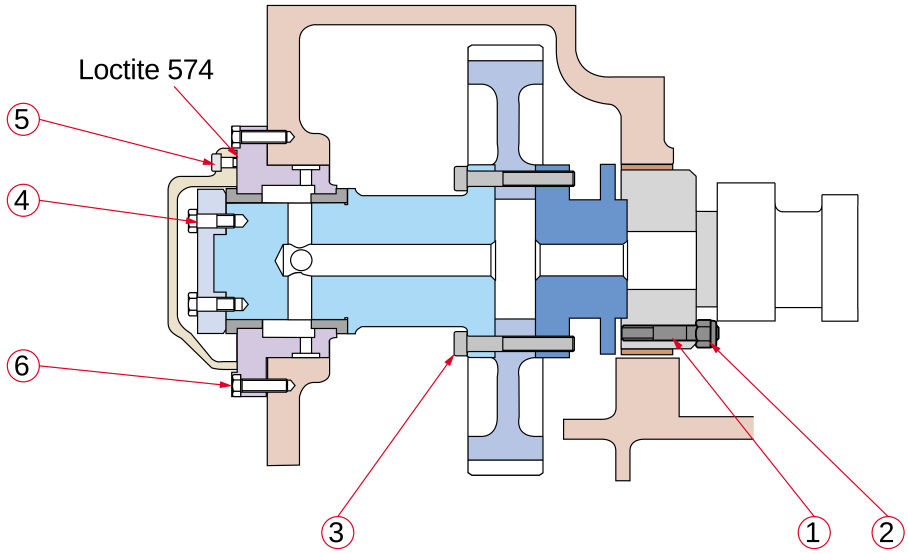


FIG. 07-14

Pos.	Designation	Torque (Nm)	
		Ph2	Ph1c
1	Screw (Loctite 270)	50	
2	Nut	182	110
3	Screw	282	110
4	Screw (Loctite 270)	25	
5	Screw	80	
6	Screw	25	

g) Intermediate gear wheel

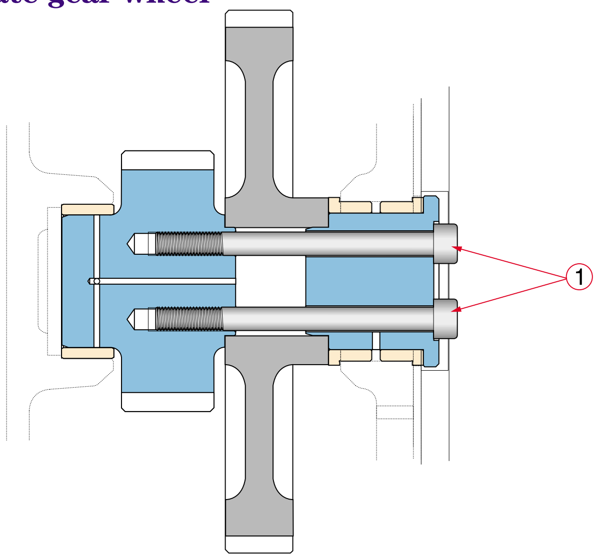


Fig. 07-13

Pos.	Designation	Torque (Nm)	
		Ph2	Ph1c
1	Screw	755	600

h) Rocker gear and prechamber

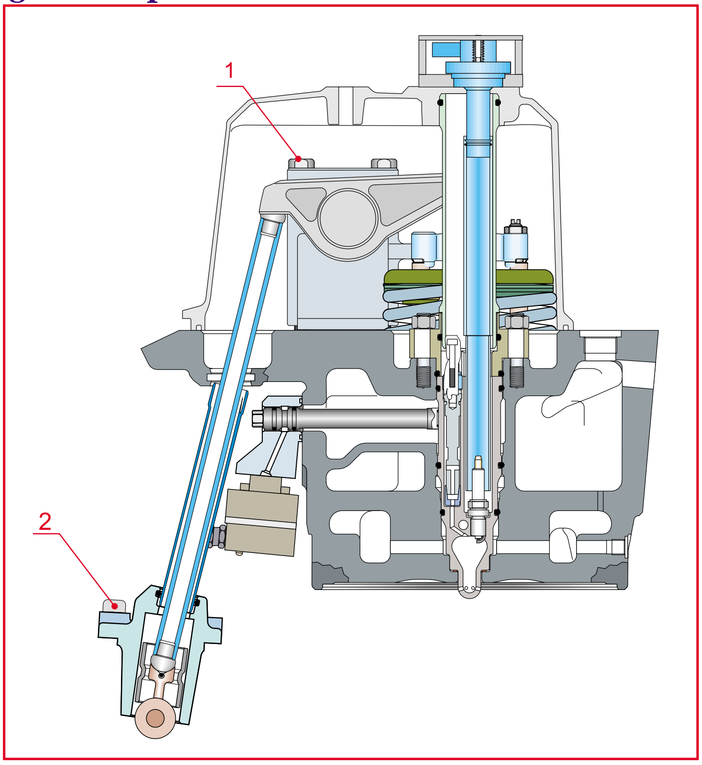


FIG. 07-15

Pos.	Designation	Torque (Nm)
1.	Rocker bracket retaining screw (see Section 12)	200±5
2.	Guide housing retaining screw	189

i) Prechamber

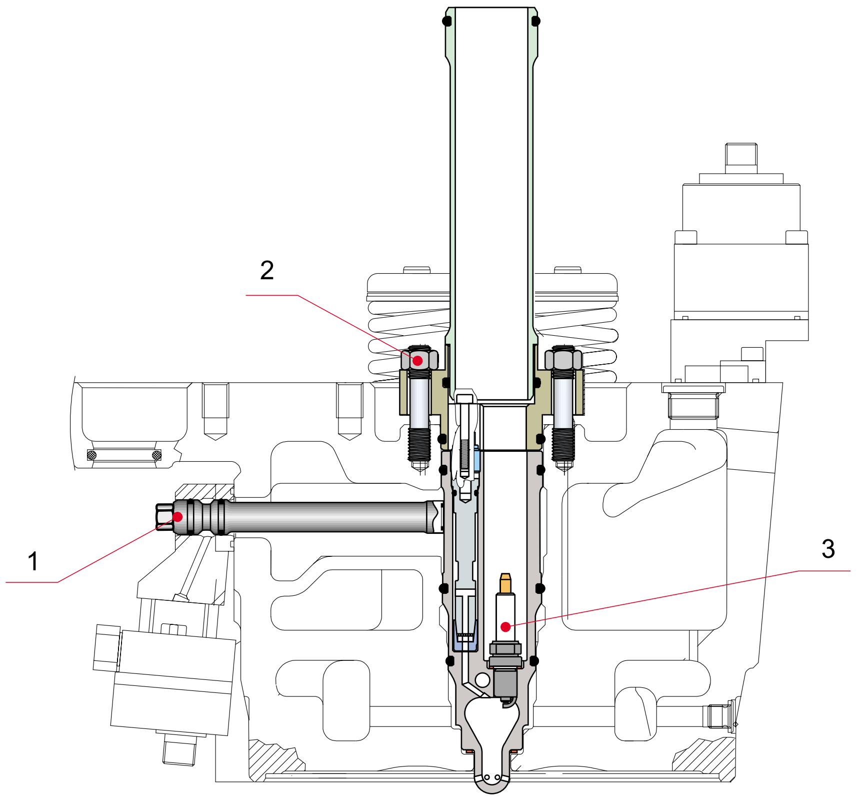


FIG. 07-16

Pos.	Designation	Torque (Nm)
1.	Gas supply manifold	25
2.	Prechamber support nut	50
3.	M14 spark plug	35

j) Prechamber valve

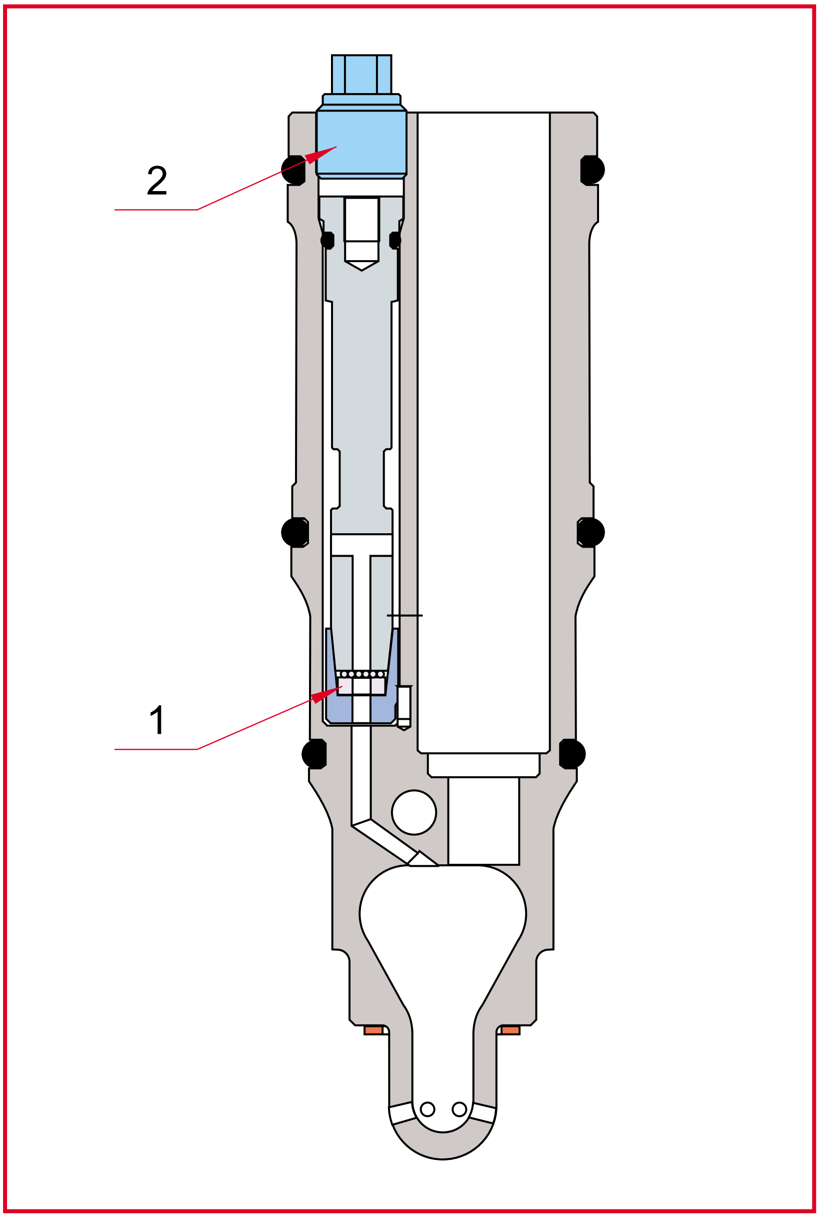


FIG. 07-17

Pos.	Designation	Torque (Nm)
1.	Valve nut	25
2.	Support plug	30

k) Piston

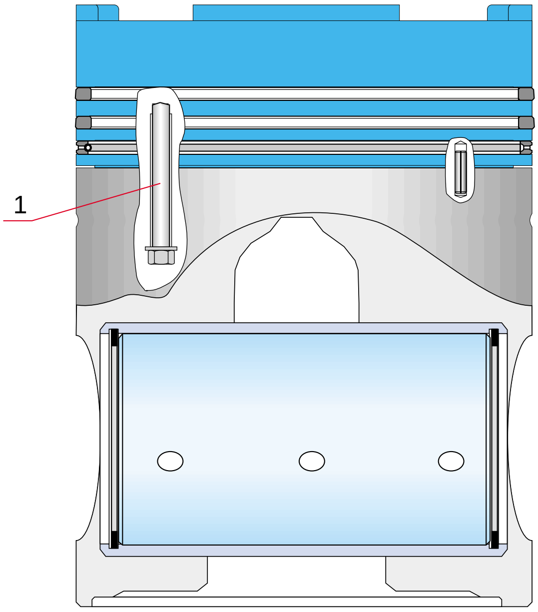


Figure 07-18

Pos.	Designation	Torque (Nm)
1.	Piston head screw	see 11.5.5

l) Connecting rod

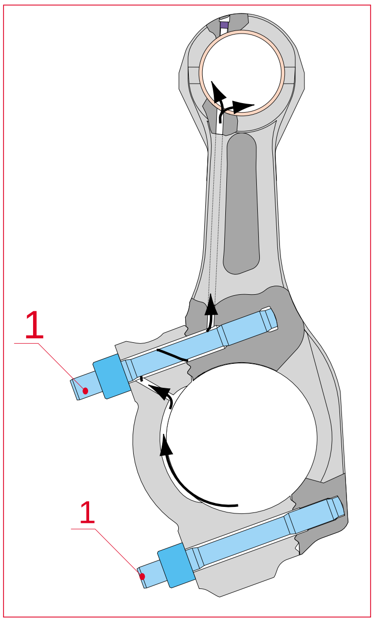


FIG. 07-19

Pos.	Designation	Torque (Nm)
1.	Connecting rod stud	100

m) Alternator coupling

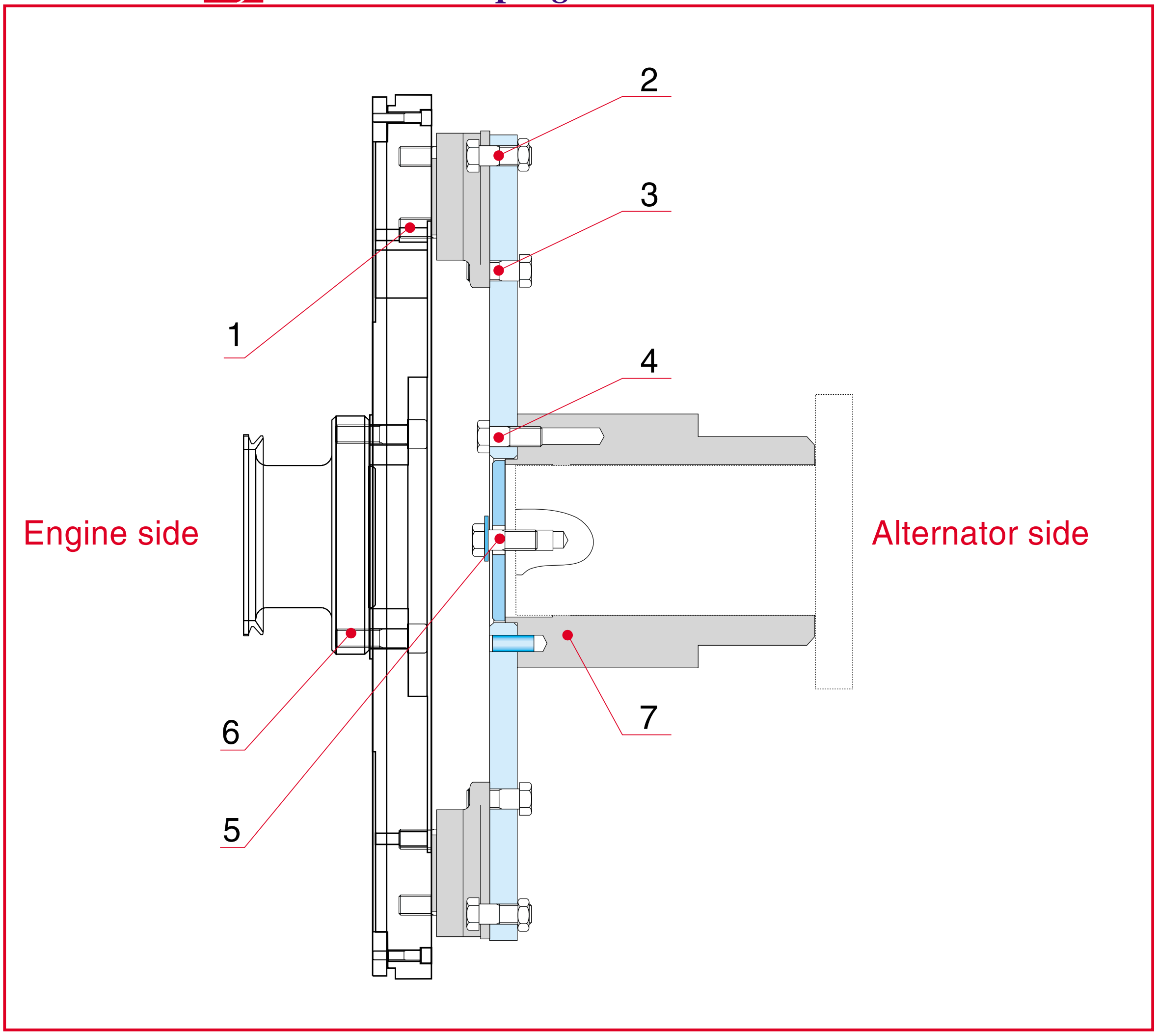


Fig. 07-20

Pos.	Designation	Torque (Nm)
1.	Hex head screw	110
2.	Hex head screw	140
3.	Hex head screw	140
4.	Hex head screw	300
5.	Hex head screw	200
6.	Hex head screw	780
7.	Must be heated to 250°C for fitting and removal	

n) **Turbocharger** for W12V220 see Fig. 07-21, for W18V220 see Fig. 07-22

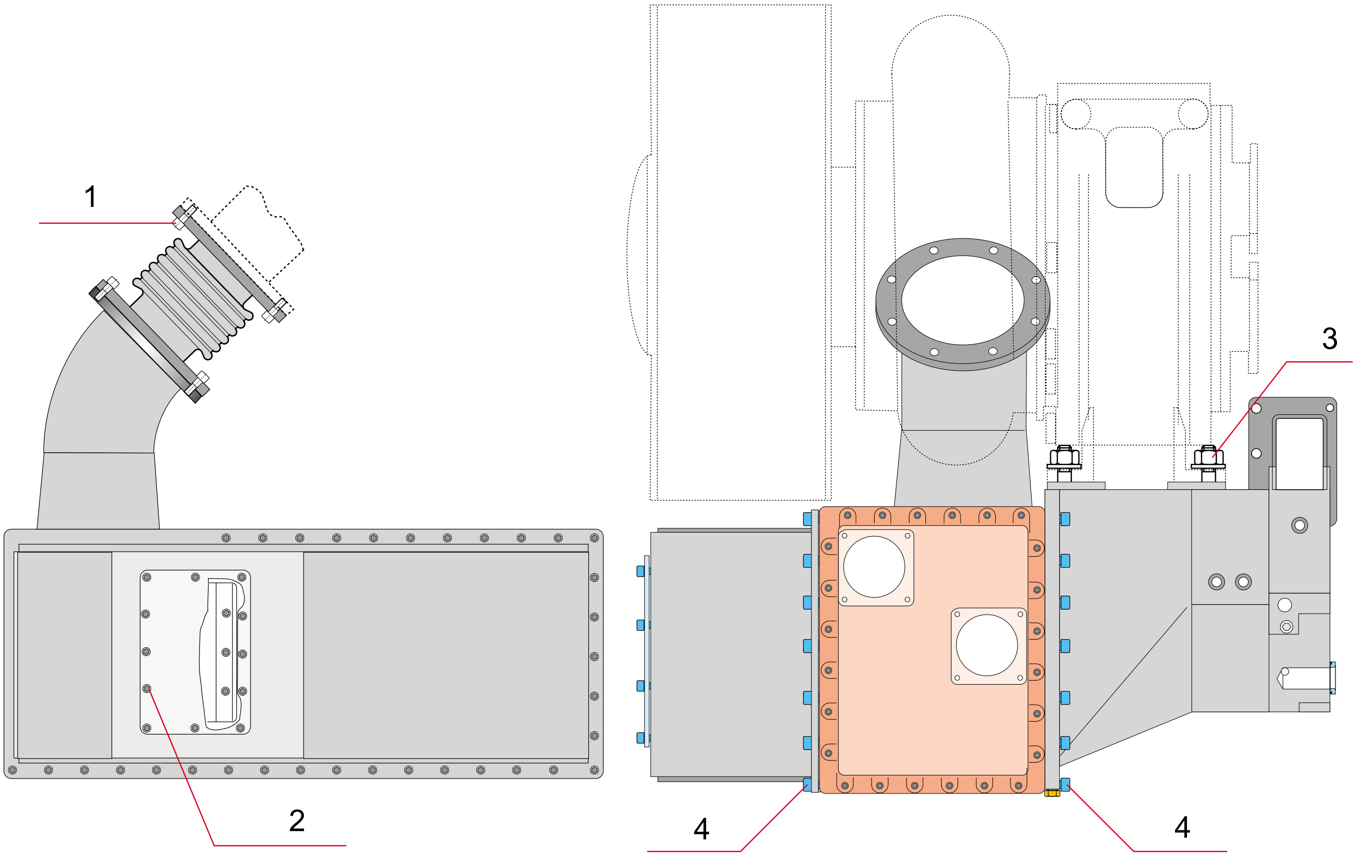


Fig. 07-21

Pos.	Designation	Torque (Nm)
1.	Hex socket screw	80
2.	Hex socket screw	80
3.	Turbocharger hex nuts	670
4.	Hex socket screw	80

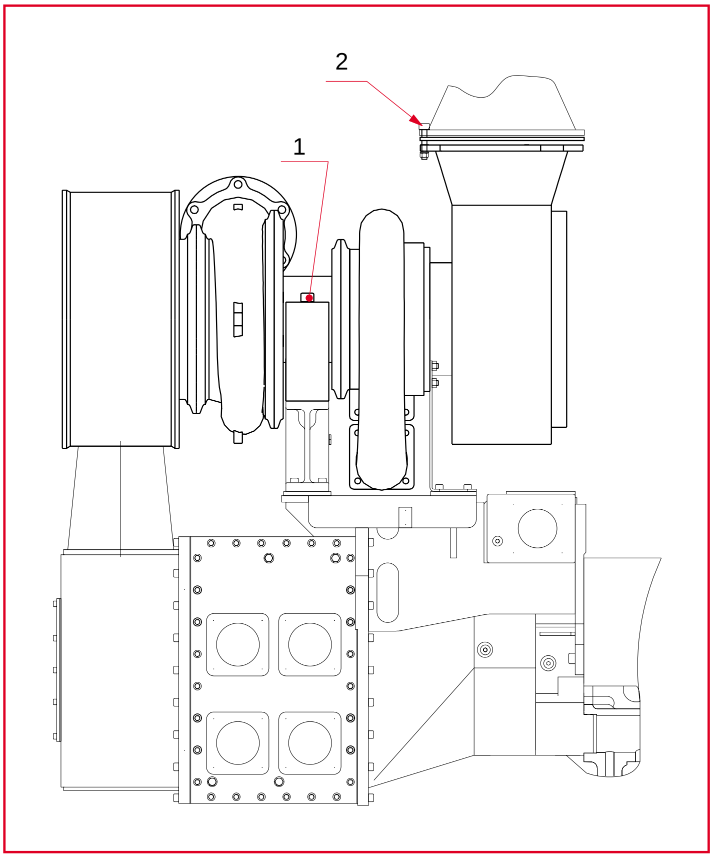


Fig. 07-22

Pos.	Designation	Torque (Nm)
1.	Stud	80
2.	Stud	455

o) Flywheel housing

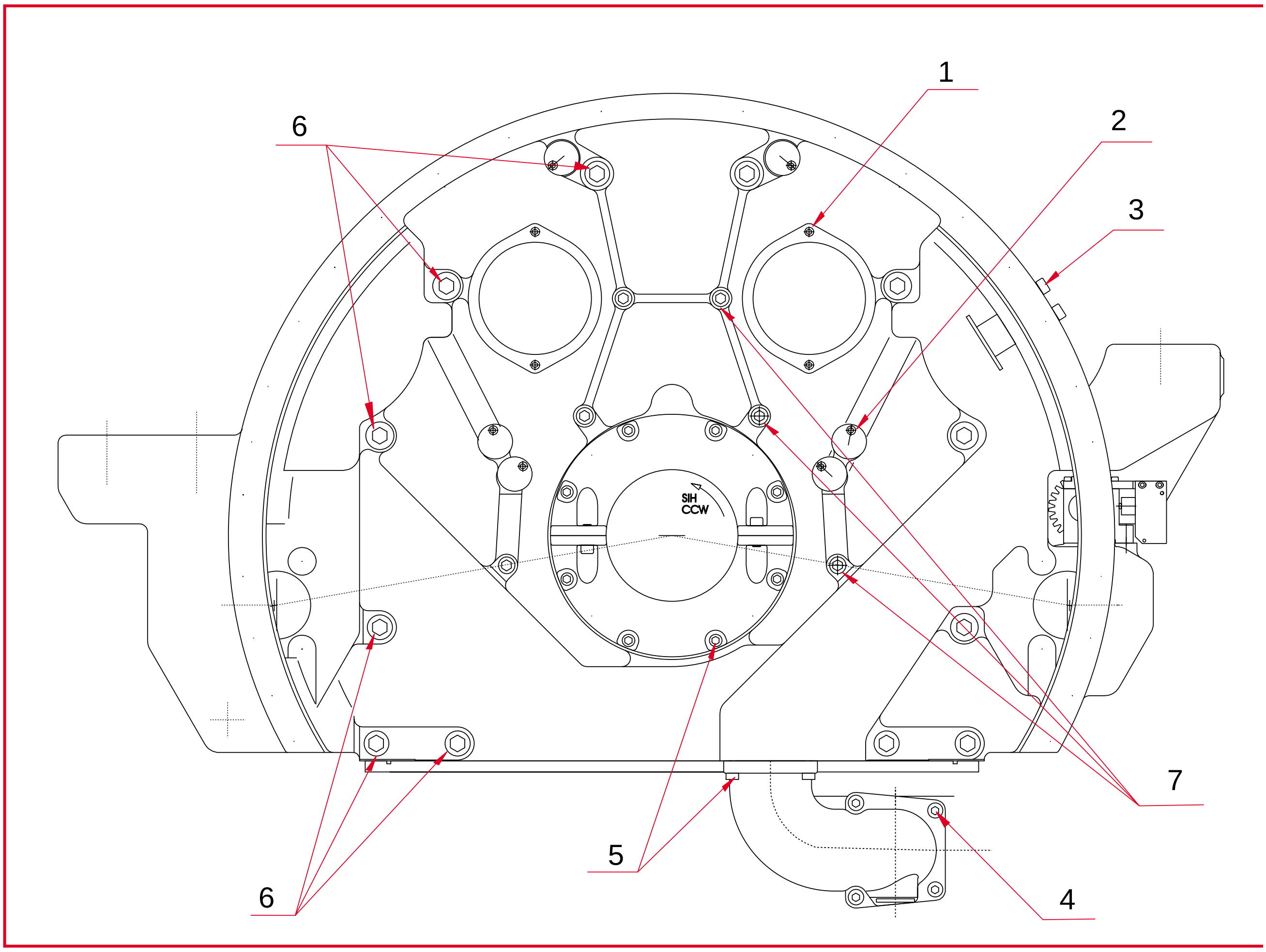


Fig. 07-23

Pos.	Designation	Torque (Nm)
1.	Screw	25
2.	Screw	25
3.	Screw	25
4.	Nut	80
5.	Screw	80
6.	Screw	700
7.	Screw	200

p) Engine-driven pumps

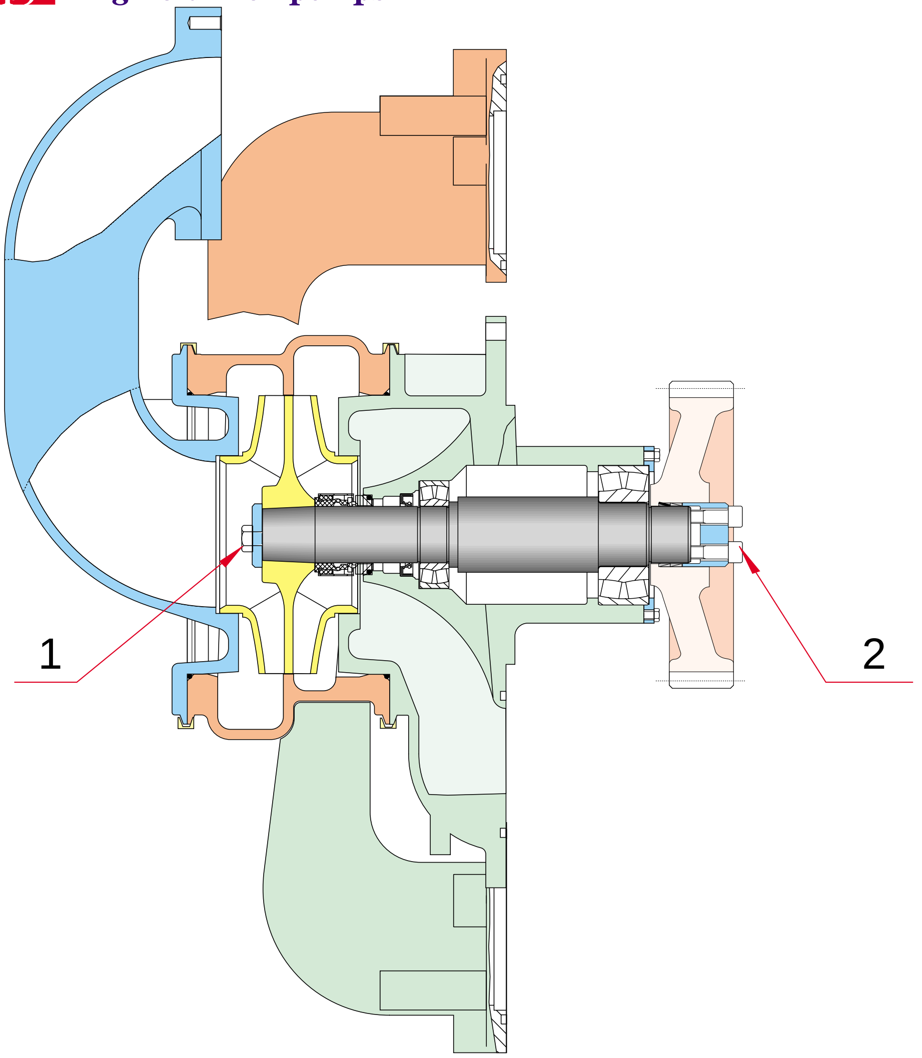


Fig. 07-24

Pos.	Designation	Torque (Nm)
1.	Water pump impeller retaining screw (Loctite 243)	250
2.	Water pump drive retaining screw	See section 7.2

07.2. Friction conical rings - mounting instructions (pump drive pinion)

Follow the mounting instructions below to assemble the two friction conical rings that connect the toothed drive gear and the fresh water pump, sea water pump and lube oil pump shafts:

Tools required:

- 20 - 100 Nm torque wrench
- 8 mm male socket wrench with 1/2" square drive.

Caution: **The screws (4) and conical friction rings (2) can be used once only and should be changed systematically whenever removed.**

1 **Clean the pump shaft and threads,** the gear wheel (1), conical friction rings (2) and flange (3).

Caution: **The underside of the heads and the threads of the screws (4) must be properly degreased.**

2 **Fit the conical rings (2) in pairs,** in accordance with the assembly drawing. Their outer diameter may be lightly lubricated.

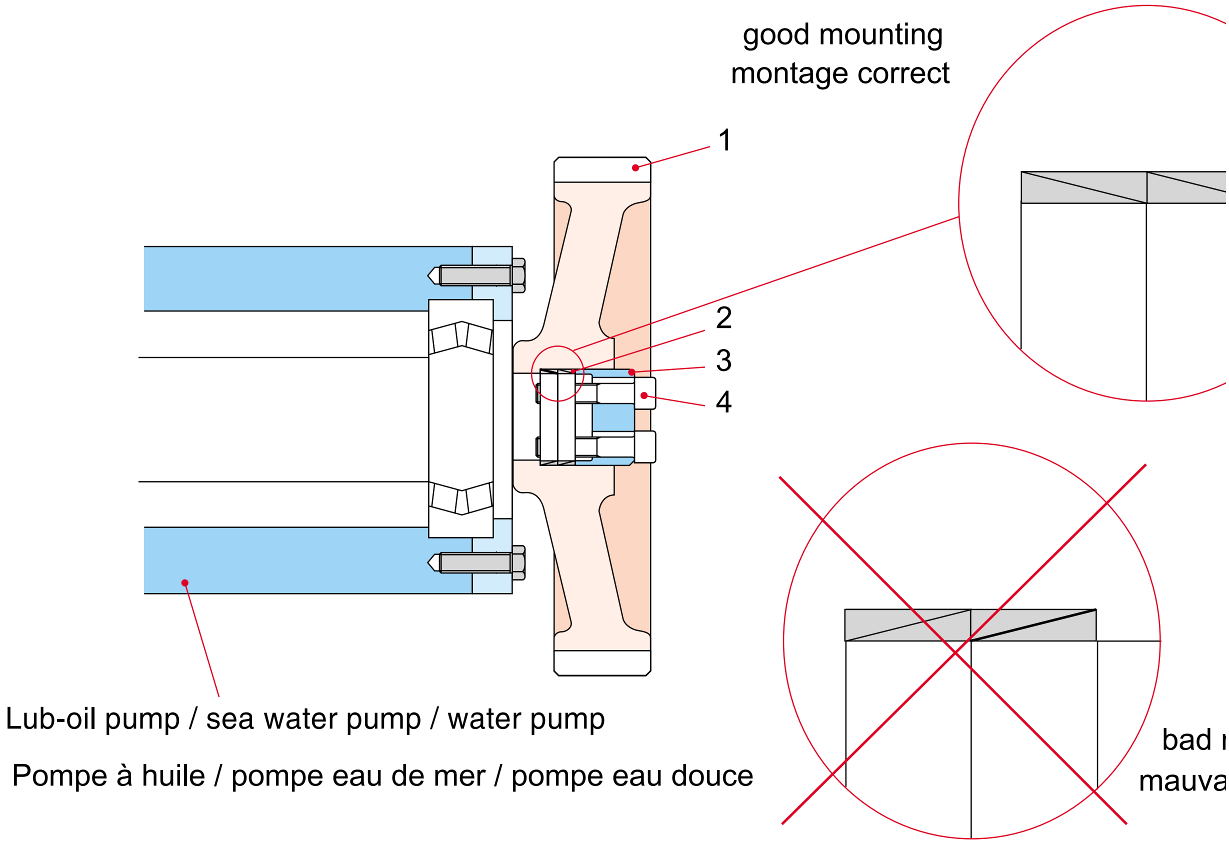


FIG. 07-25

3 **Put Loctite 243 on the screw threads,** except for those which come with polyamide threadlocker from the manufacturer.

4 **Fit the flange (3) and the screws (4).**
Tighten the screws by hand. Before the screw (4) touches the flange (3), lubricate the underside of the screw head maintaining the pump shaft horizontal to prevent oil getting onto the thread. Check that the flange (3) is correctly in position (in contact with the mating faces of the screw heads) and parallel to the face of the gear wheel (1).

5 **Tighten the screws (4)** equally working in a crosswise pattern as shown in FIG. 07-26 below. Tighten in three stages to the torque indicated in the table below.

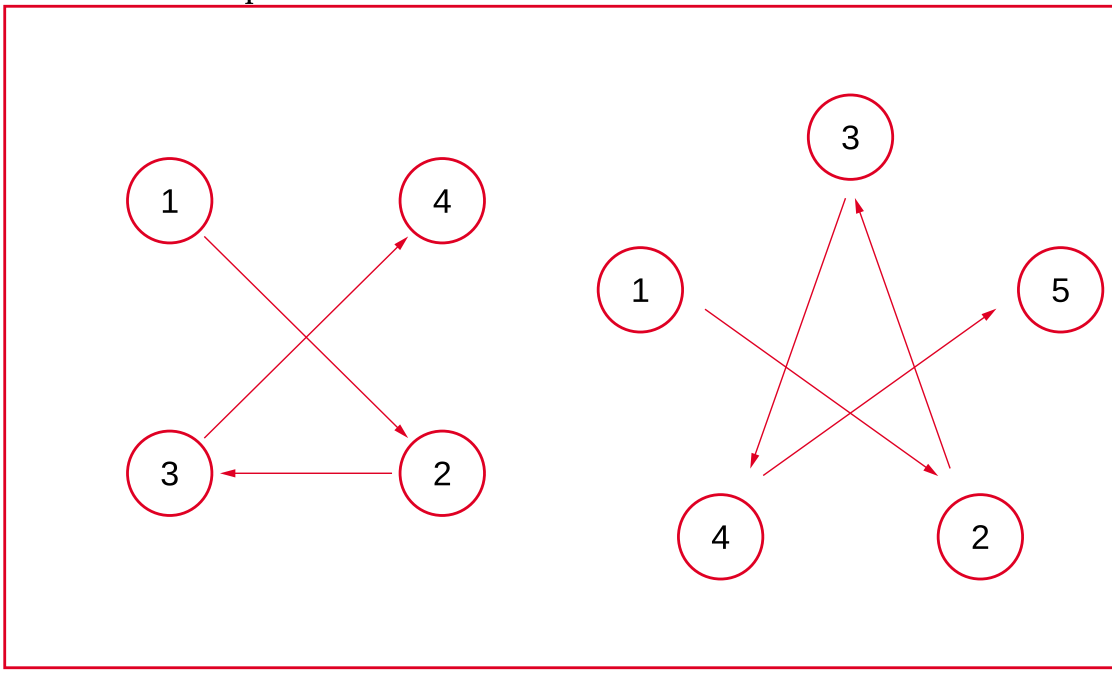


FIG. 07-26

6 **Check the torque values** in the order the screws were tightened. Assembly is completed when the screws cannot be tightened beyond the specified torque.

7 **Check the gear wheel is parallel to the flange.**

	Torque - Step 1 (Nm)	Torque - Step 2 (Nm)	Torque - Step 3 (Nm)
Dual water pump	15	30	50
Oil pump	20	40	70
Sea water pump	15	30	50

07.3. Use of hydraulic tool

07.3.1. Hydraulic tightening pressure

a) Tightening with hydraulic tool

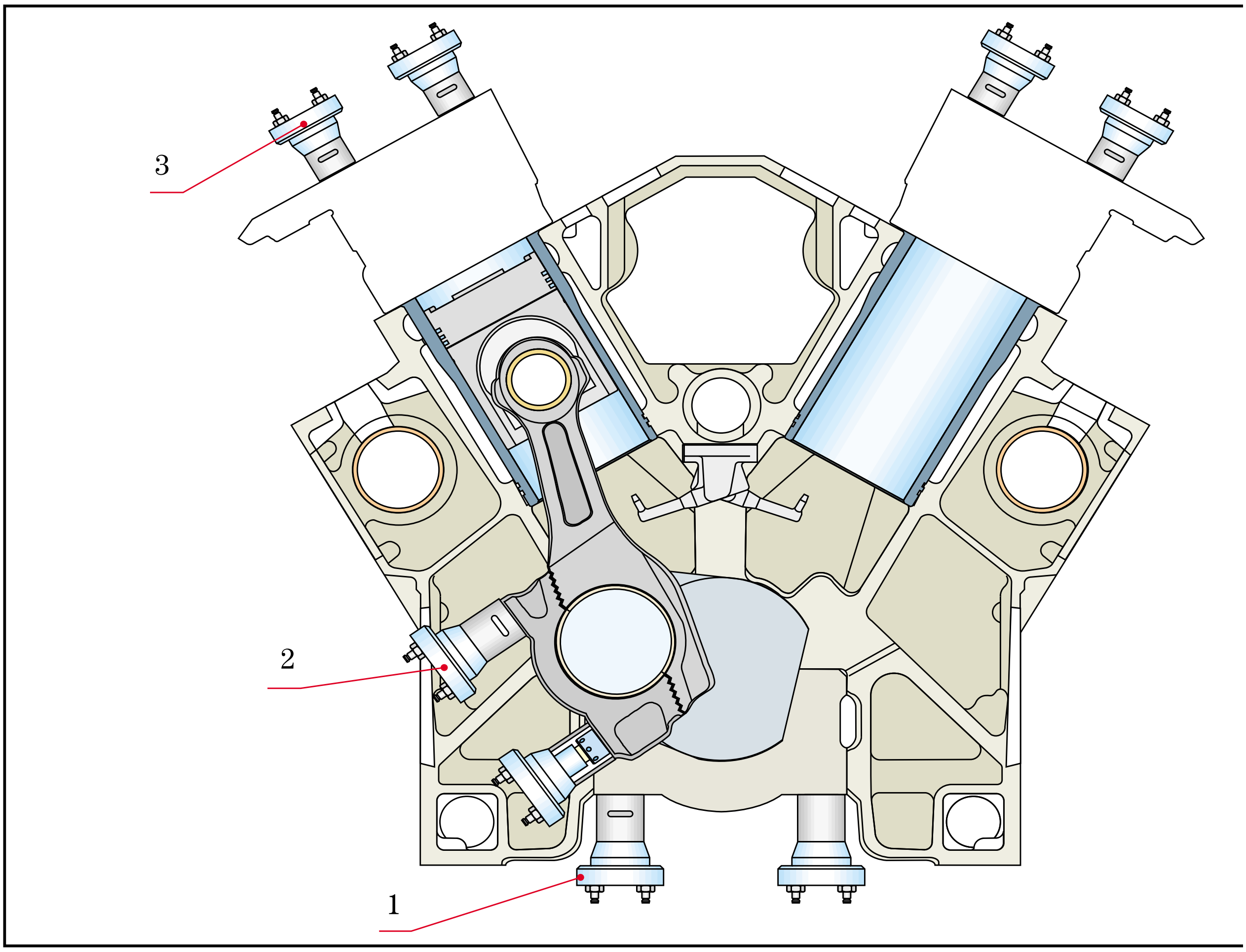


Fig. 07-27

To tighten the main bearings, connecting rods and cylinder heads, use:

- automatic hydraulic pump 861022
- manual hydraulic pump 861032
- pressure gauge 861023
- operating lever 861026
- hoses 861024 + 861025

Important : **There are two different types of hydraulic cylinder for the connecting rods and the main bearings. Depending on the type fitted, the nominal pressures differ.**
First check therefore the markings on the cylinders.

<table>
<tr><th rowspan="2">Pos.</th><th rowspan="2">Designation</th><th rowspan="2">Torque setting</th><th rowspan="2">Cylinder</th><th colspan="3">Pressure</th></tr>
<tr><th>Nominal pressure</th><th>Loosening pressure</th><th>Max pressure</th></tr>
<tr><td rowspan="2">1.</td><td rowspan="2">M 36 screw - main bearings</td><td rowspan="2">150 Nm</td><td>861021</td><td>670 *</td><td>690</td><td>700</td></tr>
<tr><td>861033</td><td>710 *</td><td>730</td><td>740</td></tr>
<tr><td>2.</td><td>M 30 screw - connecting rods</td><td>100 Nm</td><td>861027</td><td>650 *</td><td>670</td><td>680</td></tr>
<tr><td rowspan="2">3.</td><td rowspan="2">M 36 screw - cylinder heads</td><td rowspan="2">150 Nm</td><td>861021</td><td>560 *</td><td>580</td><td>590</td></tr>
<tr><td>861033</td><td>600 *</td><td>620</td><td>630</td></tr>
</table>

*** Caution:** **Hydraulic tightening process is done in two stages. See the order of procedure in Section 07.3.3.**

Caution: **The screws are overloaded if the maximum pressure is exceeded. In this case, the studs must be obligatory replaced by new ones.**

If it is impossible to turn a nut when the maximum hydraulic pressure is reached, look for corrosion on the thread, check the tool condition and check whether the pressure gauge reading might be wrong.

07.3.2. Hydraulic tool filling, bleeding and handling

The hydraulic tool is composed of a high pressure hand pump with a built-in oil tank, hoses with snap-on connectors, check valves, hydraulic heads (piston and cylinder) and a pressure gauge mounted on the pump but not connected to the pressure end of the pump.

These components are connected in series, with the pressure gauge last, to be sure that the pressure delivered to each head is correct.

The check valves of the hoses mounted in the snap-on connectors are opened by the pin located in the centre of the male and female components. If the pins are worn the connector must be replaced as it may no longer open.

- It is recommended to use special hydraulic oil or at least oil with viscosity of 2° E at 20°C.
- It is recommended, when filling the high pressure pump oil tank, to connect the hydraulic tool as indicated in Fig. 07-24. Before commencing filling, open the bleed valve (2) and drain the heads (4) by pushing the piston. Then fill the oil tank via the filler cap (1).
- After completing this operation, bleed the air by pressing the pin located in the centre of the female part of the last snap-on connector with your finger, after de-connecting the pressure gauge. Continue pumping until the oil from the connector contains no more air bubbles.
- Check the pressure gauge operation at regular intervals. A calibration pressure gauge can be provided for this; it can be fitted to the opening (7), with the pump outlet hose

connected directly to the pressure gauge valves, which means air should only be vented when filling the oil tank.

- If circumstances require a hydraulic tool to be used with partly damaged couplings, loosen the air bleed screw to open the passage to all the heads before closing the connection.

Hydraulic tool heads

1. Filling plug
   Orifice de remplissage
2. Release valve
   Vanne
3. Pressure hose
   Flexible de mise sous pression
4. Cylinders
   Vérins
5. Outlet hose
   Flexible de retour
6. Pressure gauge
   Manomètre
7. Plug hole
   Bouchon

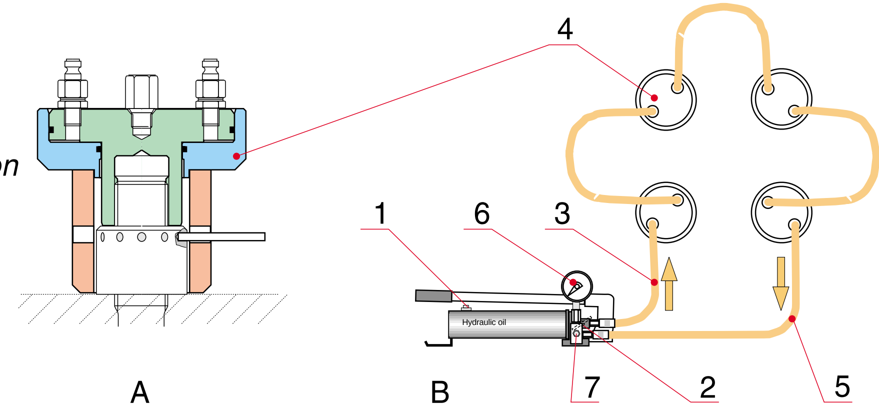


FIG. 07-28

After using the hydraulic tool, always be sure to:

1. **Open the bleed valve.**
2. **Remove all the pressure hoses.**
3. **Connect a hose between the pump and a cylinder.**
4. **Screw the cylinder clockwise to expel the oil.**
5. **Connect the hose between the pump and another cylinder and repeat operation 4.**

Note: **Each cylinder can be used 1000 times, after which it should be replaced (risk of fatigue fracture).**

07.3.3. Tightening / loosening procedure

The tightening / loosening procedure for main bearings is described in Section 10. The tightening / loosening procedure for connecting rods is described in Section 11. The tightening / loosening procedure for cylinder heads is described in Section 12. For each of the other procedures refer to the following section.

07.3.3.1. Hydraulic tightening procedure

1 **Fit the studs** to the torque stipulated in Section 07.3.1.

2 **Clean the stud and nut threads carefully.** Lubricate the threads slightly with engine oil.

3 **Tighten the nuts by hand,** clockwise and then with the rod make sure the nut is fully tightened.

4 **Make a permanent mark** on the top of each stud, in line with a nut manoeuvre hole; make another mark on the top of the nut in line with the first.

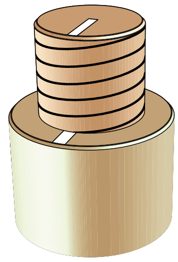


Fig. 07-29

5 **Fit the cylinders on the studs.** Take care to fit the spacers as follows to tighten the cylinder heads:

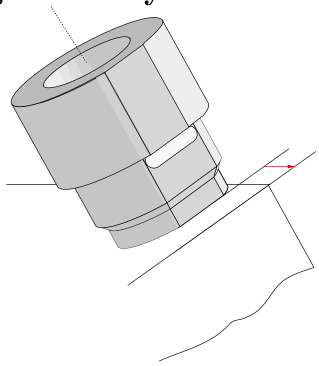


Fig. 07-30

This prevents pressure being exerted on two cylinder heads!

For connecting rods, turn the spacer so the rod can be inserted in the nut holes during tightening.

6 **Screw the cylinders hand tight,** clockwise, until they touch the bearing surface, and then release by a quarter turn.

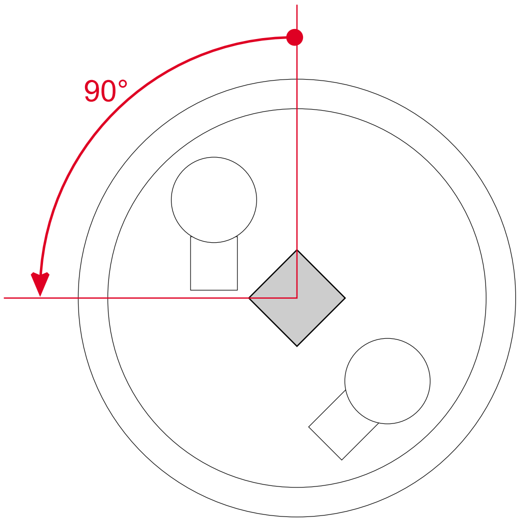


Fig. 07-32

7 **Connect the hoses as in the figure below,** with the pressure gauge at the end of the line.

Connecting rod and main bearing

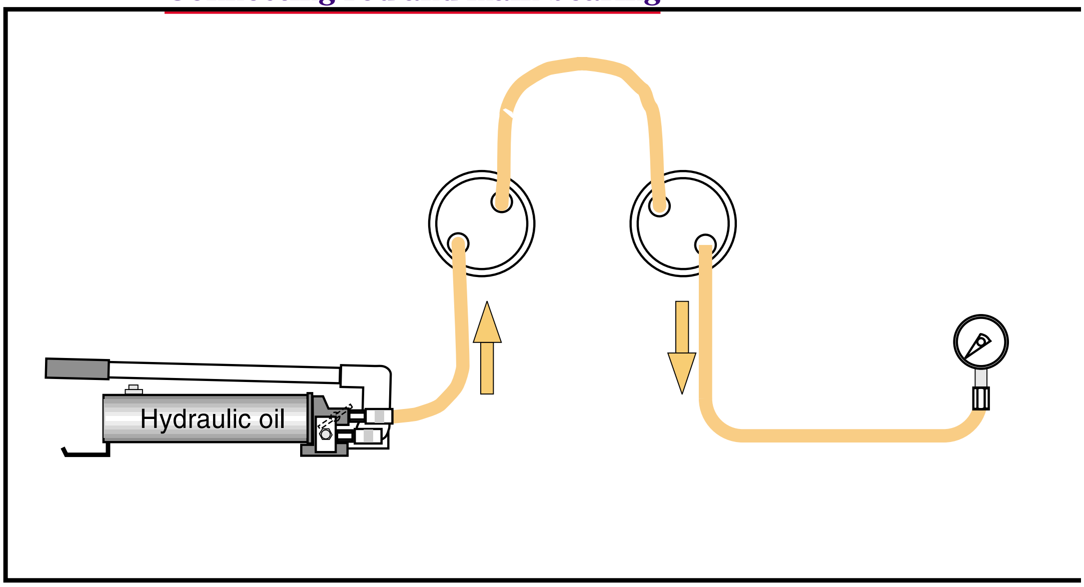


Fig. 07-31

Cylinder head

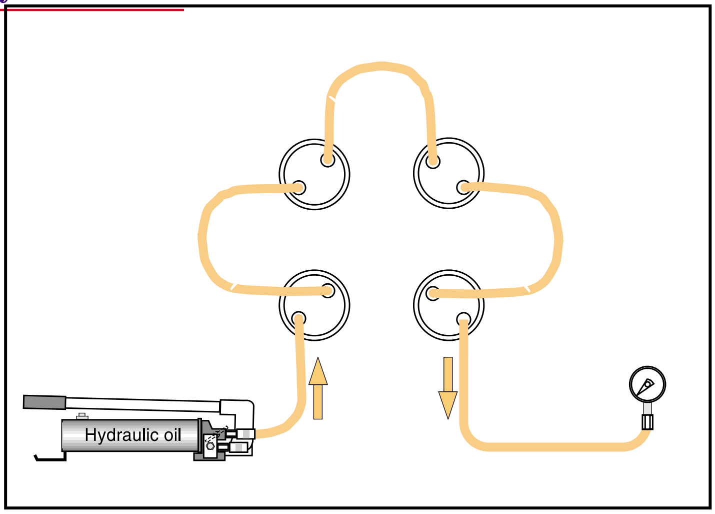


Fig. 07-33

The pressure gauge selected must be of the class 2 type at least, and preferably class 1.

8 **If necessary,** lower the pistons with a square wrench.

9 **Apply pressure in the circuit** to the value shown in table 1 below.

Table 1

Cylinder head	380 bars
Main bearing cap	500 bars
Connecting rod	380 bars

10 **Tighten the nuts** using the rod in the side holes.

11 **Release pressure** to allow the remainder of the oil to be correctly expelled.

12 **Restore pressure to the circuit** to the value shown in table 2 below.

Table 2

Cylinder head	Nominal pressure — See tab. p.20
Main bearing cap	Nominal pressure — See tab. p.20
Connecting rod	Nominal pressure — see tab. p.20

13 **Tighten the nuts again** with the rod.

All the nuts should turn. If one or more do not turn, or turn too much (i.e. more than 90° between table 1 and table 2), undo all the nuts.

14 **Release pressure slowly.**

15 **Return the pistons to the low position,** with a square wrench, by draining oil away to the pump.

16 **Remove the hoses.**

17 **Unscrew the cylinders.**

18 **If operation 3 caused difficulties,** clean the nut and stud and repeat the process from operation 3.

19 **Check the mark made** on the top of the nut has rotated at least through the angle shown below.

Connecting rod

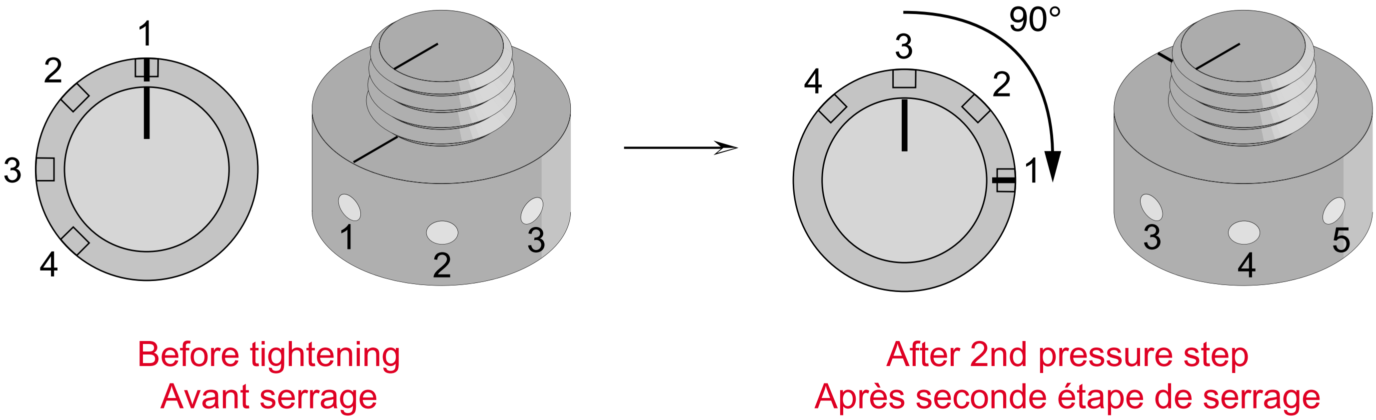


Fig. 07-34

Cylinder head

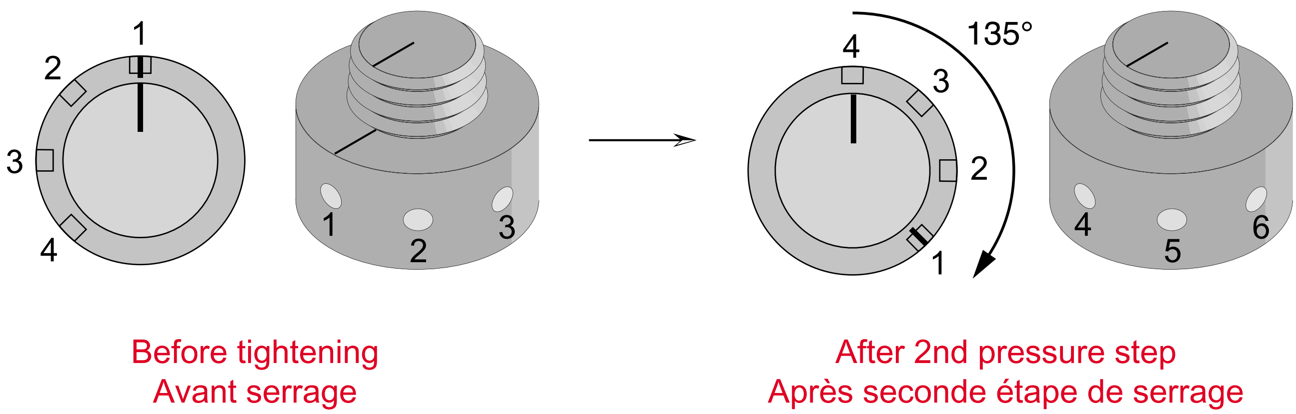


Fig. 07-35

Main bearing caps

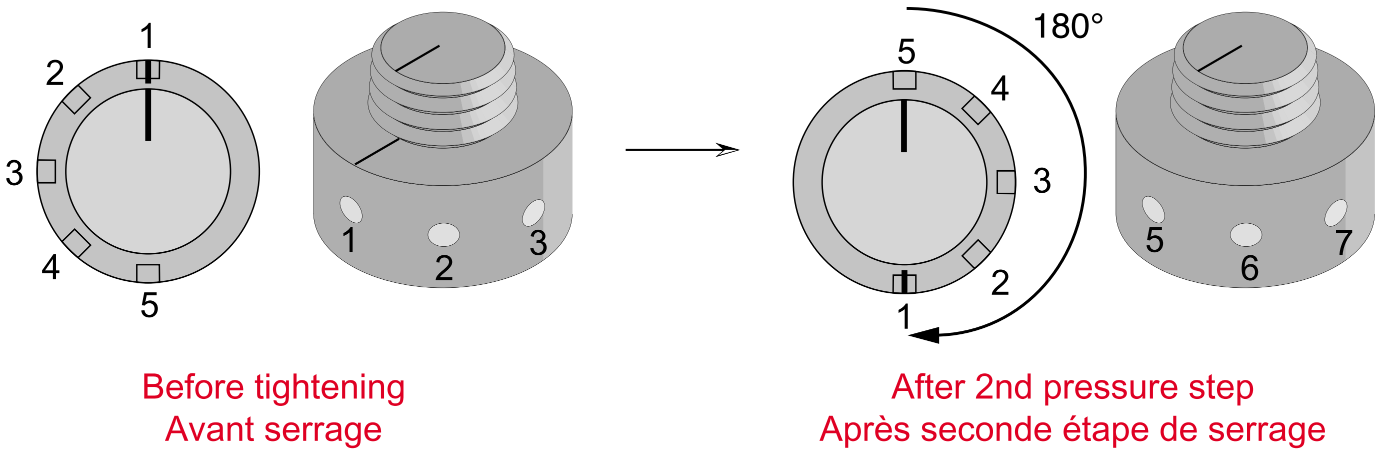


Fig. 07-36

07.3.3.2. Hydraulic loosening procedure

1 **Fit the cylinders to the studs.** Pay attention to the spacer position.

2 **Screw the cylinders hand tight, clockwise,** until they are against the contact surface, and then unscrew them by 270°, counter-clockwise.

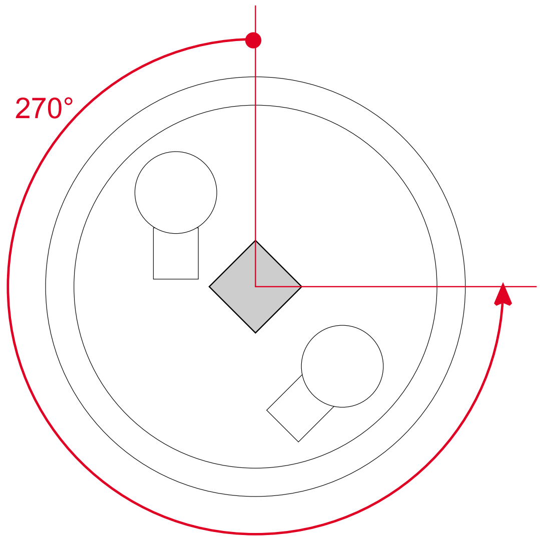


Fig. 07-37

3 **Fit the hoses as shown in the figures,** with the pressure gauge at the end.

Connecting rods and main bearing caps

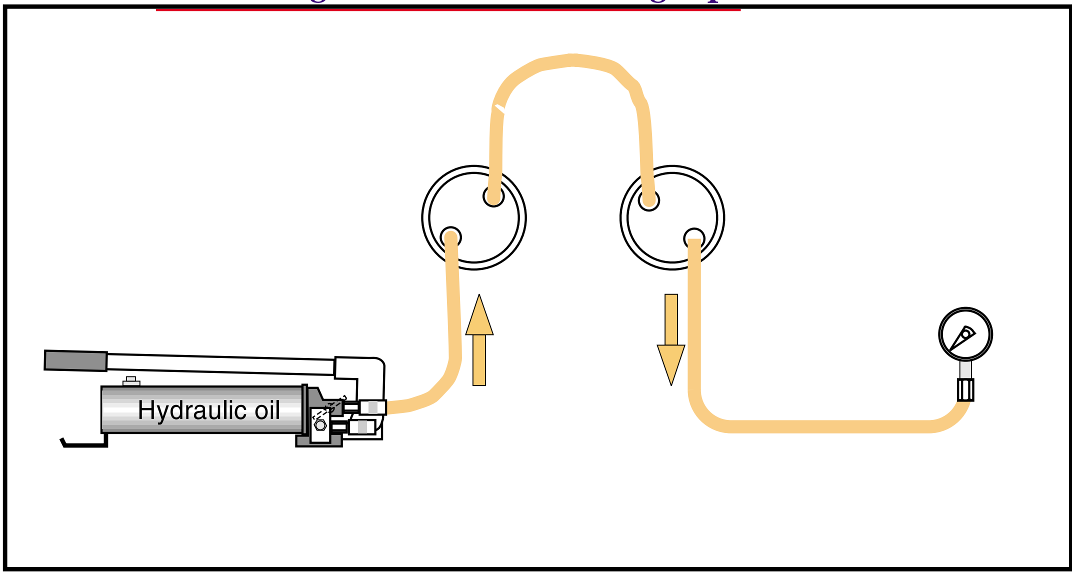


Fig. 07-39

Cylinder head

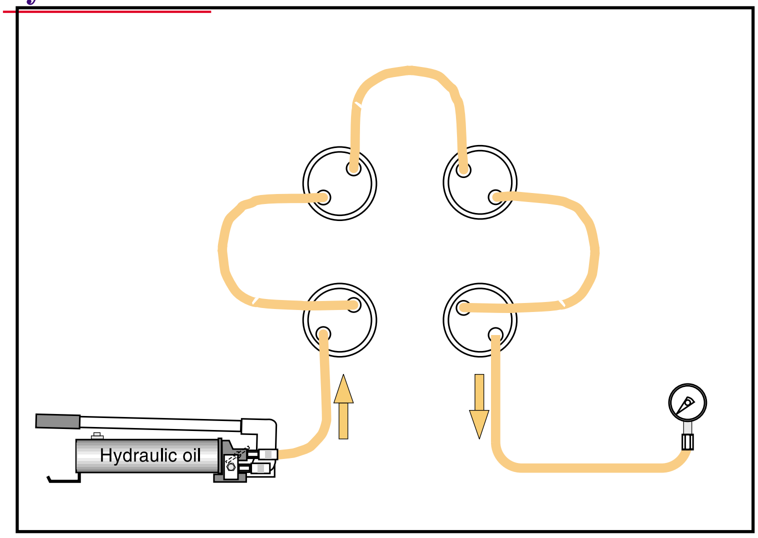


Fig. 07-38

4 **If necessary, lower the pistons** with a square wrench.

5 **Apply pressure in the circuit** to the value shown in table 2 below.

Table 2

Cylinder head	Nominal pressure, cf tab page 113
Main bearing cap	Nominal pressure, cf tab page 113
Connecting rod	Nominal pressure, cf tab page 113

6 **Release the nut by about one turn (360°)** with the rod.

7 **Release the pressure slowly.**

8 **Return the pistons to the low position** with a square key by draining the oil away to the pump.

9 **Remove the hoses.**

10 **Unscrew the cylinders and nuts.**

11 **Check the stud tightening torque.**

07.4. Instructions for assembly with Silicomet

07.4.1. Introduction

Some engine components or sub-assemblies must be assembled with Silicomet AS 312.

07.4.2. Preparation

The mating surfaces to be assembled must be properly cleaned and any grease removed.

Use a non fluffy cloth and a “Careclean” type solvent or equivalent. Allow the appropriate drying or evaporation time for the product.

07.4.3. Instructions

07.4.3.1. Essential data

- Pierce the end of the product application tube with a needle.
- Hardening time: from 10 minutes to 1 hour.
- Apply a fine bead of product (diameter not more than 3 mm).

Note: **Do not cut off the application tube end.**

- Optimal quality after 24 hours.

07.4.3.2. Working procedure

a) **As a working rule,** prepare and lay out the workstation before applying the product, so as to cut operation time to a minimum. Hardening time varies with ambient temperature.

Special cases: **For parts with narrow contact surfaces (e;g. oil module bracket), product polymerisation of 3 - 5 minutes will promote a buffer phenomenon.**

b) **Fit the positioning rods** in the part accommodating the component to be assembled, so as to protect the silicone bead.

c) **Mark the assembly contact surface,** and put silicone in the middle of the surface and around fastening holes.

Note: **Too large a silicone bead may create an unequal seal and cause filling where not desired (e.g. tapped holes, oilways, etc.).**

07.4.4. Cleaning

After assembly, clean off any excess product.

The product is easier to clean off when it has begun to polymerise.

If removing, cleaning can be done with a product similar to “Loctite Seal Remover”. Follow the safety instructions, wear safety glasses and protective gloves.

08. Operating troubles

08.1. Troubleshooting

Preventive measures: see Sections 03 and 04.

Certain incidents require rapid action.

Operating personnel must be familiar with this Section so as to be able to act without delay.

INCIDENTS AND POSSIBLE CAUSES		See Section
1.	**Crankshaft fails to turn when attempting to start up**	
a)	WECS control system indicates start prohibited because of: - insufficient oil pressure - insufficient start-up air pressure - cranking gear fault - insufficient HT coolant temperature at engine inlet - emergency stop button activated	Check and eliminate fault condition 23.7
b)	Engine in safety stop mode or emergency stop mode	
c)	Communication with external system inactive	
d)	One or more CCUs incorrectly set-up	
e)	MCU not reset after deconnecting	
f)	Automatic start-up sequence defective	
g)	Starter motor defective	08.2
2.	**Crankshaft turns but engine fails to fire**	
a)	Insufficient rotation speed (check starter motor condition)	08.2
b)	Gas injection limit incorrectly adjusted (check software parameters)	23
c)	Insufficient fluid temperature (check preheating)	
d)	Gas supply blocked or partly obstructed	17
e)	Supercharge air supply blocked or pipe fouled	
f)	Angular encoder fault or encoder incorrectly set	
g)	Ignition system fault	16
h)	Excessive difference between gas and supercharge air pressures	
i)	Gas expansion unit solenoid valves fail to open	17
3.	**Misfiring - Some cylinders fail to fire at all**	
a)	Prechamber or main chamber valve operating fault: - valve jammed in closed position - electrical connection defective or loose - excessive difference between gas and supercharge air pressures	17.4 , 17.5
b)	Firing fault in cylinder - spark plug electrodes worn - spark plug extension defective - coil defective	16.4
c)	Incorrect timing advance - software parameter fault - angular encoder incorrectly set	23.8

	INCIDENTS AND POSSIBLE CAUSES	See Section
d)	Air-gas ratio too lean - software parameter fault - throttle valve or waste gate fault - insufficient supercharge air pressure - charge air intake clogged - compressor impeller fouled - turbine fouled - air side of cooler fouled	23.9 15
e)	CCU defective	
f)	Difficulty to have V12 to V18 engines firing on all cylinders when idling because of small quantity of gas supplied This is acceptable in normal operation	
g)	Insufficient fluid temperature (check preheating)	
4.	**Engine speed unstable.**	
a)	Cylinder not firing - spark plug electrode worn	16
b)	Incorrect ignition advance - software parameter incorrect - encoder timing incorrect	23.8
c)	Air / gas ratio too lean - software parameter fault - throttle valve or waste gate fault - insufficient supercharge air pressure (see point 3d)	23.9
d)	Speed control parameters incorrectly defined in software	23.11
e)	Insufficient gas pressure	17& 23.8
5.	**Engine knock (stop engine if cause cannot be detected immediately)**	
a)	Excessive clearance in bearing shells (screw fittings loose)	11
b)	Valve spring broken	12
c)	Intake or exhaust valve jammed open	
d)	Excessive valve clearance	06
e)	One or more cylinders overloaded	
f)	Roller tappet jammed	
g)	Piston starting to seize up	
h)	Air / gas ratio too rich - software parameter fault - throttle valve or waste gate fault - insufficient supercharge air pressure (see point 3d)	23.9
i)	Prechamber or main valve operating defect - valve jammed open - particles, oxidation in gas supply manifold	
j)	Incorrect ignition advance - software parameter fault - encoder timing incorrect	
k)	Change in gas characteristics (insufficient methane index)	02.1

	INCIDENTS AND POSSIBLE CAUSES	See Section
6.	**Blue or whitish exhaust fumes**	
a)	Excessive oil consumption because of: - sump gas getting past piston rings - piston scraper ring broken - piston fire ring fouled piston compression ring fitted wrong way round	11
b)	Whitish fumes may be caused by water leak from exhaust boiler (cogeneration unit)	
7.	**Excessive exhaust temperature from all cylinders.**	
a)	Engine overloaded	
b)	Excessive supercharge air pressure - air cooler blocked at water side or fouled at air side - Excessive LT coolant T° return to air cooler (insufficient flow) - Excessive air T° in engine room (engine room ventilation)	15.6
c)	Intake and exhaust pipes fouled on cylinder heads	
d)	Exhaust back pressure - flue obstructed - fume exchange fouled (cogeneration unit)	
e)	Supercharge air circuit leak	
f)	Exhaust gas circuit leak	
g)	Air / gas ratio too rich - software parameter fault - throttle valve or waste gate fault - insufficient supercharge air pressure (see point 3d)	23.9
8.	**Excessive exhaust temperature from one cylinder.**	
a)	Exhaust valve - jammed open - negative clearance - bearing surface heat damaged	
b)	Prechamber or main chamber operating fault - valve jammed in open position - particles, oxidation in gas supply manifold	17.4 & 17.5
c)	Intake air leak	
9.	**Insufficient exhaust temperature from one cylinder**	
a)	Exhaust temperature sensor defective	23
b)	Gas circuit leak	17
c)	Failure to fire when idling (see point 3g)	
d)	Firing fault in cylinder - spark plug electrodes worn - spark plug extension defective - coil defective	16
e)	Air / gas ratio too lean - software parameter fault - throttle valve or waste gate fault - insufficient supercharge air pressure (see point 3d)	23.9

INCIDENTS AND POSSIBLE CAUSES		See Section
f)	Prechamber or main chamber valve operating fault - valve jammed in closed position - electrical connection defective or loose - excessive difference between gas and supercharge air pressures	17.4 & 17.5
g)	Prechamber valve defective - valve jammed closed	16
10.	**Low or zero lube oil pressure**	
a)	Oil pressure sensors defective	23
b)	Insufficient sump oil level	
c)	Suction pump pipe leak	
d)	Insufficient oil viscosity	
e)	Engine internal oil lines loose or broken	18
11.	**Excessive lube oil pressure**	
a)	See points 12a and c	
12.	**Excessive lube oil temperature**	
a)	Temperature sensor defective	
b)	Insufficient coolant flow through oil exchanger (pump defective, air pockets in circuit	19
c)	Oil exchanger fouled, deposits in tubes	18
d)	Thermostat element defective	18
13.	**Excessive coolant temperature from engine**	
a)	Temperature sensor defective	
b)	Air cooler fouled	
c)	Insufficient coolant flow in engine (water pump defective) air pocket in circuit, shut-off valves closed	19
d)	Thermostat elements defective	
14.	**Water in lube oil**	
a)	Leak from oil exchanger	18
b)	Water leak between cylinder liner and engine frame (O-rings defective) Test after changing cylinder liner.	
c)	Oil module defective	
15.	**Water in intake manifold**	
a)	Leak from air cooler	15.6
b)	Condensation (insufficient LT coolant inlet temperature)	
16.	**Engine loses speed or power**	
a)	Engine overloaded or power increase ramp too rapid	23.11
b)	See points 4e or 5g	
17.	**Engine cuts out**	
a)	Gas supply cut	
b)	Automatic stop or emergency stop from engine control system	23.7
c)	Engine control system power supply failure	
18.	**Engine fails to stop when stop signal sent**	
a)	Wiring fault between engine control system and control cabinet. Stop engine by closing manual gas supply valve	

08.2. Air starter breakdowns and faults

FAULT		SOLUTION
1.	**Starter fails to run**	
a)	No air supply	Check compressed air circuit
b)	Starter defective	Inspect starter
c)	Turbine jammed by foreign matter	Remove starter
d)	Exhaust blocked	Remove exhaust
e)	Control solenoid valve or relay solenoid valve defective	Replace control or relay solenoid valve
2.	**Insufficient power**	
a)	Insufficient air pressure	Check compressed air circuit
b)	Restrictions in air circuit	Remove supply pipe to locate blocked or defective point
c)	Pilot valve defective	Clean or replace
d)	Pneumatic motor defective	Replace motor

09. Installation specific features

Note: **This Section is left blank intentionally.**

The specific features of your installation are shown in your installation guide.

10. Engine block & main bearings, cylinder liners and oil sump

10.1 Engine block, inspection doors and covers

Details and dimensions
Material: nodular cast iron
Weight (dry): 3800 kg (12V220)
5400 kg (18V220)
Test pressure: 8 bars

10.1.1 General description

The engine block is cast in one piece of nodular cast iron. It is extremely robust and designed to avoid the concentration of stress forces and to minimise deformations. The block incorporates:

- part of the cooling system,
- lube oilways,
- the supercharging air manifold.

The main bearing caps are fixed to the engine block from underneath by two vertical studs tightened with a hydraulic tool and by two horizontal screws. The bearing shells are guided axially by tabs so they fit correctly in axial position. A bearing is located at the flywheel end which provides radial support for the flywheel while acting as a thrust bearing.

The camshaft bearing bushes are fitted in housings machined in the engine block.

The crankcase inspection doors and other steel sheet closures are fastened with four studs and a rubber seal.

Some of the crankcase inspection doors on the side of the engine are fitted with safety valves which open if excessive pressure builds up inside the crankcase. The centrifugal oil filter is mounted on the coolant control unit casing and has a filler cap for topping up with oil.

The modules at the ends of the engine are made of cast iron; they are flange mounted, and their mating face with the engine block is sealed with compound.

The crankcase has a venting system to remove crankcase gasses from the engine room.

12V220 engine block

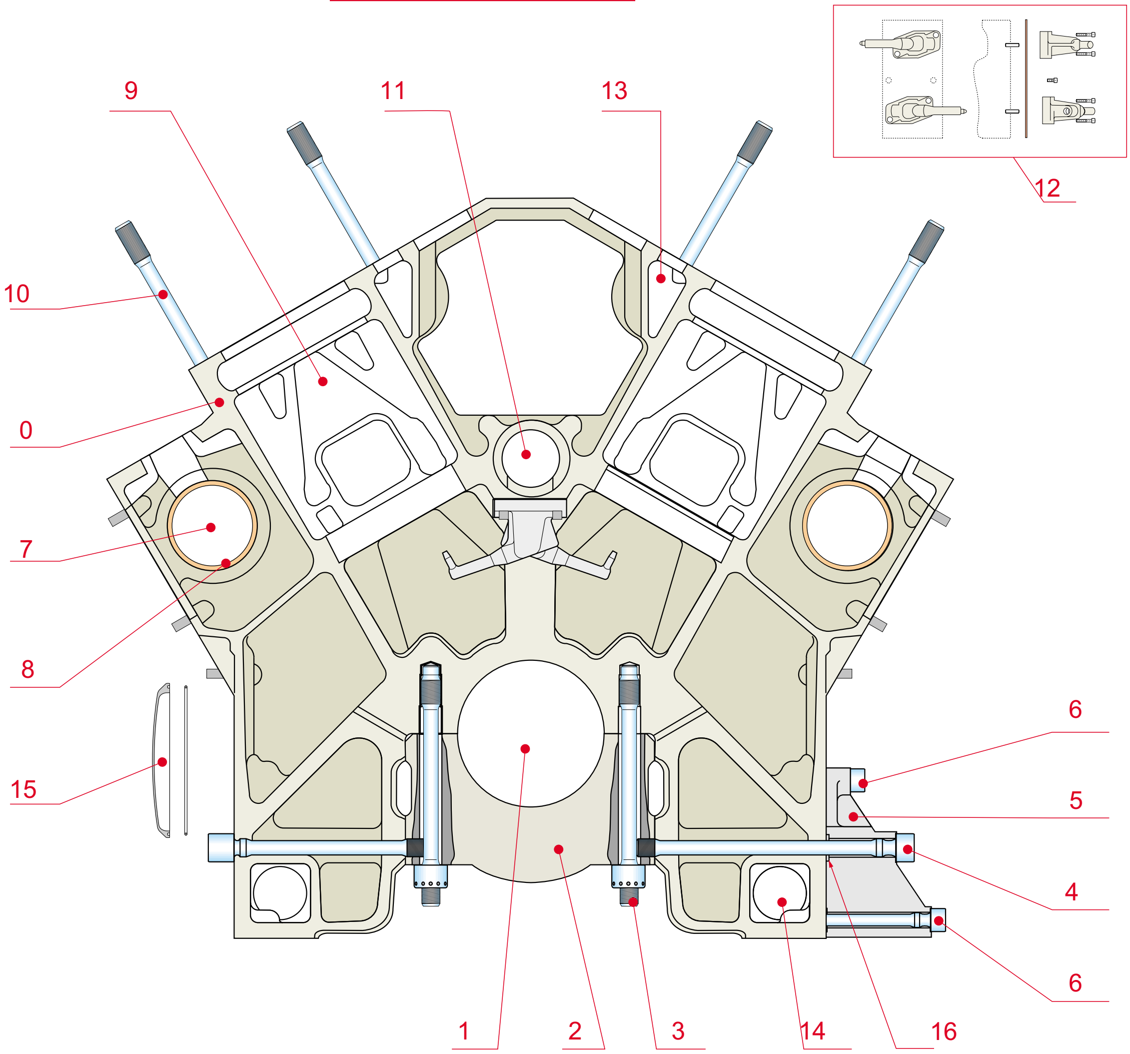


Fig. 10-1

N°	Description	N°	Description	N°	Description
0	Engine block	6	Engine foot screw	12	Lube-oil nozzle
1	Crankshaft	7	Camshaft	13	HT water integrated channel
2	Crankshaft bearing	8	Camshaft bearing	14	LT water integrated channel
3	Hydraucally tightened stud	9	Cylinder liner housing	15	Crankcase door
4	Lateral screw	10	Cylinder head stud	16	O-ring between engine block and foot
5	Engine foot	11	Integrated lube-oil channel		

18V220 engine block

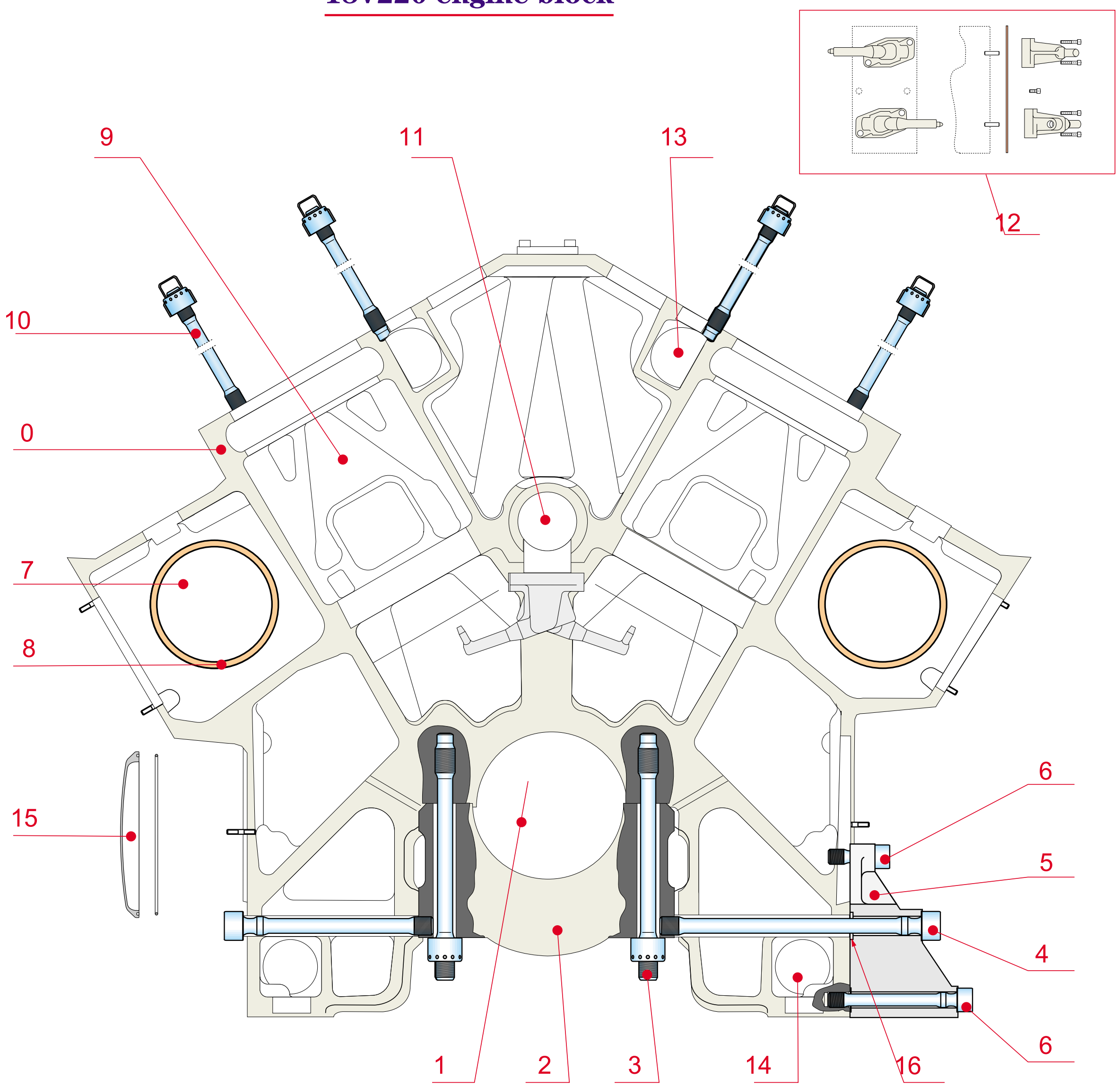


Fig. 10-2

10.2 Engine support

Details and dimensions
Material: nodular cast iron
Weight: 31 kg

Four (or six) nodular cast iron pedestals are bolted to the bottom of the engine block to provide support on the ground; they allow easy installation in a wide range of settings.

10.3 Oil sump

Details and dimensions
Material: steel sheet
Oil capacity: 450 litres (12V 220)
670 litres (18V220)

The oil sump is a welded sheet steel fabrication. It is lightweight and is fixed beneath the engine block; a rubber gasket ensures its air tightness. It contains the oil pump intake lines and the longitudinal line taking oil from one end of the engine to the other.

A dipstick is fitted through one of the crankshaft inspection doors. It indicates the maximum and minimum oil levels. It is advisable to maintain the oil level close to the maximum marking and never to let it fall below the minimum marking.

A graduated scale in centimetres on one side of the dipstick can be used to monitor oil consumption.

10.4 Main bearings

Details and dimensions
Main bearing cap weight: 22 kg

The main bearings are fitted with two bi-metallic half-shells. Only the upper half-shell has an oil groove. The thrust bearing, at the flywheel end, has no oil groove.

10.4.1 Main bearings — removal for overhaul

This is the biggest maintenance job as the engine has to be moved and inverted.

1. **Drain** the coolant and oil systems.
2. **Remove the turbocharger unit** and the lube oil module.
3. **Uncouple the generator** and remove the flywheel.
4. **Remove the cylinder heads, connecting rods, and cylinder liners.**
5. **Invert the engine block.**

Caution : **Main bearing and main bearing caps are paired. Before dismantling the caps, it is necessary to identify each one in order to locate the corresponding main bearing on the engine block.**

Nota : **See nota on chapter 07.3.2**

6. **Release the B side screws** of the main bearings (approximately tightened at 1200Nm) with tools 822001, 803001 and 820009 (see Section 05).

7 **Release in the same way the A side screws** of the main bearings (approximately tightened at 1200Nm) with tools 822001, 803001 and 820009 (see Section 05).

8 **Loosen the main bearing stud nuts** as described hereafter :

Caution : **The pressure must be simultaneously applied on the two main bearing cap stud.**
No specific order must be followed to remove the caps.

9 **Remove the nuts**

10 **Remove carefully the main bearing caps**to not damage the lower main bearing.

11 **Remove the lower half-shells**

12 **Remove the crankshaft,** handling it with two slings around n° 2 and n° 8 bearing journals.

13 **Remove the upper half-shells** and thrust washers.

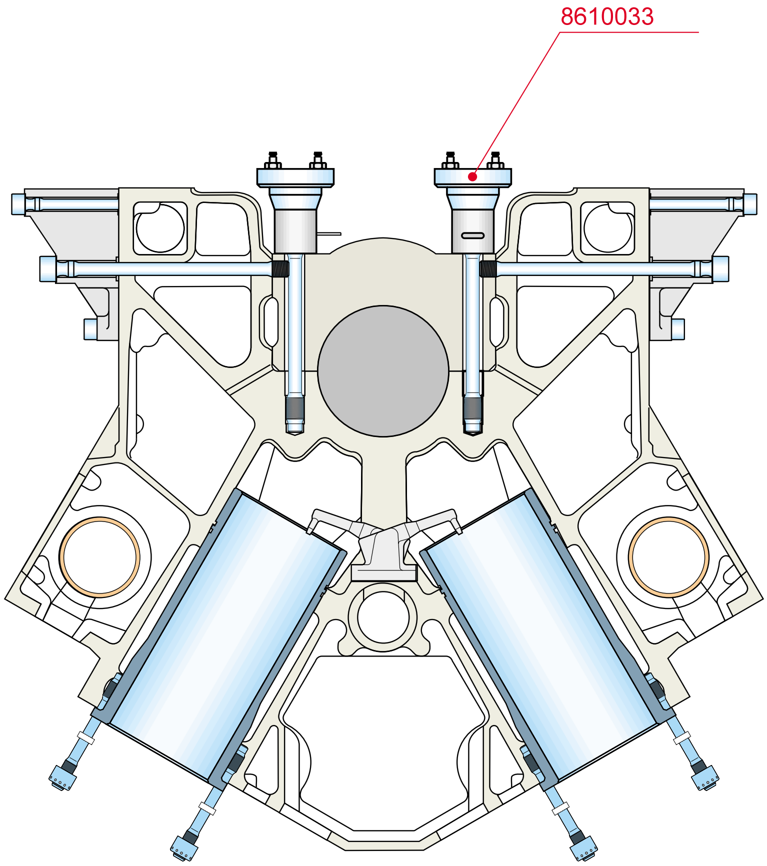


Fig. 10-3 dis9748

10.4.2 Removal of a single main bearing

1 **Remove the two inspection doors** on either side of the engine around the main bearing.

2 **Unscrew the side screws** (as described in chapter 10.4.1) of the relevant main bearing and those of the two neighbouring main bearings.

3 **Use the hydraulic tool** to loosen the main bearing stud nuts.

4 **Remove the nuts.**

5 **Remove the main bearing cap** and the lower half-shell.

6 **Remove the upper half-shell.**

10.4.3 Main bearings and crankshaft bearing journal inspection

Clean the half-shells and examine them for any signs of wear, scratching or other damage.

If excessive damage is found, change both half-shells and check the condition of the other bearing shells.

Wear can be evaluated by measuring the thickness of the lower half-shell with a ball-tip micrometer.

Observe the limits of wear specified in Section 06.2. If the thickness measurement has not reached the limit value and if the difference in thickness between all the shells is no greater than 0.03 mm, they can be reused.

Examine the surface condition of the crankshaft journals; remove any roughness, scoring, impact marks, etc. by polishing. Change the crankshaft if, after a long period of use, very unequal wear is noticed (see Section 06.2).

No scratches or other damage to the main bearing shells, caps or housings can be tolerated. Remove few burrs and then only occasionally.

10.4.4 Flywheel thrust washers inspection

Examine the crankshaft thrust washers in the same way as above.

If any half-washer is heavily worn change the set.

The thrust washers located on the same side must be replaced in pairs.

10.4.5 Main bearings refitting during overhaul

With the engine block inverted and feet mounted (see tightening torques in chapter 07) proceed as follow :

Nota **See nota in chapter 07.3.2**

1 **Clean the studs** and their threaded holes in the engine block. Tighten the studs to the torque specified in Section 07.

2 **Clean the main bearing location,** the half-shells and the crankshaft journals very carefully with clean lubricating oil.

3 **Remove the oil outlet protectors** and lubricate the journal with clean lubricating oil.

4 **Fit the upper half-shells** into their housings in the engine block, with the manufacturer's marking and the bearing order number towards the flywheel end. Grease the concave surface of the half-shells with clean Vaseline.

Note: **Do not lubricate the half-shell convexe surface because lubricating oil on this side is cause of fretting.**

Caution: **Shells that are forced into place may be distorted and so completely useless.**

5 **Lubricate the journals** and fit the crankshaft into the engine block with the gear on the flywheel side. During handling keep out not to damage the journals and crankpin surfaces.

6 **Fit the lower half-shells in their main bearing caps** and grease the anti-friction surfaces with clean vaseline.
The thrust bearing shell has to be assembled so that the manufacturer stamp is on the flywheel side.

7 **Fit the main bearing caps**into the engine block.

8 **Lubricate the threads and surface bellow the head of the side screws.** Fasten them hand tight.

9 **Lubricate the stud nuts with clean engine oil**and fasten them hand tight. Open them a half turn.

Note: **Each of the following operations must be done in the order shown. Begin with No 1 cap, work through to No 7, and finish with No 0.**

10 **Pre-tighten the A bank side screws** (straight side of the main bearing cap) to 400+10 Nm. Use tool 822001 and 822009.

11 **Tighten hydraucally** the main bearing caps according to the procedure described in chapter 07.3.1 and 07.3.2.

Caution : **Apply the pressure simultaneously on both studs of a same cap There is no order to be prefered between caps for the assembling**

12 **Tighten the A bank side screws** with an angle of 90°.

13 **Pre-tighten the B bank side screws** to 400 +10 Nm. Use tools 822001, 803001 and 822009.

14 **Tighten the B bank side screws**with an angle of 90°.

15 **Put the thrust bearing shell** on the cap #0

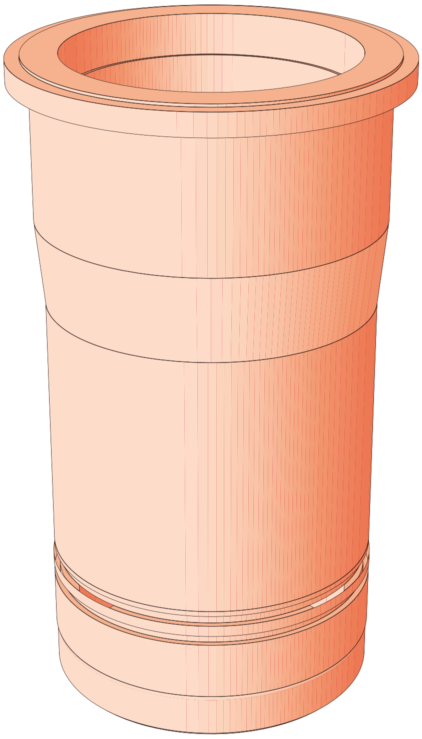
16 **Check the crankshaft axial clearance** (see value on chapter 06), by pushing the crankshaft to free end side thanks to a suitable lever.
Use a dual gauge, for instance, against the plane surface of the flywheel end.

10.4.6 Assembling a single main bearing

This paragraph follows on from the paragraph 10.4.2 “Removal of a single main bearing”.
Follow chapter 10.4.5 for the cap and the screws who were dismantled.

10.5 Cylinder liners

Details and dimensions
Material: special grey cast iron
Weight: 41 kg
Test pressure: 10 bars



10.5.1 Description

The "wet type" cylinder liners are made of special hard-wearing cast iron. The top of the liner is sealed "metal-to-metal" whereas the bottom is sealed by two O-rings.

To remove any glazing effects, the upper part of the liner has an anti-polishing ring.

10.5.2 Maintenance

When servicing a piston, examine the cylinder liner for any wear or damage. Check the bore diameter at three heights, longitudinally and transversally. If the bore is worn or glazed, the liner must be changed. Excessive lubricating oil consumption may indicate that the liner bores are worn or the internal wall is glazed.

Ovality of the cylinder liner bore cannot be corrected by honing alone.
After replacement of a cylinder liner, the piston rings have to be replaced with new ones
After work on the cylinder liner, follow the running program in chapter 03.

10.5.3 Cylinder liner removal

It is recommended to turn the crankshaft to TDC. Fit a piece of plastic to cover the crankpin so that no coolant or dirt gets into the oil sump.

1 **Drain the engine cooling system.**

2 **Remove the cylinder head** (see chapter 12).

3 **Remove the piston and connecting rod** (see chap. 11).

4 **Install the cylinder liner extractor n° 836001,** see Fig. 10-4.

5 **Turn the nut of the threaded rod** until the liner is jammed between the two plates of the tool.

6 **Extract the cylinder liner from the engine block.**

Cylinder liner removal

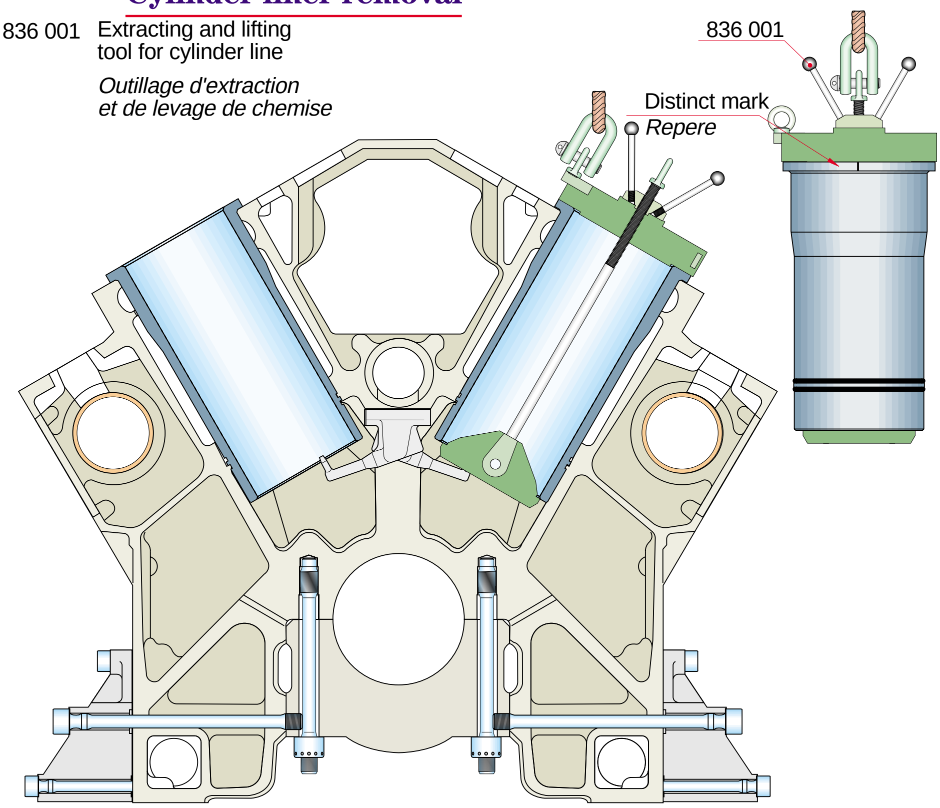
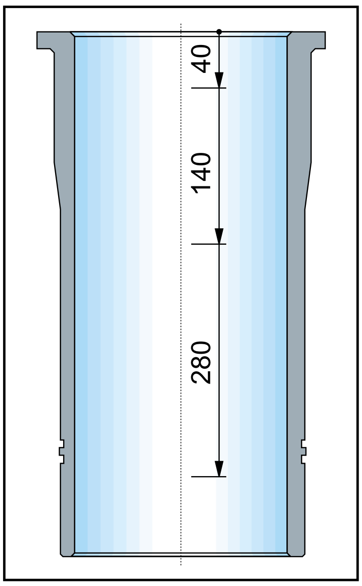


Fig. 10-4

10.5.4 Cylinder liner inspection

Clean off deposits from the outer surface with a wire brush (coolant side).

10.5.5 Cylinder liner refitting



If several liners have been removed, make sure each liner is put back into the same cylinder it was in previously. The cylinder numbers are marked on the liners.

1 **Check that the guiding surfaces** between the liner and the engine block are clean and undamaged.

2 **Check the contact** between the liner and engine block.
- Coat the engine block contact surface with methylene blue.
- Fit the liner in the engine block without the seals.
- Rotate it through 360°.
- The contact surface under the liner collar should have a uniform blue appearance.

3 **Lubricate the two O-rings** and two sealing surfaces with castor oil.

4 **Check that the liner grooves are clean** and fit the new seals.

5 **Fit the extractor tool 836001.**

6 **Apply ORASEAL sealing compound** to the engine block and the liner mating surfaces.

7 **Lower the cylinder liner into the engine block carefully.** When the lowermost O-ring touches the engine block, turn the liner so that the marking on it points to the flywheel end. Lower the liner further and press the liner into position by hand.

8 **Check the internal diameter** of the cylinder liner.

9 **Refit the piston** and connecting rod.

10 **Refit the cylinder head** and fill the cooling system.

11 **Check that the O-rings provide a tight seal** from the crankcase when the coolant is circulating. Apply a static pressure of 6 bar.

11. Crankshaft, Connecting Rod, Piston

11.1 Crankshaft

11.1.1 Description

Characteristics and dimensions
Material: forged alloy steel
Mass: 1200 kg (12V220)
2100 kg (18V220)

The crankshaft is forged from a single piece of high-tensile, case-hardened steel. The journal and crankpin fillets are recessed to reduce engine length and weight. Two counterweights, each fastened by three screws, are mounted on each crank web. The gear wheel that drives the camshafts is interference fitted at the flywheel end. The flywheel is fastened to the crankshaft by 16 bolts. At the free end of the engine, the crankshaft is fitted with a vibration damper and with a gear wheel fastened by screw to drive the coolant and oil pumps. Oilways in the engine block channel the lube oil to the main bearings and oilways in the crankshaft lubricate the connecting rod big-end bearing shells.

11.1.2 Crankshaft Counterweights

Characteristics and dimensions
Material: steel plate
Mass: 42 kg

The crankshaft is balanced by counterweights fastened by three screws on the crank webs. There is one counterweight per cylinder (see Fig. 11-1).

Note: **The stepped side of the counterweight must always be turned toward the crankpin (i.e. toward the connecting rod).**

Counterweight locations

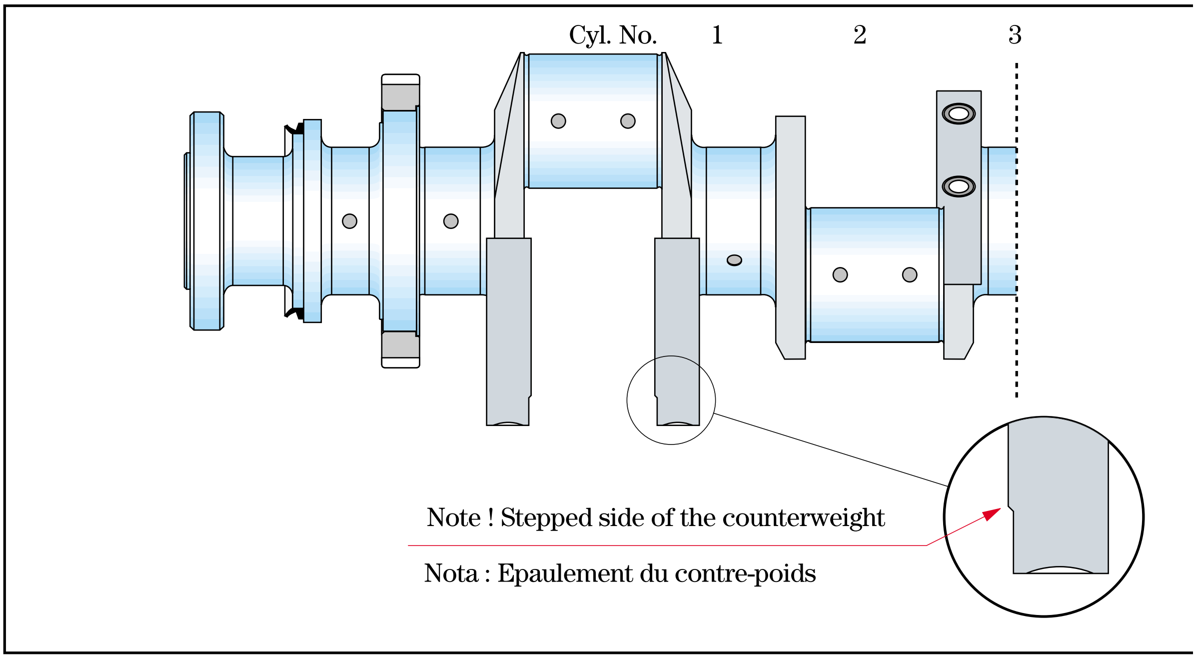


Fig. 11-1 201150v9748

11.1.3 Crankshaft stress force - testing

1 **Rotate the crankshaft** so the no. 1 cylinder piston is close to BDC and place a dial gauge between the imprints on the counterweight. The gap between the dial gauge and connecting rod must be as narrow as possible.

2 **Set the dial gauge to zero**

3 **Read off the dial gauge deflection** at each new position: toward side B, at TDC, toward side A and at BDC. Record these measurements on a Crankshaft Alignment Form.

Note : **For this stress force test, rotate the crankshaft counter-clockwise only.**

4 **Repeat the same operation** for each cylinder.

5 **The misalignment values below** are for an engine which runs at normal temperature after 30 minutes operation at 60% load, or at higher temperature after at least six hours' operation.

a) **for the same crankpin:** the difference between two measurements at diametrically opposite positions must not exceed 0.04 mm after installation or correction of the alignment. If this value is exceeded by more than 0.02 mm, the alignment must be corrected.

b) **for two adjacent crankpins :** the difference between two measurements must not exceed 0.04 mm. If it is greater, the alignment must be corrected.

c) **when no. 1 cylinder is at TDC (measurement c) :** the reading must be negative and not beyond - 0.04 mm (-0.06 mm for a flexible coupling). Check the main bearing dimensions before correcting the alignment of the engine and the driven machine.

Note: **For an engine operating at normal ambient temperature, the values must take account of experience acquired on the site or of the specific operating mode.**

Fitting and reading the dial gauge

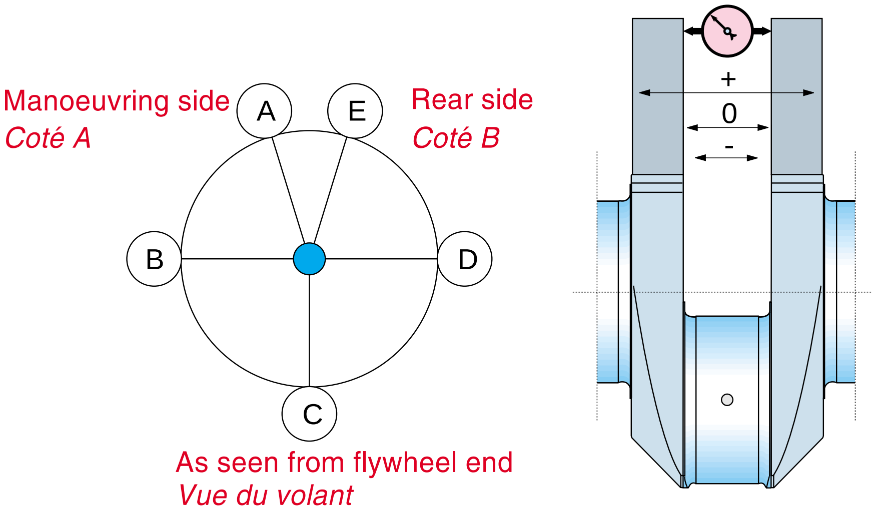


Fig. 11-2

11.1.4 Instructions for fitting the timing gear wheel on the crankshaft

11.1.4.1 Equipment

- Oven for heating to at least 220°C
- Dry cleaning solvent

1 **Check that the mating surfaces of the gear wheel and crankshaft are clean:** in particular, check there are no burrs that might interfere with the assembly.

2 **Carefully clean the mating surfaces** with dry solvent.

3 **Heat the gear wheel** uniformly to at least 200°C. It is essential to apply heat evenly to keep the gear wheel circular. This means the operation must be done in an oven.

4 **Fit the heated gear wheel onto the crankshaft** so that the counterbored area of the gear wheel abuts on the corresponding stepped area of the crankshaft. The gear wheel must be turned to align the marking on it with the marking on the crankshaft (web no. 1).

5 **Check the assembly** by measuring the gap between the gear wheel face and the face of the stepped area of the crankshaft. The maximum permissible gap is 0.08 mm.

11.2 Vibration Damper (W12V220)

11.2.1 General

To reduce torsion vibrations generated in the crankshaft, our engines are equipped with a vibration absorber at the free end which is commonly called the damper.

The damper is designed for a particular speed and frequency range.

11.2.1.1 Construction

Each damper is composed of a welded housing, a crimp-fitted or bolted cover and includes inside a loose-fitted annular inertia mass guided by two rings, all of which are immersed in a silicone type fluid whose viscosity is precisely defined for each application.

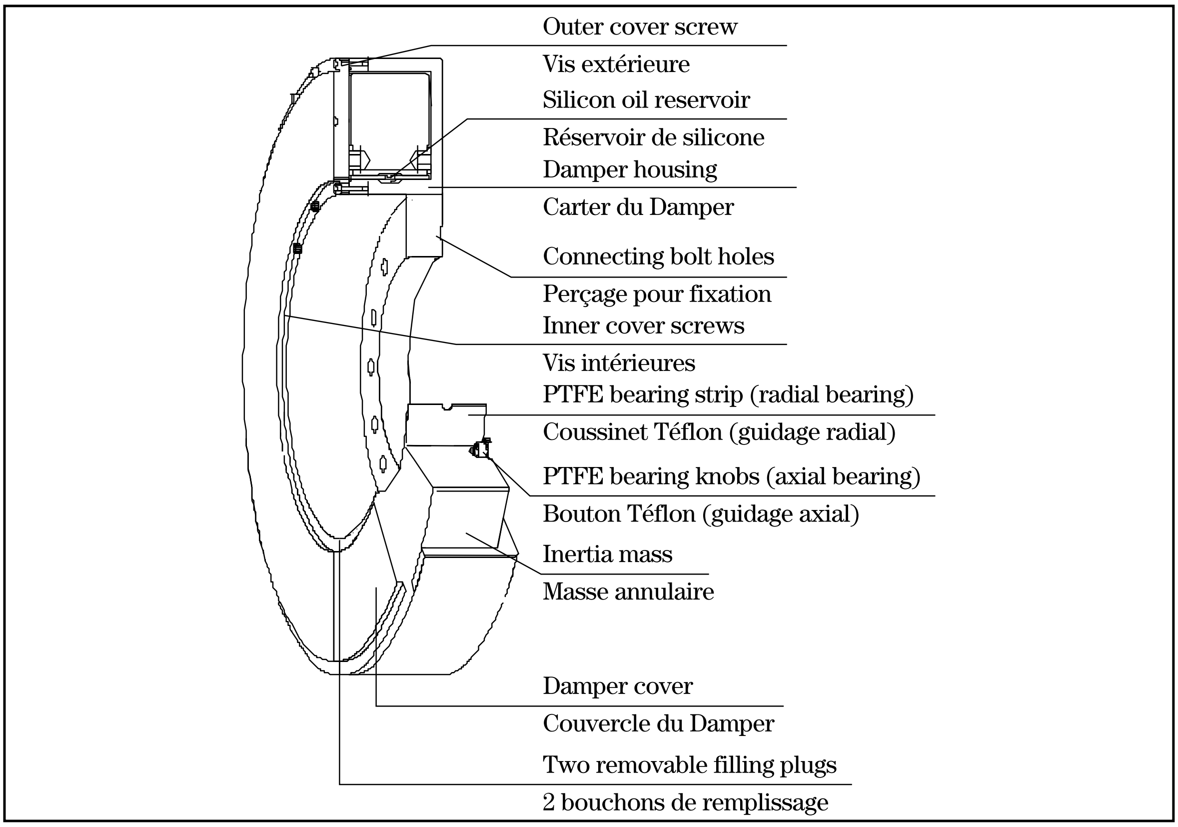


Fig. 11-3

11.2.1.2 Operation

The damper reduces torsional vibration through friction between the inertia mass on the silicone films. The transformation of torsion vibration energy into friction means large amounts of heat are given off during operation.

Accordingly it is prohibited to paint dampers.

11.2.2 Installation

11.2.2.1 Handling

The damper must be handled with great care. If shipped, the damper must be packed in a crate to protect it from any knocks or impacts. No claims can be accepted for knocks or impacts occurring at the customer's facility. To handle the damper, use the special DIN standard lifting bolts and the lifting holes provided in the centre of the damper.

If a lifting belt is used to mount or remove the damper, make sure that the belt is in contact with the damper over an angle of more than 180°.

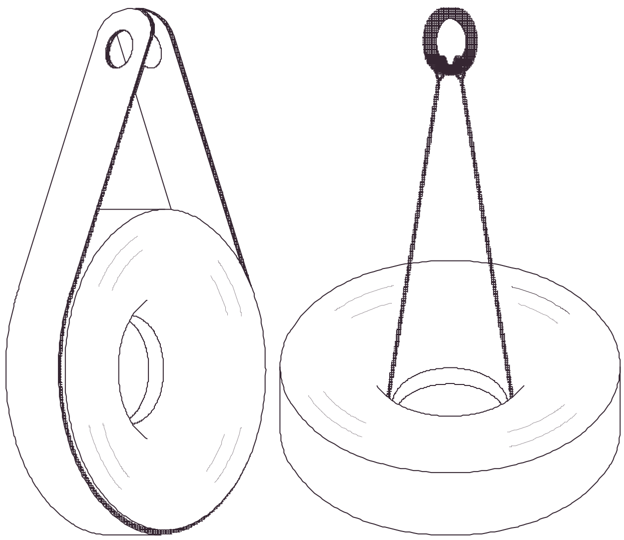


Fig. 11-4

11.2.2.2 Installation

The damper is mounted at the free end of the crankshaft.

The damper is fastened to the crankshaft by hexagonal head screws.

When the damper is installed, check that the damper and crankshaft surfaces make proper contact.

Eccentricity of 0.02 mm for a diameter of 100 mm is permissible.

11.2.3 Maintenance

Note: **Please contact Wärtsilä if the silicone leaks or if there are suspect noises or other symptoms involving the damper.**

11.2.3.1 Visual inspection

Inspect the damper visually to ensure there are no impact marks or silicone leaks.

11.2.3.2 Silicone analysis

Analysis must be carried out under the maintenance schedule to check whether:

- the silicone is contaminated,
- silicone viscosity varies by more than 25% from its initial viscosity.

In this case, the damper must be replaced by a new one.

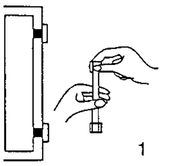
11.2.4 Silicone sampling procedure

Samples of silicone can be taken from dampers fitted with filler plugs. In most cases there are two such plugs, diametrically opposite each other in the damper cover.

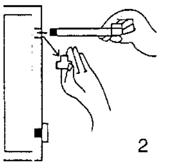
Insofar as one of these plugs can be reached, the silicone sample may be taken without removing the damper first. If the damper has to be removed from the engine, the fluid is sampled by setting the damper vertically.

It is advisable to rotate the damper until the two caps are roughly horizontal. The damper is to be left in this position for at least one hour before sampling.

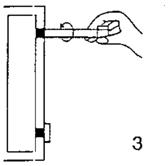
Generally there are two thread sizes for the filler holes and the sample tubes therefore have different sized threads at each end.



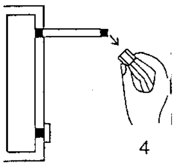
1 **If you know the size of thread on the damper,** prepare the sampling tube by removing the plug from the end to be inserted in the damper cover.



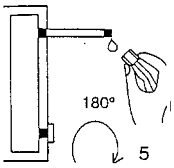
2 **Remove the filler plug on the damper;** have the sample tube ready to fit in its place.



3 **Screw the sampling tube** into the damper filler hole.

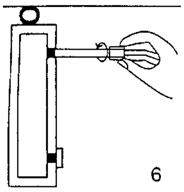


4 **Remove the other plug from the sampling tube.**

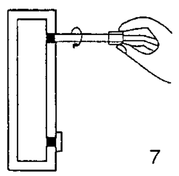


5 **Allow the silicone to flow out** from the open end of the tube.

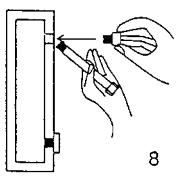
This operation may take just a few seconds or more than an hour, depending on the nature of the fluid and other factors. To speed up the process, rotate the damper through 180°.



6 **As soon as the fluid runs** from the open end of the tube, screw the plug back on.



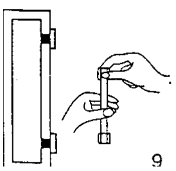
7 **Have the damper plug ready to fit on the damper hole** and unscrew the sampling tube from the hole.



8 **Screw the damper plug immediately** and tighten it::

1.5 kpm (type M10 x 1) or

4.5 kpm (type 16 x 1.5)



9 **Refit the plug on the tube** and make sure the two plugs are screwed tight but not overtight (do not use wrenches).

11.3 Vibration Damper W 18V220

11.3.1 General

The vibration Damper has been designed to reduce the torsional vibrations on the crankshaft

11.3.2 Operations

The W18V200 vibration Damper is a "tuned" type and use engine oil to absorb vibrations

1. Canal d'alimentation d'huile moteur
   Engine lub-oil chanel
2. Pigon d'entraînement des pompes
   Pumps driving gear
3. Entretoise
   Spacer
4. Goupille de positionnement
   Dowel pin

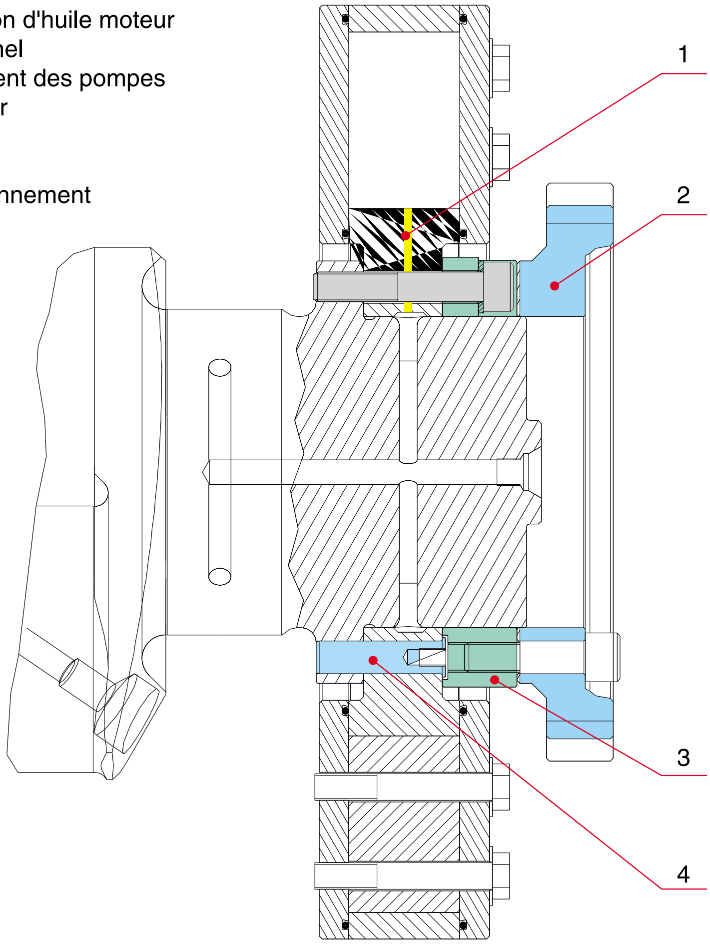


Fig. 11-5

Caution **It is forbidden to paint the Damper**

11.3.3 Installation

11.3.3.1 General

The vibration Damper is mounted on the free end of the crankshaft. It is fitted on the crankshaft by 8 screws and 8 shearing pins.

11.3.3.2 Dismantling

1 **Remove water and lubricating pumps**

2 **Remove the cover at the free end side** (see chap. 10)

3 **Remove the gear wheel drive** of the pumps

4 **Remove the** cross piece

5 **Extract the 8 pins** with the extractor 837008

6 **Remove the Damper** by using the extract screws

11.3.3.3 Maintenance

The Damper can only be reconditioned by a technician or a distributor Wärtsilä.

11.3.3.4 Reassembling

1 **Check that pins** are not weared out or folded.

2 **Screw 2 centering studs M20 (DLP 758970)** in 2 threaded bores diametrically opposite and horizontal.

3 **Locate and engage the Damper on the 2 studs** to assemble it on the crankshaft seat.

4 **Push the Damper on the seat** thanks to 2 threaded rods M20 with washers and nuts.

5 **Put in place** the 8 shearing pins

6 **Fit each pin with a HM 12x20 screw (1)** and a wire (2) see Fig. 11-6

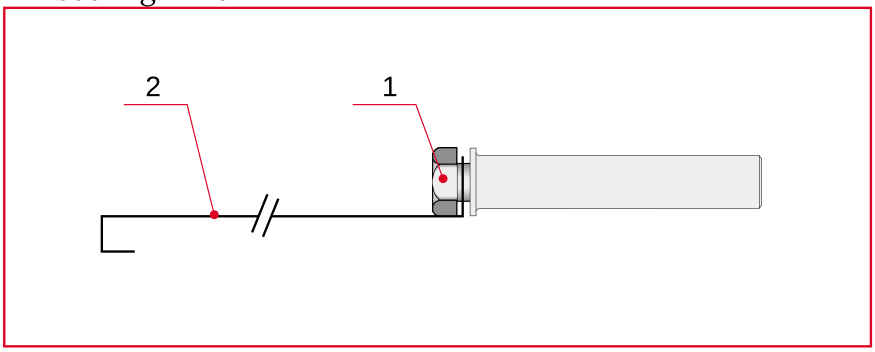


Fig. 11-6

7 **Apply a spray coat of Molykote G rapid plus type** on the contact surface of the pins

8 **Cool the pins** in liquid nitrogen

9 **Fit in place** all shearing pins

10 **Remove the two threaded rods**

11 **Assemble successively the cross piece and the 8 M20x115 screws** with their washers lubricated with engine oil (thread and under head)

12 **Tighten the screws cross-wise** see Fig. 11-7

Pre-tightening : 70 Nm

Intermediate tightening : 400 Nm

Final tightening : 500 NmFig. 11-7

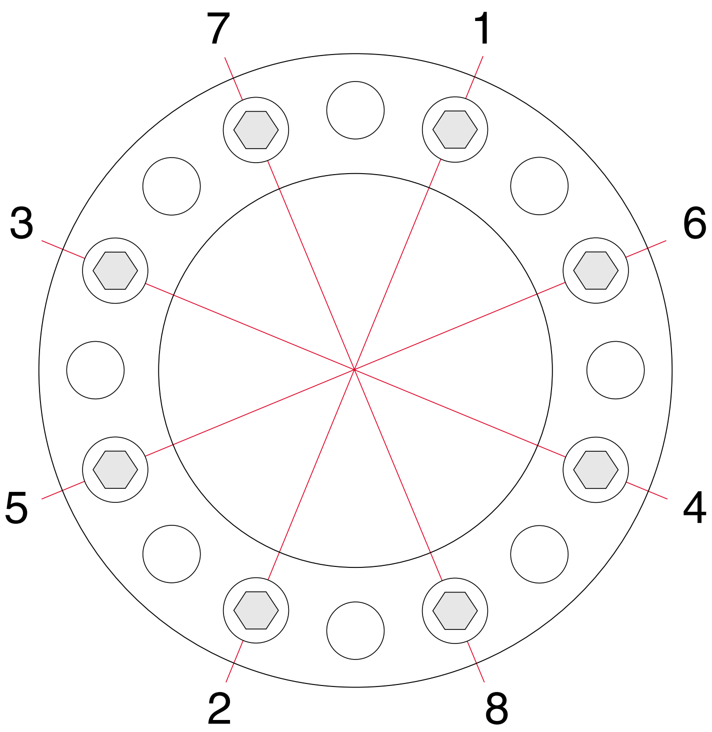


Fig. 11-7

13 **Mount the pumps gear wheel drive** with the same tightening torque as for the Damper.

11.4 Flywheel

Characteristics and dimensions
Material: steel plate
Mass: approx. 350 kg

11.4.1 Description

The flywheel is fitted to the end of the crankshaft by 16 screws and has a marking so it can be correctly positioned opposite the corresponding marking on the crankshaft.

A ring gear is mounted on the flywheel on which angle graduations from 0° to 360° show the crankpin angles. The TDC of each cylinder are shown.

These graduations allow the crankshaft angle to be read off with 1° accuracy.

Reading the position indicator

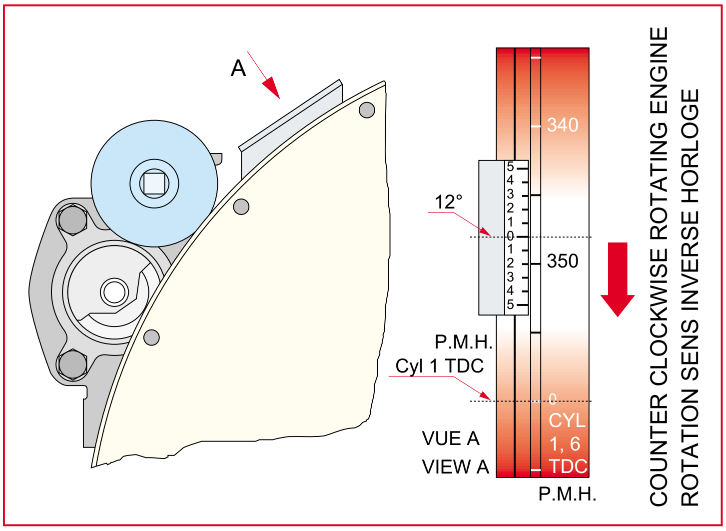


Fig. 11-8

11.4.2 Ring Gear Replacement

To change worn or damaged ring gear without removing the flywheel:

1 **Undo the screws** and remove the ring gear.

2 **The replacement ring gear** comes as two easy-to-fit half rings. The manufacturer has already provided tapped holes for the half ring ends.

3 **Fit the two half rings** and tighten the screws to the specified torque.

11.5 Turning device

To crank the engine:

1 **Remove the spark plugs** (see Section 16).

2 **Engage the cranking gear wheel located on side A** of the flywheel cover.

3 **Fit a 3/4" ratchet in place.**

4 **Crank the engine in one direction or the other** depending on the ratchet position.

5 **Disengage the cranking gear wheel.**

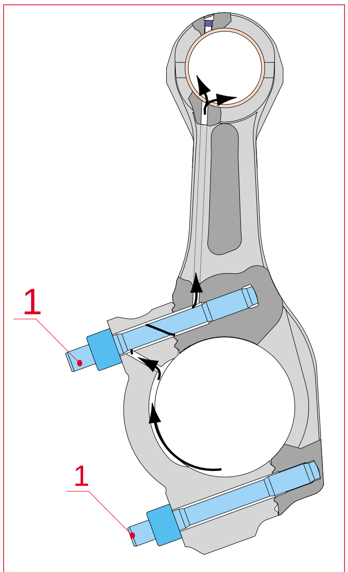
6 **Refit the spark plugs** (see Chapter 16).

Note: **A safety device prevents the engine being started when the cranking gear wheel is engaged.**

11.6 Connecting Rods and Pistons

11.6.1 Connecting Rod - Description

Characteristics and Dimensions
Material: special, drop forged steel
Mass: 32 kg
Shells: tri-metallic



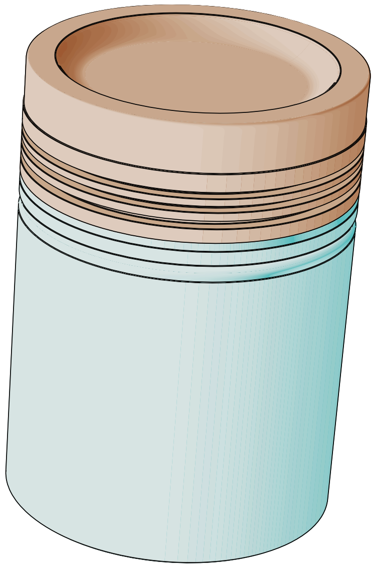
The connecting rods are drop forged with an I-shaped cross-section between the big- and small-ends. The big-end is split with a stepped parting plane and precision notched, allowing for crankpins of maximum diameter without preventing the connecting rod from passing through the cylinder liner for extraction and removal.

The big-end half-shells have axial guide tabs for correct positioning and the special crankshaft design means the upper shell needs no oil groove.

The two parts of the big-end are assembled by nuts that are hydraulically tightened on two studs.

The lower part of the small-end shell is broadened out to provide the largest possible bearing surface at the point where the load is greatest. The lubricating oil is fed to this surface via an oilway bored in the connecting rod stem.

The gudgeon pin is "float" fitted, and held by circlips in the axial direction. Its ends are closed by plugs that are tight fitted in the bore. Oil from the big-end and from the small-end shell travels along the gudgeon pin to the piston to lubricate the piston skirt.



11.6.2 Piston - Description

The piston is composed of an aluminium skirt and a forged steel head which are bolted together. The skirt is treated against corrosion (phosphate + graphite coating).
The piston crown is cooled by oil sprays incorporated in the engine block. An oilway in the skirt feeds oil into a ring-shaped circulation chamber in the head called the "gallery" and into a central space from where it is returned to the oil sump.
Oilways in the crankshaft feed oil from the main bearings to the big-ends and via passages in the connecting rods to the gudgeon pins and piston anti-friction bushes. From these bushes the oil runs along small passages to lubricate the skirt.

Caution: **Handle pistons carefully so as not to damage the anti-corrosion coating on the skirt.**

The piston rings include a fire ring, a compression ring and an oil scraper ring. The fire ring has a specially, extra hard-wearing coating. The compression ring is chrome-plated. The oil scraper ring is also chrome-plated and has an expander spring.

The word "TOP" is marked on the surface of the fire ring and of the compression ring which is to be fitted facing upwards.

11.6.3 Piston and Connecting Rod - Removal and Separation

Characteristics and dimensions:
Mass: 75 kg

1 **Remove the cylinder head.** Scrape the carbon deposits from the upper part of the cylinder liner. To do this, it is best to cover the top of the piston with fabric or paper that is firmly held in place (with an old piston ring) against the cylinder wall so as to collect the material scraped off.

2 **Remove the anti-polishing ring,** using a special-purpose tool if required. The piston pushes this ring out when the crankshaft is turned.

3 **Position the crankshaft** to 30° after TDC for side A and 30° before TDC for side B.

4 **Use the hydraulic tooling 861027 M30** to release the nuts (see Section 07).

5 **Remove the nuts** and the lower stud with the extractor tool 861152. The tool's lock screw has a left-hand thread.

6 **Raise the big-end cap** with its lower half-shell and remove it from the engine block.

7 **Remove the upper stud.**

8 **Raise the piston slightly** to remove the big-end upper half-shell without damaging the crankpin or cylinder liner.

9 **Protect the crankpin oil holes** with adhesive tape.

10 **Raise the piston and connecting rod** and remove them from the engine block without damaging the cylinder liner by using the connecting rod extractor tool 832002. The lever 836039 mounted on the inspection door is used to push the connecting rod upwards until the piston fire ring is clear.

11 **Maintain the piston and connecting rod in this position,**and remove the piston fire ring with the piston ring pliers 843003.

12 **Fit the lifting support 832002** into the piston fire ring groove.

13 **Raise the piston and connecting rod assembly clear of the engine block** taking care not to damage the cylinder liner.

14 **Use the pliers 843004** to remove one gudgeon pin circlip.

Caution! **Compress the circlip just long enough to remove it from its groove.**

15 **Drive out the gudgeon pin through the opposite end.** If this proves difficult at low temperature, heat the piston to 30°C in a bath of oil to facilitate removal.

16 **To clean and measure the piston rings** and grooves, remove the piston rings with pliers 843003 after noting their position so as to be sure to refit them in the correct groove. It is recommended to use these pliers so as not to put excess strain on the piston rings.

Note: **The use of other tools may damage the piston rings.**

Piston and connecting rod - removal

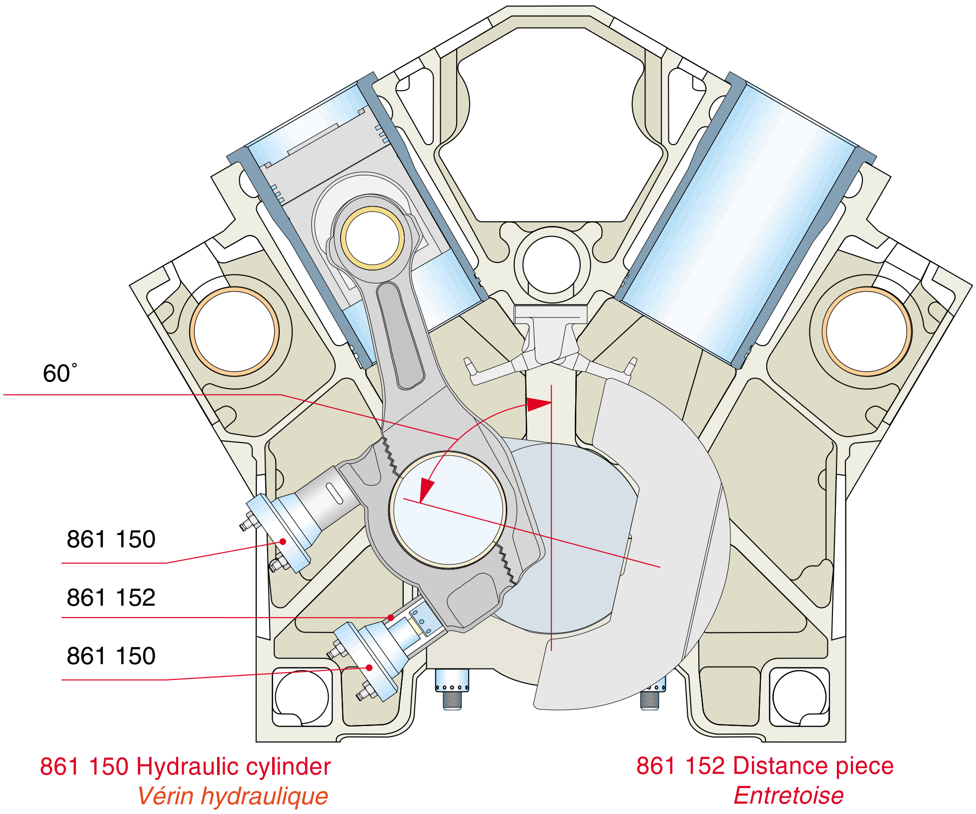


Fig. 11-9

11.6.4 Pistons, Piston Rings and Connecting Rod Bearing Shells - Maintenance

1 **Clean all the parts carefully.** Remove the piston rings with tool 843003 and clean all carbon deposits from the piston and piston ring grooves without damaging the cylinder.

Note : **Never clean the piston skirt with abarsive cloth.**

To facilitate cleaning, soak the fouled parts in kerosene or diesel fuel. Good quality solvent (Ardrox no. 668 or similar) can be used to clean the piston crown easily. Do not use chemicals to clean the piston skirt as they could attack the phosphate/graphite outer coating.

2 **Check the piston ring groove depths.**

Note : **When a cylinder liner is changed all the piston rings of the corresponding piston must be changed too.**

3 **Check the clearance of the gudgeon pin** and big-end bearing shells by measuring separately the diameter of the gudgeon pins and the shell bores.
When measuring the bore of the big-end bearing shell, the stud nuts must be tightened to the specified torque.

Measure the thickness of the bimetal shells using a ball-anvil micrometer to determine the extent of wear. Maximum permissible wear is shown in Paragraph 06.2.

If either of the two big-end bearing shells is worn, both must be changed.

Caution! **Bearing shells must be fitted with the utmost care.**

11.6.5 Piston crown - Fitting and tightening

1 **Lubricate the thread and seat of the screw head** with Molykote GN Plus.

2 **Tighten the four screws in a crosswise pattern** (torque 35 Nm).

3 **Loosen the four screws again.**

4 **Retighten the 4 screws in a crosswise pattern** to 15 Nm.

5 **Finish tightening** at a 90° angle.

11.6.6 Pistons and connecting Rods - Re-assembly and refitting

1 **Lubricate the gudgeon pin** and refit it from the same end as it was removed from, by positioning the end with the corresponding drawing number as it was before removal.
The cylinder number is stamped on the piston cap and on the connecting rod.
If the piston is changed, mark the cylinder number on the new piston at the same location as on the old piston.
If it proves difficult to fit the gudgeon pin into place at low temperature, heat the piston to 30°C in a bath of oil and the gudgeon pin can be put in place without difficulty.

2 **Refit the circlip.**

Caution! **Compress the circlip just long enough to refit it into the groove. Change the circlip if it is loose when refitted into the groove.**

---

3 **Fit the piston rings** using the pliers 843003 except for the fire ring. If the old piston rings can be reused take care to fit them the correct way up. Before fitting new piston rings check that the wear of the grooves does not exceed the maximum permissible value. Stagger the ring slots by 120°. The word “TOP” is marked close to the slot.

4 **Lubricate the piston** and fit the piston ring compressor 843002 around the piston. Check the piston rings are seated properly in their grooves.

5 **Fit the lifting tool 832002** to the top groove of the piston.

6 **Remove the adhesive tape** covering the crankpin oil holes and lubricate the crankpin with clean oil.

7 **Turn the crankshaft** to 30° after TDC for the connecting rod on side A and to 30° before TDC for the connecting rod on side B.

8 **Raise the piston and connecting rod.**

9 **Clean the bearings and the conrod big end bore** with “Careclean” type solvent and with a lean free rag.

10 **Check that the bearing half shells** are from same pair.

11 **Apply slightly engine oil** to the back of the bearing shells. Wipe away excess of oil with a clean lean free rag to obtain only a very thin oil film (cf Fig. 11-10 Rep C)

12 **Mount the upper big end bearing** onto the connecting rod.

Caution! **To install the bearing half-shell make sure that the tab is in the groove and that spacing between half-shells is the same on both sides.**

13 **Mount the lower big end bearing** (with oil channel if equipped) in the cap.

Note : **With the new square profile conrods, the oil channel has been suppressed on the lower bearing shell. For this conrod type only, the half bearing shells are symmetrical and can be mounted in the big end or in the cap.**

14 **Grease the internal bearing surface** with Vaseline paste (cf. Fig. 11-10 Rep B).

15 **Gently lower the piston and connecting rod** into the cylinder liner.

16 **Continue to lower the piston** until the piston ring compressor is in contact with the cylinder liner.

17 **Use the lever mounted on the inspection door** to hold the connecting rod.

18 **Remove the lifting gear from the piston ring groove.**

19 **Fit the fire ring.**

20 **Loosen the piston ring compressor** to include the fire ring.

21 **Continue to lower the assembly** until the connecting rod rests on the crankpin.

22 **Clean the upper edge of the lower bearing** (contact surface between both half bearing shells) and coat only this edge with “Molykote GN Plus” (cf. Fig. 11-10 Rep A).

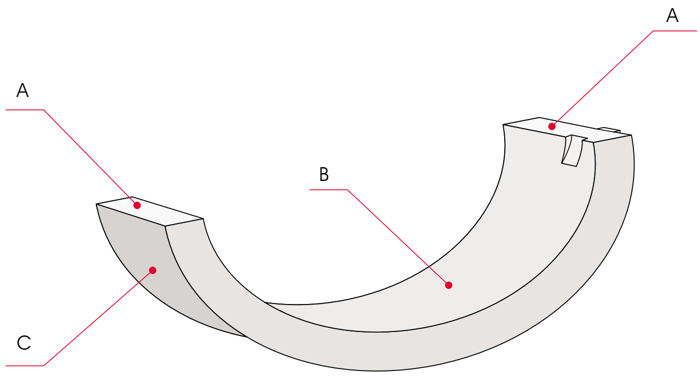


Fig. 11-10

Caution : **No Molykote GN Plus on the bearing shell crankshaft surface contact.**

23 **Check by feel at the side of the cap** that the cap and the bearing are in ligne and that no step can be detected. Check the same thing between the connecting rod and the bearing.

24 **Check that the conrod and the cap** have the same serial number.

25 **Degrease the contact surface** between the nuts and the cap.

26 **Clean carefully the threads** of the studs and the nuts, and check that there is no impact on the threads.

Important : **To make easily the assembly, for each crankpin, the B side conrod will be fitted before the A side conrod.**

11.6.7 Connecting rod tightening

Important : **Each conrod cap must be fitted and hydraucally thightened on the conrod before turning the crankshaft and following conrod fitting.**

1 **Put in place by hand** the upper stud and put in place the conrod cap against the conrod.

2 **Check that the bearing** is always well located.

3 **Tighten by hand** the upper nut.

4 **Fit the lower stud** and tighten it with the stud tightening tool (SPC 8030011) at 100 Nm.

5 **Tighten by hand** the lower nut.

6 **Remove the upper nut.**

7 **Tighten the upper stud** with the stud tightening tool (SPC 8030011) at 100 Nm.

8 **Fit and tighten** until contact the upper nut.

9 **Check alignment** of the conrod and the conrod cap.

10 **Check by feel** at the conrod side that the cap mating faces and the bearings are in ligne and that no step can be detected.

11 **Tighten the nuts** on the cap with the nut rotating tool.

12 **Write a mark** on the nut and on the cap as showed in the Maintenance manual Chap. 07

13 **Fit the jacks** and execute the following tightening procédure :

- Compress the jacks if necessary.
- Pressurise to 380 bars.
- Tighten the 2 nuts with the nut rotating tool (SPC8610027).
- Release the pressure slowly to 0 bar.
- Pressurise to 650 bars.

Caution : **Never tighten more than 680 bars. In case of overpressure it's absolutely necessary to change the studs.**

- Tighten the nuts with the nut rotating tool.
- Release the pressure slowly until around 600 bar.
- Pressurise to 630 bars.
- Check that the nuts can't move. Finish the test like if you want to tighten the nut.
- Release the pressure slowly.
- Check that the marks done in step 1 has rotated more than 90°.
- Write a permanent mark (A or B) on the block to prove that the checking process has been done.

- Check that the connecting rod still has some axial clearance after the stud nuts have been tightened.

Note : **In case of doubt, don't hesitate to return to step 2**

Note : **The conrod jacks must consist of one jack with 90° degree positional connections and the other jack should have straight connections. The jack with straight connexion is used for fitting B bank conrod lower stud.**

14 **Fit a new anti-polishing ring** to the cylinder liner.

15 **Refit the cylinder head.**

11.6.8 Engine starting procedure

1 **Change the lub-oil filters** and clean the centrifugal filter (if it has not been done before).

2 **Start the engine** during 5 mn at idle speed and stop it.

3 **Control by hand** the conrod temperature. The temperature must be around 45°C. The conrod must be moved axially freely.

4 **Restart the engine** during 10 mn at rated speed with 25% of load minimum and stop it.

5 **Control the conrod temperature** with a contact or infrared thermometer. The temperature must be around 70°C. The conrod must be moved axially freely.

6 **Run the engine** for a 5 hours test.

7 **After one hour running,** reset the calibration of the lub-oil pump module regulating valve in order to obtain 4.5 to 5 bars (follow the operation instruction WPH100596).

8 **Check lack of metal particles** in the centrifugal filter.

The engine is ready for operation.

12. Cylinder Heads and Valves

12.1 Description

1 Support de culbuteur
Bracket
2 Culbuteur
Rocker arm
3 Palonnier de soupape
Yoke for valves
4 Bride de préchambre
Flange for prechamber
5 Culasse
Cylinder head
6 Rotocap
Rotocap
7 Siège de soupape ECH
Exhaust valve seat
8 Soupape ECH
Exhaust valve
9 Soupape ADM
Inlet Valve
10 Siège de soupape ADM
Inlet valve seat

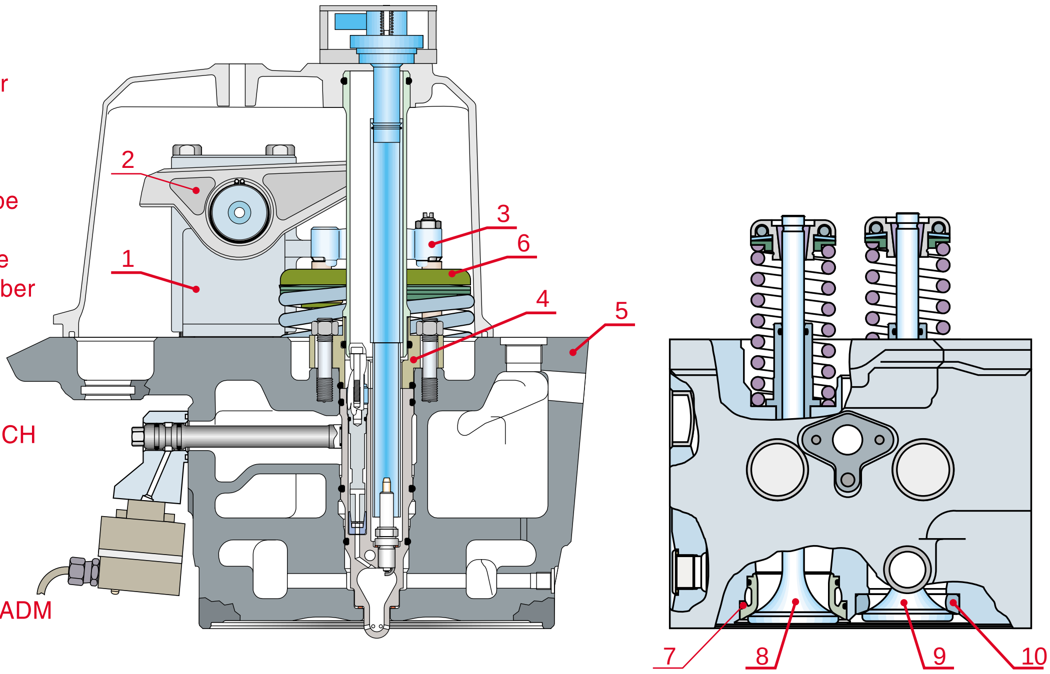


Fig. 12-1 culassg9748

Characteristics and Dimensions
Material: Grey cast iron
Tensile strength: 250-300 N/mm2
Mass: 92 kg
Combustion chamber
- design pressure: 200 bars
- test pressure: 240 bars
Coolant jacket
- test pressure: 10 bars
Service temperature
- coolant return temperature: 95°C

The cylinder heads are made of high-strength, grey cast iron. Each cylinder head has two intake valves, two exhaust valves and a prechamber in which the spark plug is housed. The cylinder heads are fastened onto the cylinders by four studs and hydraulically tightened nuts. A metal gasket is fitted between the cylinder liner and the cylinder head to ensure that the combustion chamber is airtight. The air intake duct and the exhaust manifold is a single component which is fastened to the cylinder head by six screws. The fastening system with four tie-rods (studs) and the truncated cone shape are classical, tried and tested features of the cylinder heads. The use of four studs facilitates maintenance and means the air intake and exhaust gas ducts can be properly configured and of large dimensions. This type of cylinder head uses the “double-deck” technique, i.e. a first deck comprising a comparatively thin wall and transfer of mechanical stress forces to a very robust intermediate deck; this improves cooling and makes for rugged cylinder heads. The parts of the cylinder head subjected to the greatest thermal stresses (valves and prechambers) are cooled by water circulating through specially adapted cavities. The prechamber is described in Section 16.

12.2 Cylinder head removal and refitting

12.2.1 Removal

1 **Drain the cooling system.**

2 **Remove the spark plugs.**

3 **Take off the cylinder head stud caps.**

4 **Remove the rocker cover.**

5 **Rotate the crankshaft** to bring the intake and exhaust valves to the closed position; remove the rocker bracket and push rods.

6 **Remove the number of pipes necessary,** the supply line, prechamber and main chamber, the oil system pipes and protect their unions and those of the exhaust and intake ducts.

7 **Remove the multiduct / cylinder head retaining screws.**

8 **Install the hydraulic tool 861033 M36.**

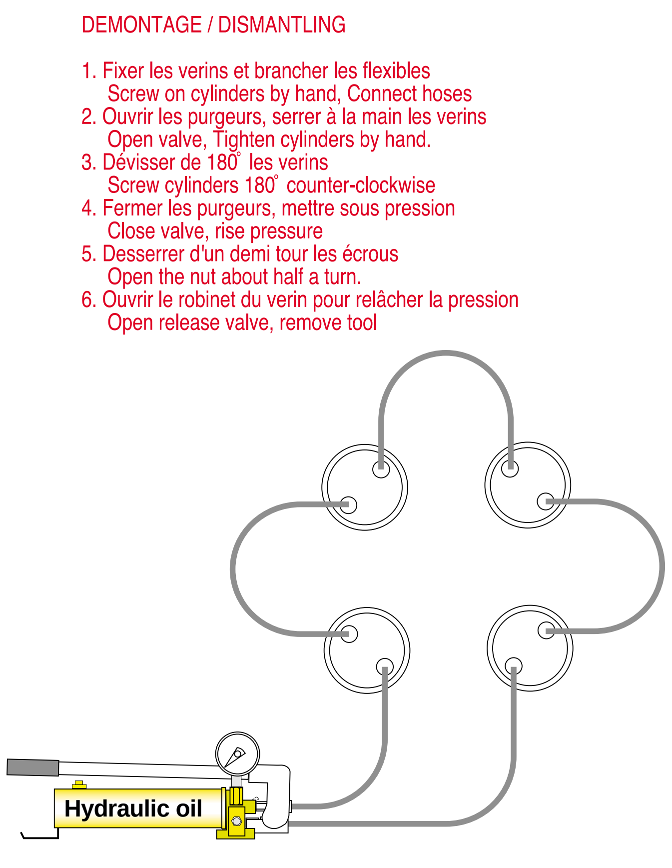


Fig. 12-2 fhyd-4a9748

9 **Remove these nuts.**

10 **Remove the cylinder head** with the special lifting tool 832004.

11 **Block the cylinders** with a piece of plywood or similar object and protect the stud threads with the caps provided.

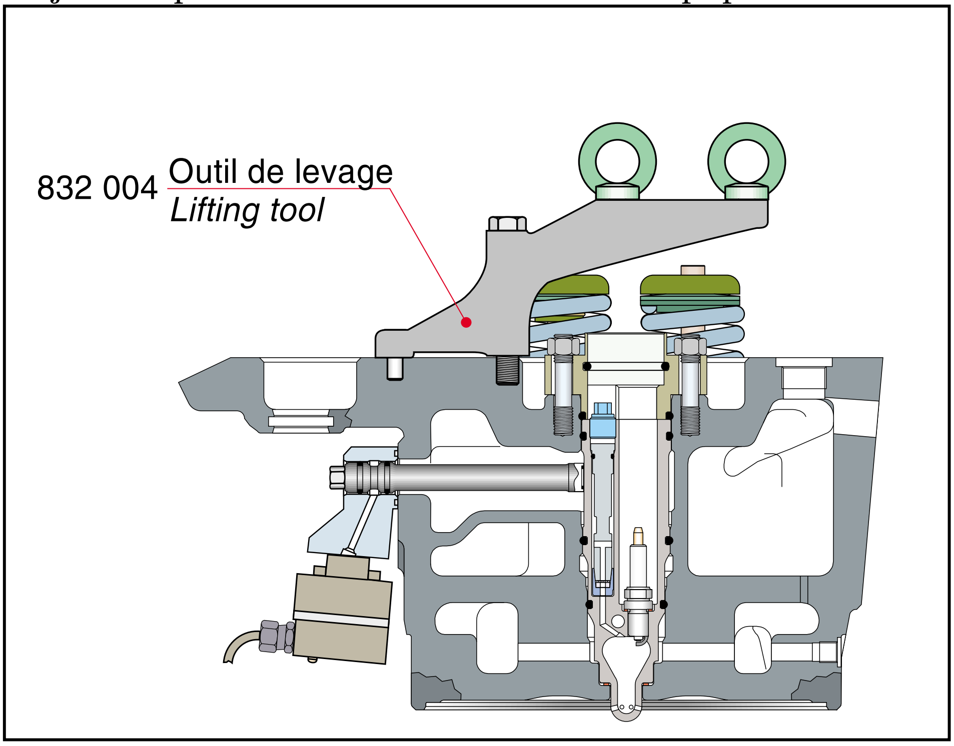


Fig. 12-3 f2012559748

12.3 Maintenance

12.3.1 General

At each cylinder head overhaul, every valves, guides, seats, springs, rotocaps and O-rings must be replaced by new ones. The controls and remounting process are explained in the Reconditionning Book. Contact the Wärtsilä France Network.

Another possibility is to contact the Wärtsilä France Network to replace your cylinder head by pre-equiped cylinder head sub-assembly exchanger.

12.3.2 Cylinder head - refitting

1 **Clean the mating surface** between the cylinder head and multiduct, replace the cylinder head gasket, change the multiduct gasket and fit new O-rings on the coolant passage and push rod sheaths.

2 **Lubricate the O-rings** with oil or grease.

3 **Fit the lifting tool 832004 onto the cylinder head.**

4 **Set down the cylinder head** without damaging the multi-duct gasket. Check that it is undamaged and correctly fitted.

5 **Coat the screws** between the multiduct and the cylinder head with high temperature grease and tighten the screws.

6 **Fit the retaining nuts** on the cylinder head.

7 **Install the hydraulic tool 861033 M36** and tighten the nuts to nominal torque given chapter 07. Check that the screws between the multiduct and cylinder head are still tight.

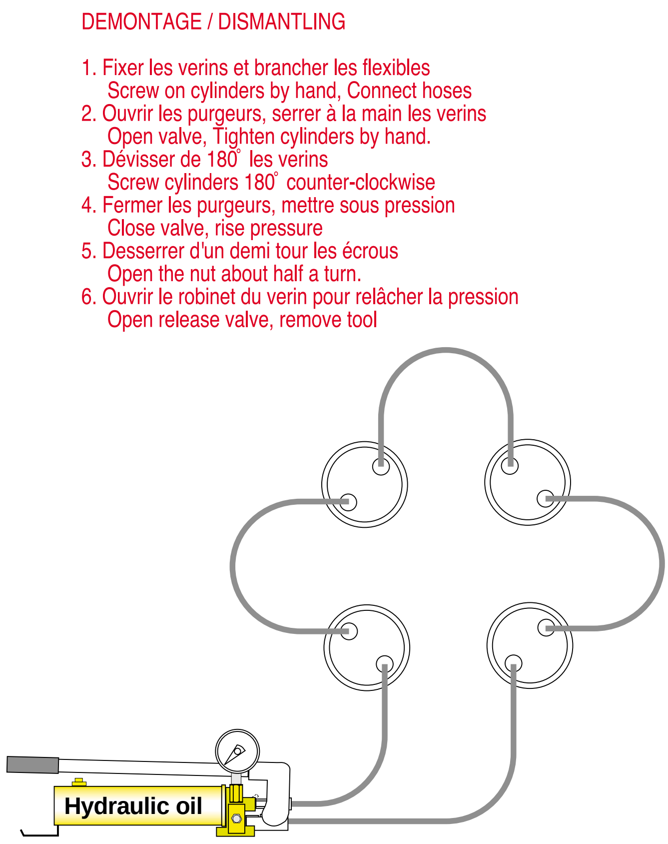


Fig. 12-4 fhyd-4a9748

8 **Connect all the fluid pipes** (gas and lubrication systems).

9 **Fit the push rod sheaths.**

10 **Fit the push rods** and rocker bracket.

11 **Adjust the valve clearance** as shown in Section 12.2.4. (Values are indicated in Section 06).

12 **Fit the rocker cover.**

13 **Protect the stud threads** with the caps provided.

14 **Before starting the engine,** fill the cooling system. Rotate the crankshaft through two turns with the cranking gear while the spark plugs are removed.

12.3.3 Valve clearance adjustment

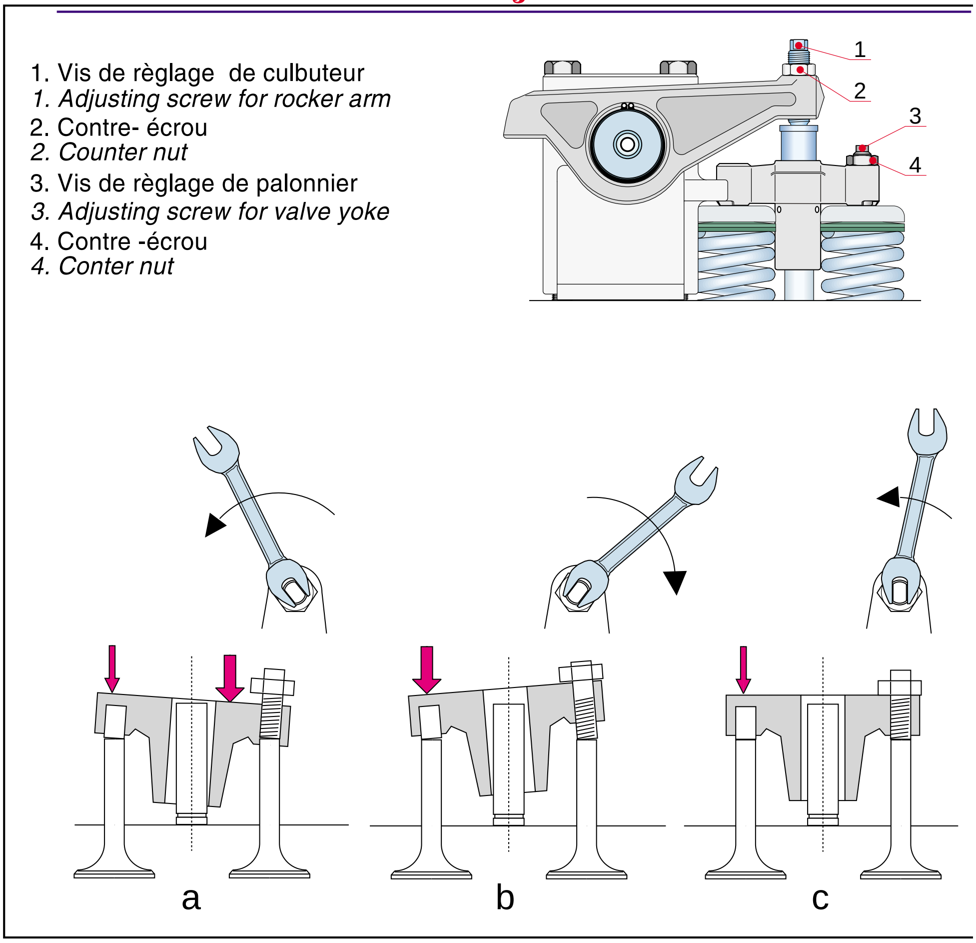


Fig. 12-5 f2012539748

1 **Position the crankshaft** so the corresponding piston is at TDC (ignition).

2 **Loosen the adjustment screw lock nuts** of the rocker arms (2) and yokes (4) and turn the adjuster screws counter-clockwise until a comparatively large clearance is obtained.

3 **Press on the top of the yoke** until its fixed end abuts against the valve stem. Tighten the adjuster screw (3) until it touches the end of the valve stem and note the wrench position (a). Then press on the fixed end tightening the adjuster screw until the yoke tilts and the clearance between the guide and the stem chan-

ges sides and the fixed end of the yoke straightens and is no longer in contact with the valve stem. Note the wrench position (b).

4 **Turn the adjuster screw** counter-clockwise to the balanced position " c " between " a " and " b "; tighten the lock nut (4).

5 **Insert a feeler gauge** of the same thickness as the required clearance between the yoke and the rocker tip. Tighten the adjuster screw (1) until a minimum effort is required to move the feeler gauge. Lock the adjuster screw in the corresponding position by tightening the lock nut and check the clearance after tightening.

12.4 Intake valves, exhaust valves and valve seats

Characteristics
Material: high tensile steel

Diameter:
- intake valve 73 mm
- exhaust valve 66 mm

Valve seat
Material: high tensile steel

Seat angle:
- intake valve seat: 20°
- exhaust valve seat: 30°

12.4.1 Description

Each cylinder has two intake valves and two exhaust valves made of high tensile, hardened steel. The intake valves are larger than the exhaust valves.
The valve stems slide in cast iron guides which are shrink-fitted in the cylinder head and may be changed when worn.
The O-ring in the upper part of the guide bore forms an air tight seal with the valve stems.
The valves are held against their seats by a return spring and are fitted with a rotator.
The valve seats are shrink-fitted in the cylinder head and can be changed when worn. The exhaust valve seats are water-cooled and are fitted with two O-rings.

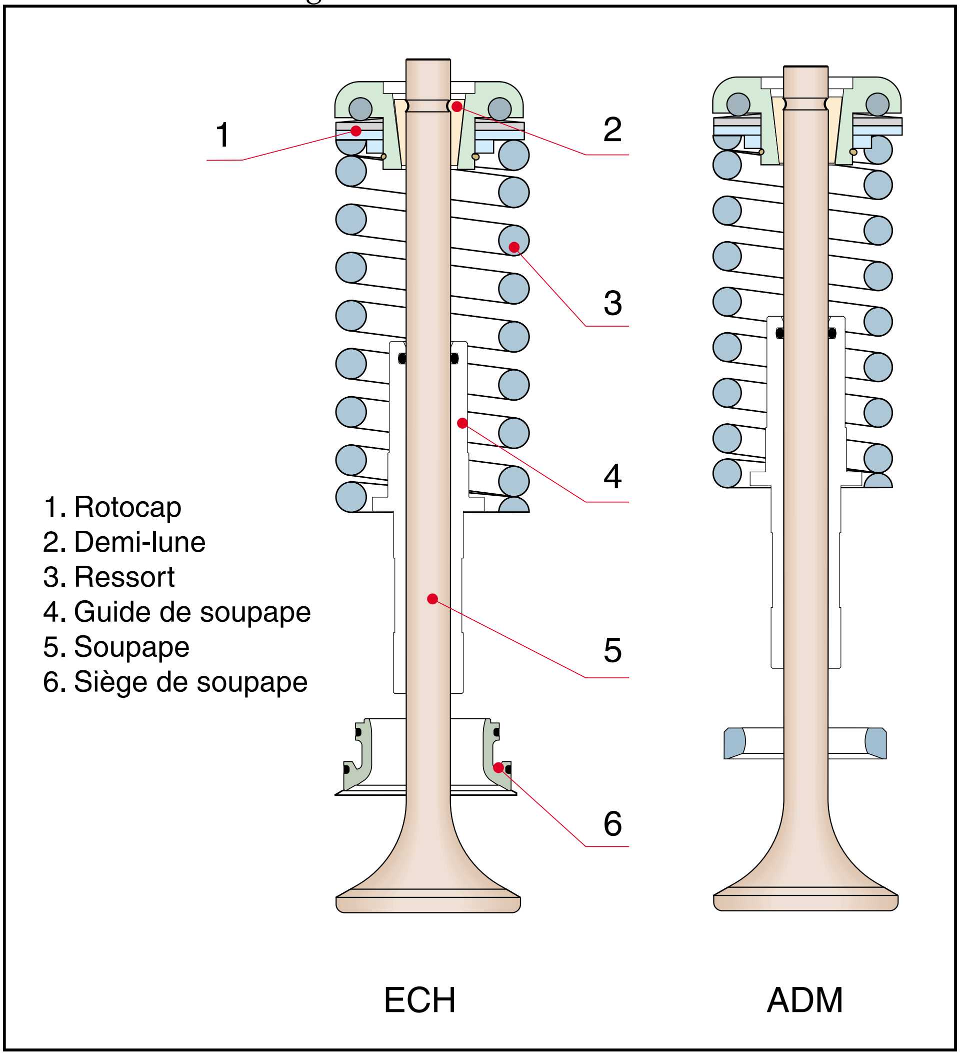


Fig. 12-6

12.5 Repair procedure

12.5.1 In case of rotocap or valve failure

This procedure must be applyed cylinder by cylinder from dismantling to remounting. The cylinder head is fitted on the engine.

12.5.2 Dismantling

1 **Turn the crankshaft to move the piston** until TDC injection (valve closed, pushrod free) of the failed cylinder head

2 **Remove the rocker arm**

3 **Fit the tool** 846010 according to Fig. 12-7

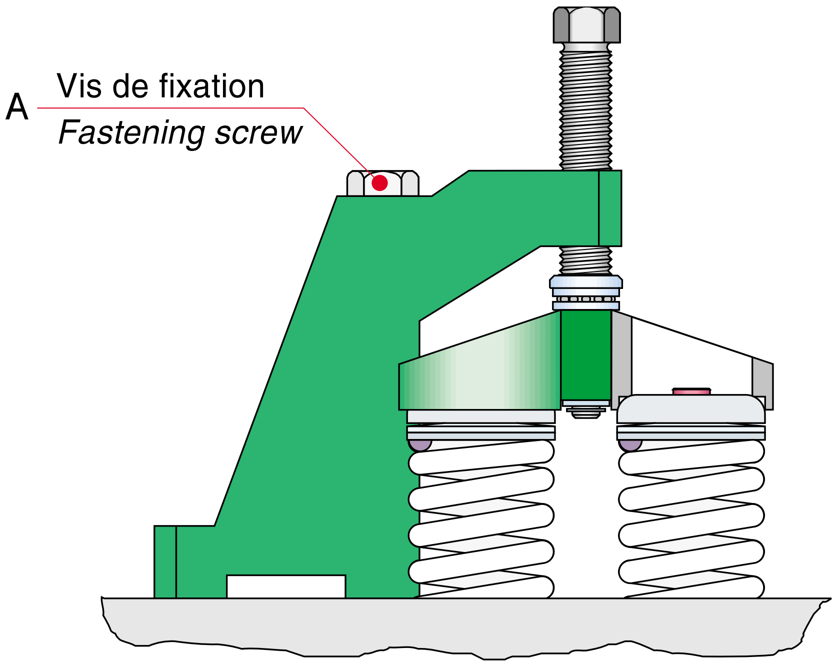


Fig. 12-7

4 **Compress the springs** about 15-20 mm by the screw.

5 **Knock at the centre of the valve discs** with a soft piece of wood, plastic hammer or similar, whereby the valve cotters come loose and can be removed.

6 **Unload the tool.**

7 **Spring retainers and springs can now be removed.**

8 **Note the marks of the valves**or mark them as shown on Fig. 12-8 to be able to refit them at the same place if they are reusable

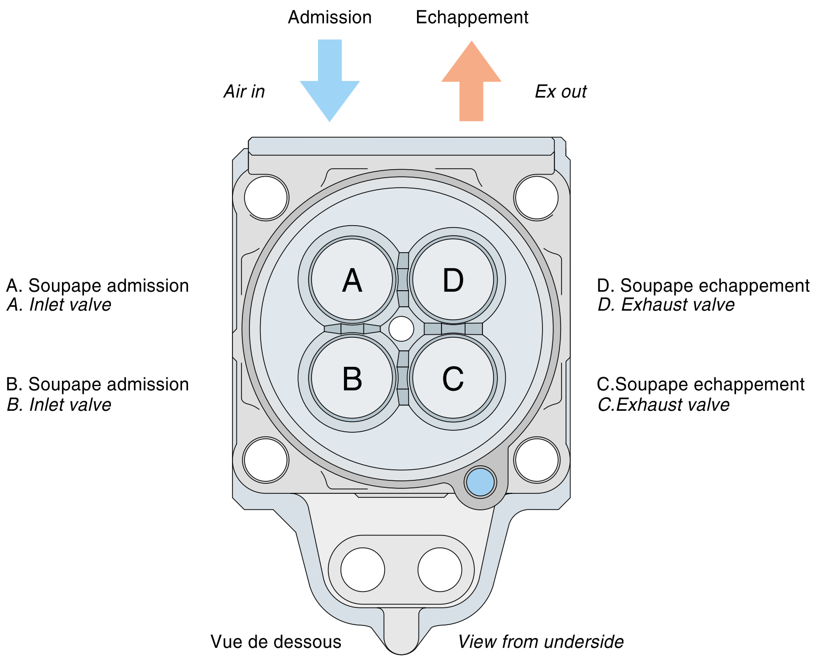


Fig. 12-8

12.5.2.1 Remounting

The remounting should be done with two new valves colters.

1 **Replace failed spring or rotocap**

2 **Put on the springs** and rotocap on the valve. (See Fig. 12-6)

3 **Chanfer the sharp edges** of the two new valves colters. (see Fig. 12-9)

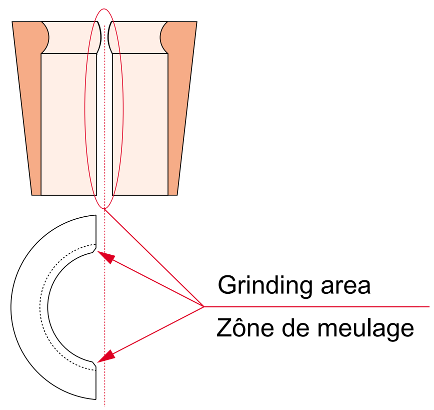


Fig. 12-9

4 **Compress the spring** with the tool set.

5 **Put in the valve colter.** Share out the clearance between the two valves colters. (See Fig. 12-10)

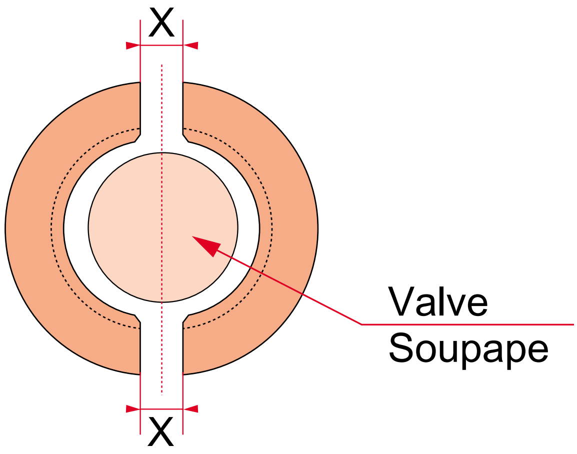


Fig. 12-10 f2012549748

6 **Unload the springs.**

7 **Check that the valve colters** are fitted properly.

8 **Fit the rocker arm assembly.** Follow tightening torques given chapter 7

9 **Adjust the valve clearance.**

12.5.3 In case of water leakage

In case of water leakage, remove the cylinder head and make a pressure test with a 10 bar test pressure.

13. Camshaft Drive

13.1 Description

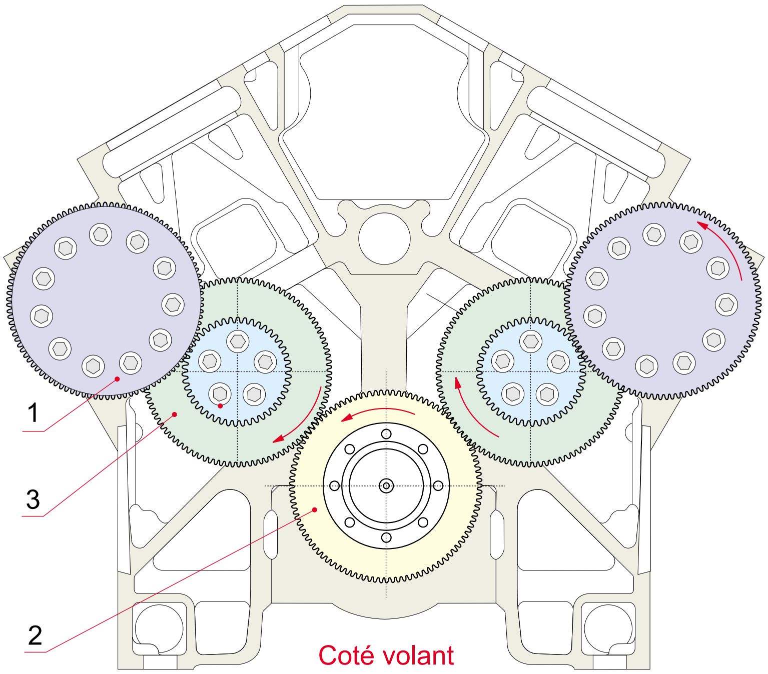


Fig. 13-1

The camshaft drive system (1) is incorporated entirely within the engine block. The drive system is identical for both camshafts. The crankshaft drives a large intermediate gear via a gear wheel. These two gears are friction fitted and contact is ensured by five screws. The small intermediate gear drives the camshaft gear wheel. The gear train is lubricated by oil sprays. The camshaft rotates in the same direction as the crankshaft but at half the speed of the crankshaft.

13.2 Intermediate and camshaft gears

The case-hardened intermediate gears are fitted on a common shaft and mechanically clamped. The camshaft bearings are lubricated by oil from an oilway in the camshaft. The drive wheels are lubricated by oil sprays. Timing is adjusted by separating the two intermediate gear wheels. The camshaft can then be adjusted relative to the crankshaft.

Caution! **If timing is incorrectly set, the pistons will strike the valves and cause serious damage to the engine.**

13.2.1 Camshaft gear train - maintenance

Whenever possible check the condition of the gears. Measure the bearing clearance as shown in Section 06. Early detection of worn gear teeth can prevent serious damage.

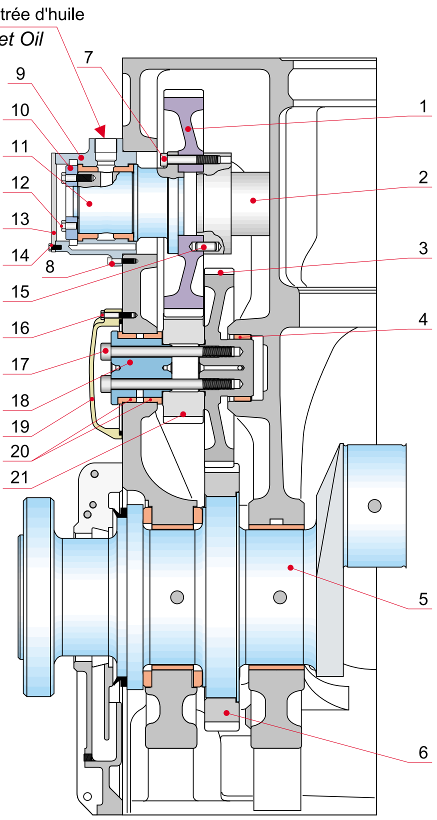
13.3 Timing

Timing is adjusted by altering the relative position of the two intermediate gears (3 and 21) (which changes the position of the camshaft relative to the crankshaft).

This operation can be carried out without removing the flywheel and must be with the cylinder heads and rocker gear cylinders A1 and B1 mounted.

13.3.1 Bank B timing relative to the exhaust cam

Côté B - B side



1. Pignon d'arbre à came	*1. Gear wheel for camshaft*
2. Elément d'arbre	*2. Extension shaft*
3. Pignon intermédiaire	*3. Intermediate gear wheel*
4. Coussinet	*4. Bearing bush*
5. Vilebrequin	*5. Crankshaft*
6. Pignon de vilebrequin	*6. Gear wheel for crankshaft*
7. Vis	*7. Screw*
8. Vis	*8. Screw*
9. Palier	*9. Housing*
10. Cale	*10. Shim (side B)*
11. Elément d'arbre	*11. Extension shaft*
12. Vis	*12. Screw*
13. Couvercle	*13. Cover*
14. Vis	*14. Screw*
15. Goupille	*15. Guiding pin*
16. Vis	*16. Screw*
17. Vis	*17. Screw*
18. Arbre	*18. Shaft*
19. Couvercle	*19. Cover*
20. Coussinet	*20. Bearing bush*
21. Pignon intermédiaire	*21. Intermediate gear wheel*

Fig. 13-2

Note: **The relative position of the two gear wheels is set at the factory and must not be changed unless absolutely necessary.**

1 **Crank the engine** to gain access to the intermediate gear cover (19) through one of the openings in the flywheel.

2 **Undo the screws (16)** and remove the intermediate gear cover (19). Remove the camshaft gear wheel side protecting box.

3 **Make sure the screws (17)** of the intermediate gears (3 and 21) on sides A and B are loose.

4 **Timing is to be set on the exhaust cam** to prevent the piston hitting the exhaust valves.

5 **Fit the timing tool 848007** to the exhaust rocker arm push rod (left-hand rod when the operator is facing the cylinder head).

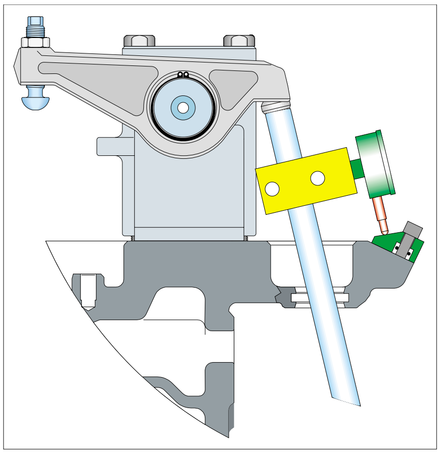


Fig. 13-3

6 **Crank the engine** in the direction of operation to position it 162° after TDC of cylinder B1.

7 **Rotate the camshaft gear (1) by hand** to bring the back of the exhaust cam of the cylinder in question opposite the dial gauge tip.

8 **Remove any slackness from the exhaust rocker arm** of the cylinder in question in order to ensure the dial gauge support and fine tune the adjustment.

9 **Set the dial gauge needle to zero** with a stroke of 8 mm.

10 **Crank the camshaft gear wheel by hand again** in the direction of operation to raise the cam by 6.11 + 0.02 mm.

11 **Lock the intermediate gear wheels (3 and 21)** with the screws (17). Torque setting: 200 Nm.

13.3.2 Bank B timing check

1 **Crank the engine in the reverse direction of operation** until the dial gauge is at zero (cancel the 6.11 mm cam lift).

2 **Crank the engine in the direction of operation** to reposition the crankshaft at 162° after TDC for cylinder B1.

3 **Check the cam** is lifted by 6.11 + 0.02 mm.

4 **Repeat the adjustment operation** if the recorded value is outside the tolerance.

5 **Tighten the intermediate gear screws (17) permanently.** Torque setting: 755 Nm.

6 **Remove the tooling.**

13.3.3 Bank A timing relative to the exhaust cam

Coté A   A Side

1	Pignon d'arbre a cames	*Gear wheel for camshaft*
2	Elément d'arbre	*Extension shaft*
3	Pignon intermédiaire	*Intermediate gear wheel*
4	Coussinet	*Bearing bush*
5	Vilebrequin	*Crankshaft*
6	Pignon de villebrequin	*Gear wheel for crankshaft*
10	Entraineur du codeur	*Encoder driver*
11	Elément d'arbre	*Extension shaft*
12	Vis	*Screw*
15	Goupille	*Guiding pin*
16	Vis	*Screw*
17	Vis	*Screw*
18	Arbre	*Shaft*
19	Couvercle	*Cover*
20	Coussinet	*Bearing bush*
21	Pignon intermédiaire	*Intermediate gear wheel*
22	Codeur angulaire	*Encoder*
23	Accouplement	*Coupling*
24	Support codeur	*Encoder support*
25	Vis	*Screw*
26	Bague d'étanchéité	*Sealing ring*
27	Tole de fixation	*Fixing plate*

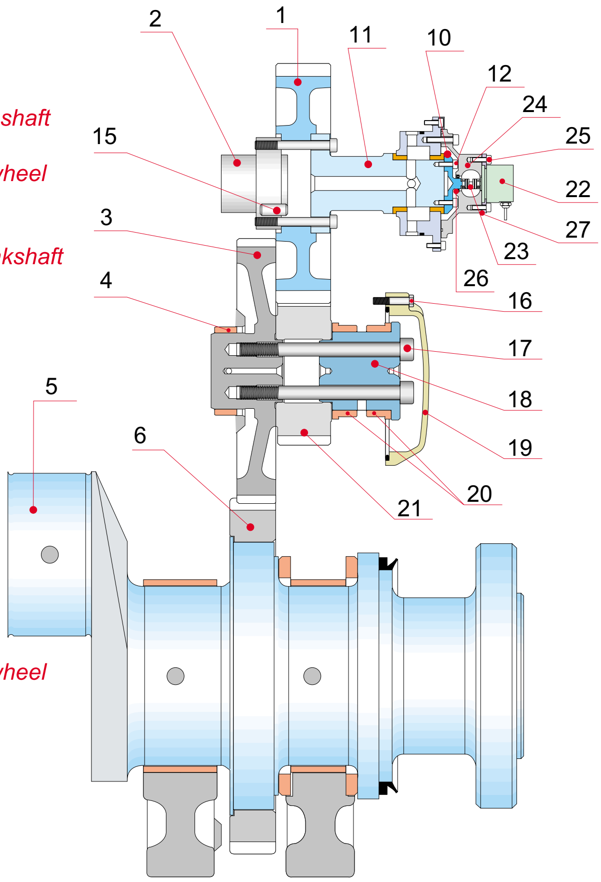


Fig. 13-4 2013519748

1 **Crank the engine in the direction of operation,** to position the crankshaft at 162° after TDC of cylinder A1.

2 **Fit the rocker assembly** of cylinder head A1.

3 **Fit the timing tool assembly 848007** to the intake rocker stem (right-hand stem when the operator is facing the cylinder head).

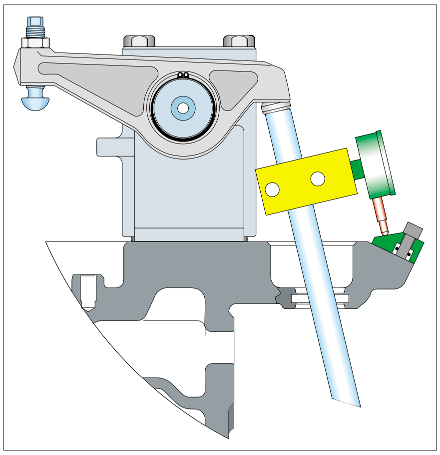


Fig. 13-5 8480079748

Note: **Position the tooling crosswise to the engine.**

4 **Continue as for camshaft timing adjustment on side B**

see Section 13.3.1

13.3.4 Bank A timing check

1 **Crank the engine in the reverse direction of operation** until the dial gauge is at zero (cancel the 6.11 mm cam lift).

2 **Crank the engine in the direction of operation** to reposition the crankshaft at 162° after TDC for cylinder A1.

3 **Continue as for camshaft bank B timing check**
see Section 13.3.2

13.4 Camshaft gear train removal

1 **Remove the flywheel.**

2 **Remove the oil lines** (sides A and B).

3 **Remove the angle encoder (22)** (side A).

4 **Remove the drive gear covers** on either side of the engine block.

5 **Extract the screws (14)** and remove the cover (13).

6 **Remove the encoder drive (10)** (side A).

7 **Remove the screws (8)** and the housing (9) (remove the No. 9 housing bearing bushes if necessary).

8 **Remove the screws (7)** and the shaft extension (11).

9 **Remove the camshaft gear wheel** through the side port of the engine block.

10 **Remove the screws (16)** and covers (19).

11 **Remove the screws (17)** and intermediate gears (3) and (21).

Caution! **Do not drop the gears on the engine block while dismantling.**

13.5 Crankshaft gear wheel for camshaft drive

The crankshaft drive gear (6) is interference fitted on the crankshaft.

Fitting and removal are intricate operations and must be carried out by the engine manufacturer.

13.6 Camshaft drive gear fitting

1 **Fitting is the reverse procedure to removal.**

2 **Repeat the timing adjustment** after refitting the intermediate drive gear. See Section 13.3

3 **Angular encoder timing (22)** see Section 23.12.7.

14. Rocker gear and camshaft

14.1 Valve mechanism

1. Galet
   Roller
2. Axe de galet
   Roller pin
3. Poussoir
   Push button
4. Corps de guidage
   Roller tappet housing
5. Douille de protection
   Protection socket
6. Tige de poussoir
   Push rod
7. Circlips
   Circlips
8. Culbuteur
   Rocker arm
9. Vis
   Screw
10. Palonnier de soupape
    Valve strap
11. Support de culbuteur
    Rocker holder
12. Vis
    Screw
13. Vis de sécurité
    Safety screw
14. Joint torique
    O-ring

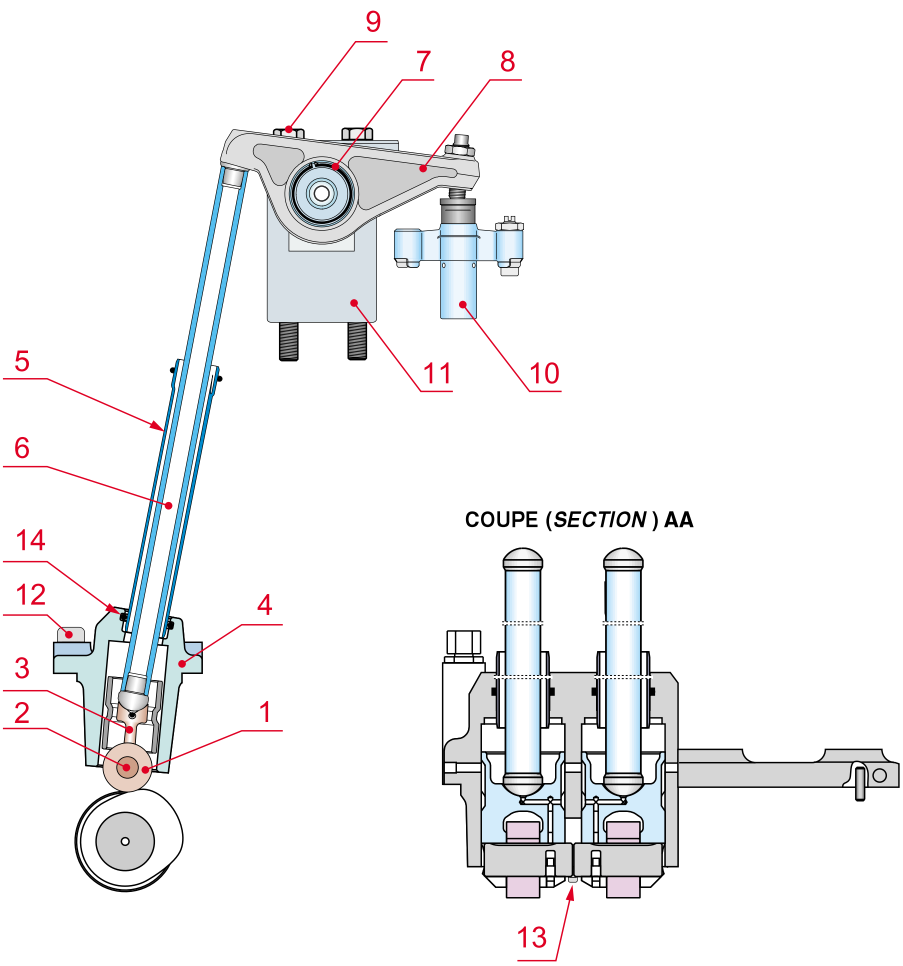


Fig. 14-1

14.1.1 Description

The valve mechanism controls the movement of the inlet and exhaust valves in accordance with a fixed timing arrangement.

It is composed of roller pushrods (3) which slide within guides (4), hollow pushrods (6) with ball joints, rocker arms (8) pivoting on a pin fastened through the rocker bracket (11), and of yokes (10) guided by a vertical spindle protruding from the cylinder head.

14.1.2 Function

The pushrod motion is controlled by the cam profile and is transmitted by the stem to the rocker arm which in turn controls the valves via a yoke. The rocker bracket is mounted on the cylinder head by two long screws. The steel rocker pin is force-fitted into the bracket and its position is important for the supply of lubricating oil to the rocker gear. The rocker arms actuate the yokes which are guided by an eccentric spindle. To allow expansion, clearance is left between the rocker arm and yoke. All adjustments are made with the engine cold, as per the instructions in Section 12. Each yoke controls two valves simultaneously. The oil for the yoke is fed via oilways in the cylinder head, the rocker bracket and rocker arm. The rocker arm can only supply oil when it is in the “valve open” position. The oil that is fed into the yoke lubricates the valve rotation mechanism. The oil returns to the crankcase sump by running freely within the pushrod protector tubes.

14.1.3 Rocker gear maintenance

This mechanism is normally maintenance free. However, component wear should be checked at the times specified in Section 04. See Section 06 for settings and limits of wear. Mark the components when dismantling the rocker gear so they can be refitted in the same position to avoid unnecessary wear.

14.1.3.1 Rocker gear removal

1 **Remove the rocker covers,** and camshaft cover for the cylinder in question.

2 **Rotate the crankshaft** to a position where the valve tappet rollers are free.

3 **Undo the screws (9),**and remove the rocker bracket (11).

4 **Remove the circlip (7),** with the pliers, and the rocker arm (8).

5 **Remove the pushrods (6)** and tubes (5).

6 **Remove the screws (12)** and take off the body (4).

7 **Undo the safety screws (13).**The pushrods can then be removed. Mark the parts beforehand so they can be put back in the correct position.

8 **The tappet (1) and its spindle (2)** can then be removed by pushing the stop pin into the spindle. As the pin is free, stop it from coming out of the spindle with adhesive tape.

14.1.3.2 Rocker gear inspection

1 **Clean the rocker arm bore** and measure the extent of wear. While cleaning, take particular care of the oil holes.

2 **Clean and inspect the pushrod components** taking care of the oil holes.

3 **Measure the bore** in which the pushrod slides to assess the extent of wear.

4 **Replace the O-rings (14)** of the housing (4) if they are hardened or damaged.

14.1.3.3 Rocker gear refitting

1 **Lubricate the pushrod tappet and spindle** with clean oil and assemble them in alignment with the position marks made at the time of removal.

2 **Insert the pushrods (3)** into their guide housing (4).

3 **Fix the closure plate** with the screws (13).

4 **Lubricate the O-rings,** fit the tubes (5) and rods (6) in the guide housing (4).

5 **Refit the yoke (10).** See Section 12.2.4. for adjustment.

6 **Lubricate the rocker bore (8),** and fit it on the bracket.

7 **Fit the circlip (7) with the pliers;** check the axial clearance of the rocker and make sure it pivots freely.

8 **Turn the crankshaft** so that the Inlet and Exhaust cam profile are on the cylindrical part of the cam (TDC Ignition) for the cylinder head that we want to fit to the rocker arm bracket.

9 **Mount the rocker arm bracket (11)** on the cylinder heads and tighten the screws (9) to the nominal torque (see chapter 7).

10 **Connect the lubricating oil lines.**

11 **Check the valve clearance** as in Section 06.1 and close the covers.

14.2 Camshaft

Characteristics and dimensions
Material: special case-hardened steel
Space requirements for camshaft maintenance: 3 cyl. 900 mm; 4 cyl. 1200 mm
Mass per section: 55/75 kg

14.2.1 Description

The camshaft is composed of three sections for the W 12V220 and W 18V220 engines.

The sections are joined together by flanges. The camshaft rotates in bushes that are nitrogen fitted into the engine block. They may be removed with a special hydraulic tool.

The camshaft may be removed from the engine or fitted into it from either end.

The lubricating oil for the camshafts is fed in at the flywheel end via the governor drive gear protector box (side A) or via the box on side B.

The oil flows through the camshaft along an oilway and lubricates the camshaft bearings.

14.2.2 Removal of a camshaft section

1 **Uncouple the alternator and engine.**

2 **Remove the flywheel.**

3 **Remove the flywheel cover.**

4 **Remove the side access doors,** remove the rocker gear brackets.

5 **Remove the camshaft drive gear** without touching the intermediate gears (See Section 13.4)

6 **Undo the flange clamping nuts.**

7 **Remove the shaft end closure.**

8 **Separate the camshaft sections.**

9 **Fit the support tools.**

10 **Note the position of the parts** so they can be refitted in the same location.

11 **Move the freed section carefully** toward the end of the engine and extract it.

14.2.3 Re-installing the camshaft section

1 **Clean and degrease all screw threaded components** and the connecting flange faces.

2 **Clean and lubricate the anti-friction bushes** with clean oil.

3 **Carefully slide the camshaft section into place** using the support tool. Use the marks made as in Section 14.2.2 to position the different sections correctly.

4 **Change the nuts for new ones** and tighten them to the torque specified in Section 07.

5 **Refit the camshaft gear** (see Section 13.4).

6 **Refit the protecting boxes (9)**
(see figs. 13-2 and 13-3).

7 **Carefully check the valve pushrods and cam followers.** The latter must be changed even if only slightly damaged.

8 **Refit the flywheel cover and the flywheel.**

9 **Check the timing setting**on cylinders 1 and 4 (See Section 13.3).

10 **Fit the inspection doors.**

11 **Check the valve clearances.**

12 **Couple up the engine to the alternator** and check the alignment.

14.3 Camshaft bushes

14.3.1 Camshaft bushes - examination

When the camshaft is removed, the bush bores can be measured using a ball-tip micrometer without removing the bushes. The limit of wear is given in Section 06.2. If it is reached or exceeded for one bush, change all of them. A special tool with a hydraulic extractor cylinder, (extractor No. 834050), is available for this job.

14.3.2 Anti-friction bushes - removal

1 **Fit the extractor.**

2 **Tighten the hydraulic tool 837005** by exerting traction on the screw 836010.

3 **Connect the hydraulic pump flexible lines** to the tool.

4 **Extract the bush.** If it does not come out, tap the end flange lightly.

5 **Open the pump valve,** disconnect the lines and remove the tool.

14.3.3 Bushes - refitting

This is a very intricate job. It is recommended to contact the manufacturer. The camshaft bushes are fitted by using liquid nitrogen. Bushes must be refitted with regard to the markings made at the time of removal.

Note : **Check that the lubricating hole in the engine block matches up with the lubricating hole in the bush.**

15. Supercharging and Air Cooler

15.1 Turbocharger

Characteristics and dimensions
Mass (empty): 590 kg (12V220)
290 kg (18V220)
Max. speed: 31,000 rpm
Max. turbine inlet temp.: 650°C
Materials:
- Castings : cast steel
- Turbine : forged steel
- Compresso r: aluminium rotor
- Legs : cast steel

15.1.1 General Description

The turbocharger is designed to use the energy of an internal combustion engine's exhaust gases (which would otherwise be wasted) to activate a turbine and also a compressor. The compressor increases the pressure and density of the cylinder air charge, which increases power beyond the level that could be attained with an atmospheric engine. The turbocharger is made up of a single-stage axial turbine and a centrifugal compressor connected by a single rotor shaft supported by built-in bearings. The W12V220 engine is equiped with a single turbo type NA295 (see Fig. 15-1). The W18V220 engine is equiped with 2 turbos type TPS57 (see Fig. 15-2).

15.1.2 Mode of operation

The exhaust gases from the cylinders are feed into the turbine intake casing and accelerated through a nozzle which projects them onto the turbine blades, causing the shaft to rotate. The exhaust gases are then fed through the turbine outlet casing and discharged into the atmosphere via an exhaust pipe. The air required for engine operation is drawn in through a filter which serves as a silencer, via the compressor intake casing, compressed by an impeller and diffuser and collected in the compressor outlet from where it is injected into the engine combustion chamber. Make sure the inlet to the supercharge air cooler is clean and that no foreign matter can get into the air intake. The turbocharger is equipped with hydrodynamic bearings which are lubricated from the engine oil system. An adjustable orifice plate in the turbocharger support is used to regulate oil pressure to the bearings.

Caution: **Oil pressure ahead of the turbocharger must be greater than 2.3 bars.**

The turbocharger air discharge is connected to the engine air intake duct by an expansion joint (3) which allows the duct to expand. The duct is designed to decelerate the air substantially before it enters the air cooler.

Caution! **The surfaces of the turbocharger and intake air pipe get hot.**

The engine exhaust pipes are also connected to the turbocharger with metal expansion joints. The turbocharger outlet exhaust pipes must be arranged in accordance with the installation instructions. The turbocharger is equipped optionally with water injection cleaning systems for the turbine and compressor. The turbocharger is mounted on a welded support and bolted to the free end of the engine block.

Turbocharger type NA295

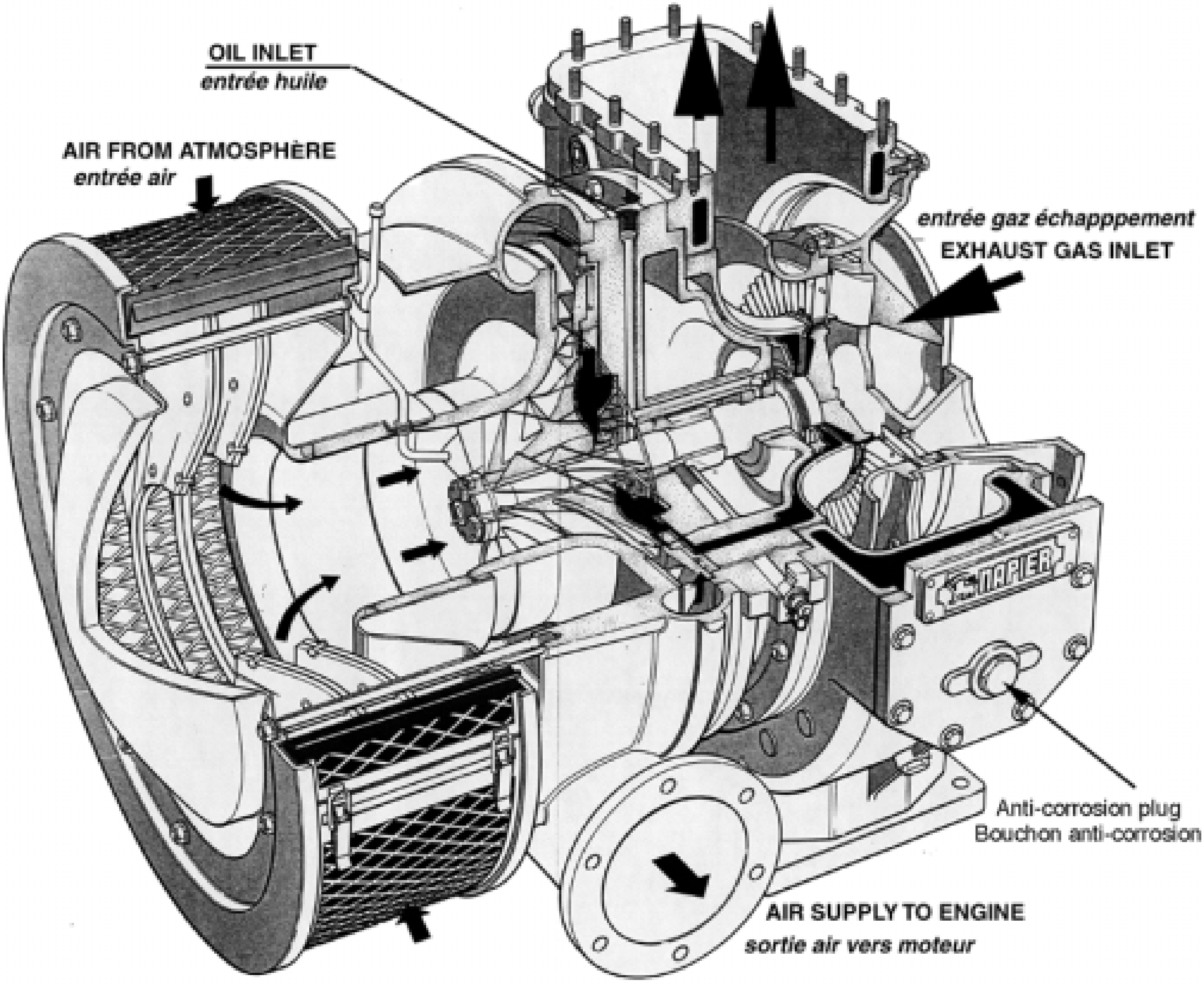


Fig. 15-1

Turbocharger types TPS 52 and TPS 57

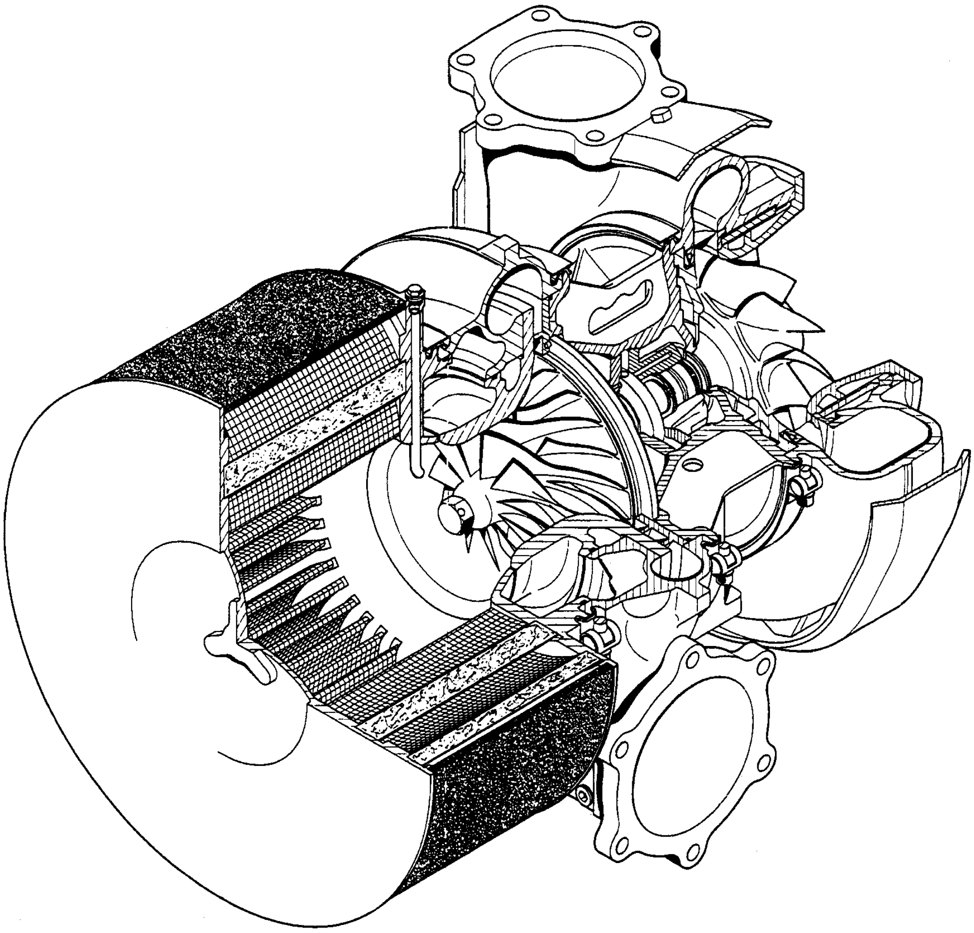


Fig. 15-2

15.2 Instrumentation (W12V220 single turbo)

15.2.1 Speed Measurement

The turbocharger rotary unit is constructed so as to produce two pulses for each turn of the shaft.

The threaded detector probe (sensor) is held in place by a captive O-ring and a lock plate and is positioned on the top of the main casing.

The electrical connections to the sensor are made by a two-conductor isolated, shielded cable, with the braid grounded at the indicator end only and NOT at the sensor end. Each sensor is equipped with a miniature cylindrical connector.

- Cannon KPT.02.E.8.2.S socket,
- Cannon KPT.06.F.8.2.P plug.

The connector is suitable for soldered connections.

15.2.1.1 Operating Characteristics

Temperature range: -20°C to +150°C

The turbocharger maximum permissible speed is shown on the data plate.

15.2.1.2 Sensor installation

1 **Check that the lock plate** and O-ring are correctly positioned on the main body of the sensor, just below the cylindrical connector. Oil the thread slightly.

2 **Fit the sensor into its socket** located in the turbocharger main casing making sure that the socket bore is clean and not obstructed and that the sensor body is clean.

3 **Turning clockwise** and without forcing, screw the sensor fully home until it abuts against the turbocharger shaft.

4 **Adjust the gap between the sensor and the shaft** by turning the sensor half a turn counter-clockwise. The sensor is then correctly adjusted and the gap is 0.7 mm.

5 **Lock the sensor in position** by tightening the retaining screws of the lock plate.

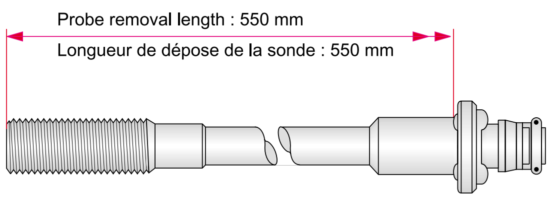


Fig. 15-3

15.2.2 Starting a newly installed or newly serviced engine for the first time

Checks to be made when starting the turbocharger installed on an engine for the first time. Before starting the engine:

1 **Check that all the bolts** fastening the turbocharger to the engine mounting surfaces are tight.

2 **Open the vent valves or plugs** at the high points of the cooling system and check that cooling water flow is not prevented by air pockets.
Close the valves and refit the plugs when no more air bubbles escape.
If the turbocharger cooling system is separate from the engine cooling system, make sure the coolant circulates freely.

3 **Start the engine** and increase speed to the no load speed.

4 **Check and record the oil pressure** at the turbocharger inlet.

5 **Check there are no leaks** from the gas, air and cooling water lines.

6 **After a reasonable time,** touch the turbine casing and cooling pipes. Temperature should build up gradually and uniformly. An object at 70°C and more is too hot to touch with bare hands. Estimate the coolant temperature during this inspection. In order to have a database for future performance tests of the turbocharger and engine, record for different engine loads:

- the turbocharger speed,
- the supercharge air discharge pressure.

If possible:

- temperatures before and after the turbine,
- temperatures before and after the compressor,
- temperatures before and after the supercharge air cooler.

15.3 Normal Operation (W12V220 single turbo)

15.3.1 Normal Starting

Before starting the engine, check the following points:

1 **Check in the log book** and if possible by observation, that all maintenance work has been carried out in accordance with the Maintenance and Inspection Schedule.

2 **Proceed as described in Section 15.2.2, 15.4** "Starting the engine for the first time".

15.3.2 Monitoring

The turbocharger requires only visual monitoring when running. Check the oil and cooling water supplies.

Record:

- supercharge air discharge pressure,
- pressure drop at the compressor intake,
- rotor speed,
- the gas temperature at the turbine intake, during visual inspection of the engine.

Remarks : **Any gradual or sudden deterioration in these values indicates the need to clean the inside of the turbocharger or service it. This information also helps in defining the reasons for poor engine operation.**

15.3.3 Stoppage

When stopping it is recommended to let the turbocharger speed stabilise, with the engine running off-load before stopping. This procedure applies in particular when there is a fast shedding of the load. When an emergency stop is made, oil must circulate immediately, if possible for five minutes. If the oil cannot circulate, allow 30 minutes before restarting.

15.3.4 Extended Stoppage

The turbocharger must be protected against corrosion at the start of any period of non-use which is expected to last more than one month. This procedure is described in detail in Section 15.4.

15.3.5 Turbocharger hunting

Hunting is a phenomenon that may arise in any turbocharger system of whatever type or construction. It is defined as the operating point at which the compressor ceases to maintain a stable flow rate for a given pressure and when reverse flow could occur. This condition is usually accompanied by pulsing sounds, which may be moderate or sometimes loud and of large amplitude. It is essential to avoid hunting when the engine is running, as the rotating parts could be damaged, which could lead to damage of the entire turbocharger.
The following conditions can cause hunting:

- Sudden change in engine load or excessive overload.
- Excessive rise in water temperature in the supercharge air cooler.
- Heavily fouled intake or exhaust manifolds.
- Imbalance between the compressor and turbine components for a particular engine.
- The turbine nozzle ring and blades collect carbon deposits from burnt residue of impurities in the fuel and lube oil additives, resulting in high turbine speeds, high pressure and increased exhaust gas temperature. Accumulated deposits increase the exhaust gas temperature sufficiently to cause hunting.

15.3.6 Turbocharger - adapting

The turbocharger output is determined depending on the supercharge demand of the engine and the characteristics of its exhaust by the choice of the impeller, of the compressor diffuser, of the turbine nozzle ring and of the blade length so that the speed is correct and the performance optimal. Consequently, although the same size of Napier turbocharger frame can be used on more than one size of engine, the different diffuser and turbine wheel combinations are not interchangeable.

15.3.7 Anticorrosion plugs

The turbine discharge casing has two covers on the cooling jacket. A zinc anticorrosion plug is fixed inside each cover. Check the plugs and remove scale from them as necessary when servicing. Replace them if they are heavily corroded. Corrosion is accelerated if sea water is used as a coolant instead of treated fresh water.

15.3.8 Operating problems

Operating problems can be avoided provided that the daily operating data of the turbocharger are measured and that the scheduled and routine maintenance operations are carried out. The table below has been drawn up to help users identify the causes of poor performance:

Operating Problem	Probable Cause	Remedies
The engine begins to turn over but not the turbocharger.	Foreign matter / debris jammed between the turbine blade tips and turbine wheel shroud.	Clean and prevent any foreign bodies entering.
	Blade tips rub against the shroud.	
	Defective bearings.	Check and replace with new bearings.
Turbocharger hunting occurs during operation.	Turbine nozzle ring and blades fouled.	Clean the turbine side of the compressor.
	Engine cylinder not balanced.	See the engine manufacturer's manual.
REMARK: Rapid changes in engine load and in particular during the stoppage sequence may cause turbocharger hunting (see Section 15.3.5, 15.8).		
Supercharge air pressure higher than normal turbo discharge temperature.	Turbine nozzle ring or blades fouled or damaged.	Clean the turbine end of the turbocharger or change the components.
	Insufficient air for example.	Clean if necessary
	Excessive discharge back pressure.	Look for the cause.
	Supercharge air cooler fouled, excessive cooling water temperature	Clean and adjust
	Engine fuel injection system defective.	
Supercharge air pressure less than normal.	Defective pressure gauge or leaking connection.	Correct the fault.
	Gas leak from engine exhaust manifold.	See the engine manufacturer's instruction manual.
	Fouled air filter causing pressure drop.	Clean if necessary.
	Turbocharger fouled.	The turbocharger must be cleaned thoroughly.
	Turbine blades or nozzle ring damaged.	Check and replace if necessary.
Supercharge air pressure higher than normal.	Incorrect pressure gauge reading.	Correct the fault.
	Nozzle ring clogged by carbon deposits.	Clean if necessary.
	Engine overload, engine power higher than normal.	See the engine manufacturer's instruction manual.
	Defective fuel injection system.	
Turbocharger vibrations.	Rotor badly out of balance because of dirt or damaged turbine blades.	Rebalance the rotor assembly.
	Bowed rotor shaft.	Check and replace if necessary.
	Defective bearings.	
	Bearings incorrectly mounted.	

To sustain peak performances between maintenance interventions, there is a simple system for washing compressor components when the engine is running. Provisions are made for mounting such equipment on all turbochargers. The system is composed of an injection pipe located on the intake piping, with a spray nozzle positioned to spray the compressor eye; injection is done by a syringe or a pressurised system.

15.4 Protection against corrosion for turbo type NA295

The mating surfaces, oilways, thrust bearing surfaces, etc. in all turbochargers from the Napier factory are protected with Shell Ensis 158 oil. It is recommended to protect turbochargers that are not to be used for more than one month in an identical manner.

The anticorrosion protection must be renewed every four months if the turbocharger remains unused. Turbochargers fitted on engines that are to be stopped for long periods of time or turbochargers that are to be kept as spares must be prepared for long duration storage.

Instructions for more thorough treatment can be supplied on request.

15.4.1 Anticorrosion protection of an installed turbocharger

1 **Disconnect the lube oil supply** to the top of the main casing.

2 **Remove the lube oil drain flange and pipe.**

3 **For a short period** pour anticorrosion oil (e.g. Shell Ensis 158) through the open union above the main casing for the turbocharger rotor bearings. At the same time, rotate the shaft by hand while letting surplus oil flow out.

4 **Spray or brush the inside surfaces** of the turbocharger with anticorrosion oil.

5 **Refit the drain flange and pipe** that were removed previously, or plug the drain hole.

6 **Plug all the air vents** and open unions of the turbocharger with textile tape.

15.4.2 General anticorrosion treatment

To avoid damaging the turbochargers during transport and short-term storage, in addition to anti-corrosion treatment, the following precautions are taken before shipment from the factory:

- Each unit is finished with high quality paint.
- The external steel parts and all bare metal parts are coated with non-acidic mineral grease.
- Blind flanges are fitted to all machined mating surfaces, outlet holes, etc.
- Spares and tools are treated in an identical manner with a protective agent and greaseproof packaging.
- Rubber seals and sheaths are sprinkled with talk (Briançon chalk) and wrapped in greaseproof paper.
- All the other seals are dry wrapped.
- The turbocharger is bolted to a wooden stand whose frames prevent movement inside the packing crate if used.

- The packing crate, if provided, is lined with waterproof material for shipment by sea.

15.4.3 Thrust bearing wear

Operating experience shows that the main thrust bearing may wear during service mainly because of contaminated lubricating oil. Wear has also been observed in certain specific cases during initial engine operation, when running-in compounds are used.

The comments below answer the following questions:

- What is the acceptable extent of wear before replacing the bearing?
- How do you measure bearing wear?

Bearing wear is measured as follows:

1 **Measure dimension X (see Fig. 15-4)** for all bearing pads and then calculate the mean value.

2 **If this measurement is less than 3.5 mm,** the bearing must not be re-used for a period longer than that already completed. This is based on an “as new” value of 5.5 mm. For other wear values and required operating times around these values, evaluations can be made proportionally.

3 **For example, if bearing mean wear reaches** the mean value between 3.5 mm and 5.5 mm, the authorised duration of use may be doubled.

4 **If in doubt about the condition of the bearing,** it is recommended to contact Wärtsilä France

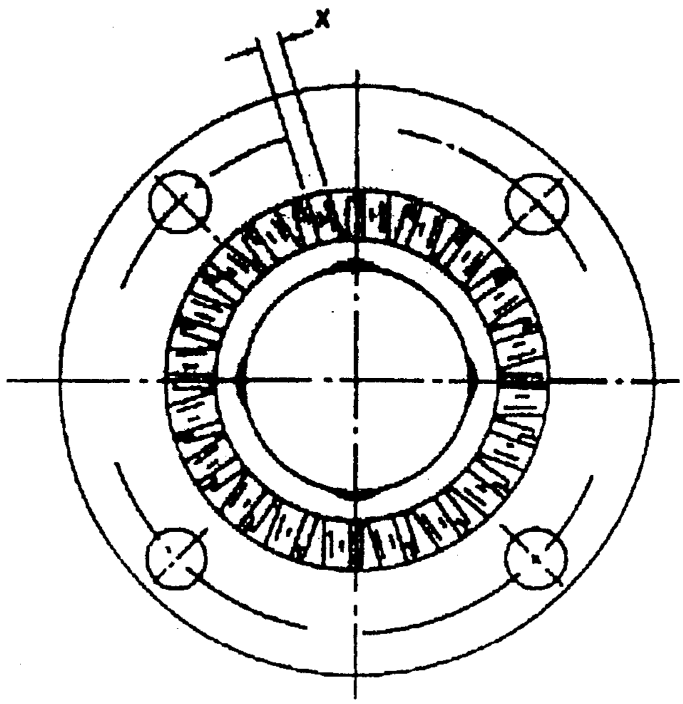


Fig. 15-4 patpalbu9748

15.5 Turbocharger maintenance (W12V220 single turbo)

This section contains the information required for dismantling the turbocharger completely. It also includes the inspection instructions for dismantling when there are no special installations. It is accepted that dismantling inspection and servicing are related and that they depend on the engine servicing times recommended by the engine manufacturer. When the turbocharger is being serviced, the engine air filter and lube oil filters must be serviced. A complete overhaul including detailed inspection, search for cracks and pressure testing can be carried out.

Each turbocharger comes with a set of tools. The individual tools mentioned in the following instructions are ascribed product numbers specified in a complete list given in Section 5. Although some components can be removed with other tools than the specified ones, the use of the correct tools from the list referred to prevents damage to the components and neighbouring parts and injury to personnel. The spanner wrenches and torque bars provided are designed to be long enough so that the resulting torque cannot exceed the values considered as suitable for the components to which they are applied.

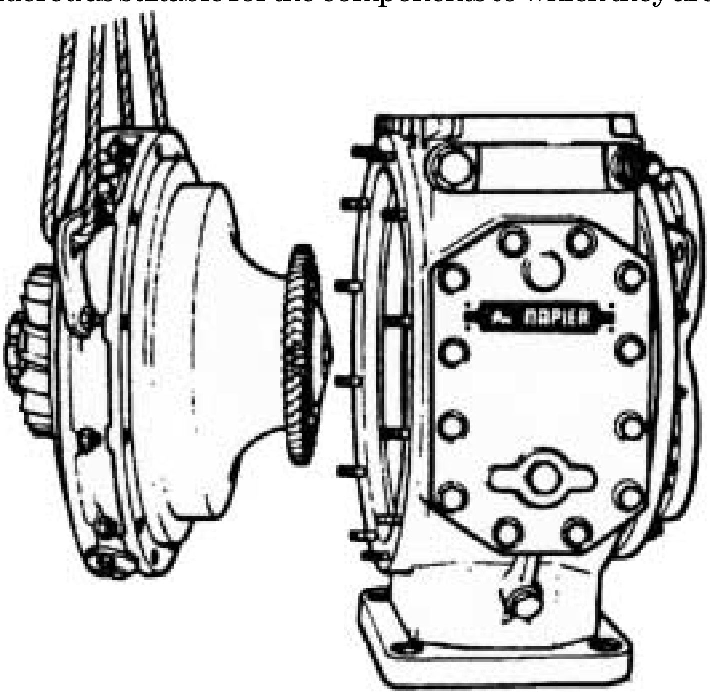


Fig. 15-5

a) Before beginning dismantling, mark the top centreline of all the casing flanges and seals so as to be sure all the components are refitted in their proper relative positions. The identifying marks must not damage the flanges, etc. but must be distinct enough to remain visible after cleaning.

1 **Drain** the lubricating and cooling systems.

2 **Disconnect** the lubricating and cooling systems.

3 **Disconnect** the air and exhaust pipes and ducts.

4 **Disconnect** the supercharge air cooler.

5 **Disconnect and protect** all the instruments fitted.

6 **Plug up all the openings** until ready for refitting.

7 **Handle the shims,** thrust washers and rotor components carefully.

Replacement may result in delays and expense. Damage to them can alter the clearances or disrupt rotor dynamic balance.

The very precise dynamic balance of the rotor must be maintained and protected by “M” markings on:

- the shaft end,
- the impeller drive washer,
- the impeller clearance shim,
- the thrust ring.

15.5.1 Personnel safety

When removing the turbocharger casings, watch for the shift in the centre of gravity.

The reduced stability of the assembly is a source of danger (e.g. when the turbine intake casing is removed).

Before removing any section, the operators should make sure that the fastening bolts to the engine cannot fall by accident.

If the assembly must be separated from the engine for servicing, suitable lifting gear must be available in the work area.

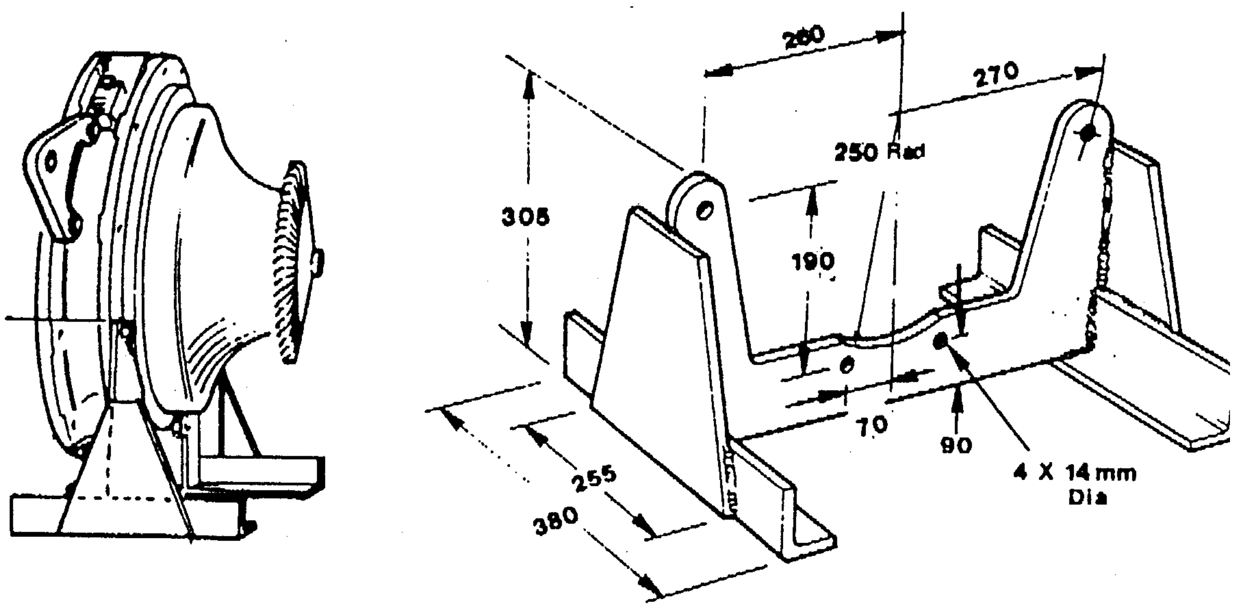


Fig. 15-6

15.5.2 Dismantling operations

1 **Disconnect the compressor washing pipes** and the turbocharger speed measurement connector.

2 **If the compressor has a side intake casing,** remove the compressor discharge casing, or:

- If fitted, remove the air filter / silencer from the compressor discharge casing. First remove the three-part filter panel; each part is fastened by two toggle clips. Suspend the remainder of the assembly from a hoist to prevent the compressor discharge casing coming free accidentally.
- Remove the nuts and washers maintaining the compressor casing on the main casing after it has been suspended from a hoist or held by hand (by two operators). Remove the compressor casing taking great care not to damage the impeller during removal.

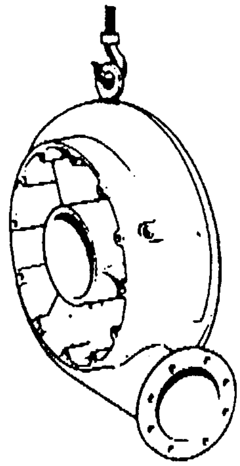


Fig. 15-7

3 **To remove the diffuser,** loosen the “long loc” countersunk retaining screw at the rear of the compressor outlet casing.

Dismantling tool: 866032.

4 **Bring the lifting brackets** to the flange on the compressor side of the main casing.

The oil inlet hole with gas thread 3/4" (BSP) which was plugged earlier MUST NOT UNDER ANY CIRCUMSTANCES BE USED FOR SCREWING IN A LIFTING EYE BOLT.

The cartridge now composed of the main casing and the complete rotor shaft must be removed from the engine to continue with dismantling. As the turbine blades and the impeller are liable to be damaged, it is recommended to keep the cartridge horizontal on a specially made stand or to suspend it from a service hoist (see Fig. 15-5).

5 **Remove the nuts and washers connecting the main casing to the turbine discharge casing.** The M8-40 mm long jacking screws supplied may be used to release the flange.

6 **Extract the cartridge without tilting** or letting it go so as to protect the turbine blades.

7 **Set it down on a stand, if available** (see 15.5.1 "Personnel Safety") or a well-adapted work surface.

8 **Release the speed measurement sensor** (if fitted) as follows:

- Check whether the main casing is fitted with a speed measurement sensor.
- If it is, loosen the screws on the lock plate and turn the sensor at least five full turns counter-clockwise.
- Doing this prevents any damage to the sensor when removing the rotor shaft later.

Dismantling tool : 866011, 866012, 866024.

9 **Prepare to remove the components** of the rotor assembly from the cartridge.

Care: **KEEP THE SHAFT HORIZONTAL**

10 **Make an "M" marking** on the shaft end to facilitate refitting.

11 **Release the lock washer** on the shaft nut.

Caution: **DO NOT DAMAGE OR DEFORM THE LOCK WASHER.**

12 **Remove the shaft nut.**

13 **Remove the lock washer and impeller drive washer.** A slight tap may be needed to release the drive washer.

14 **Remove the impeller assembly,** if necessary using the extractor. Keep the rotor shaft horizontal
(see Fig. 15-9).

Remark: **This assembly includes the impeller, a sleeve and the ring seal support. The components should not be separated under any circumstances. The ring seals at the compressor end may be removed for checking and cleaning.**

Dismantling tools: 866002, 866003, 866004, 866005, 866007, 866008, 866018, 866025.

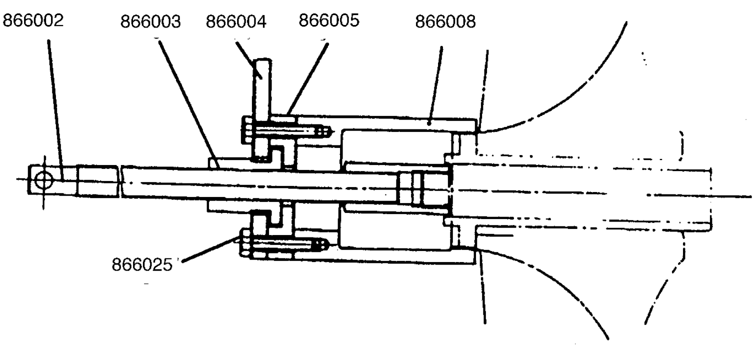


Fig. 15-9

15 **Lock the jack screw** on the threaded end of the rotor shaft.

16 **Screw the impeller adapter** to the "nose" of the impeller sleeve.

17 **Bring the body, nut and handle assembly** up to the adapter.

18 **Fit the two M8 screws** to the assembly.

19 **After mounting the torque bar** on the end of the jack screw, turn the nut counter-clockwise to separate the impeller from the shaft.

20 **Undo and extract** the 6 screws and nut locks fastening the ring seal bush at the compressor end to the main casing.

21 **Remove the ring seal bush,**if necessary with three extractor screws, together with the ring seal.

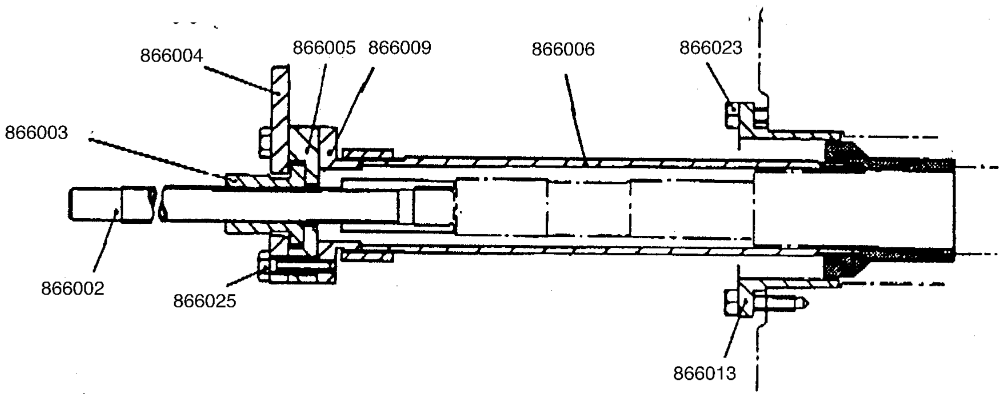


Fig. 15-8

Dismantling tools: 866015, 866023.

22 **Remove the bearing at the compressor end,** the support plate and the impeller shim as follows:

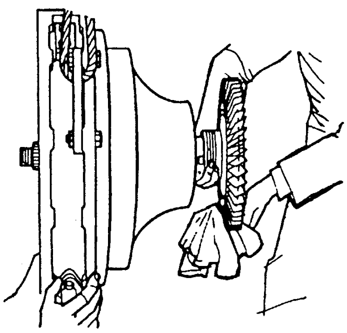
- Undo and extract the four “long loc” screws and tab washers fastening the bearing,
- the bearing support plate and shim of the impeller to the main casing;
- if necessary, use jack screws to remove the bearing and shim.

Dismantling tools: 866015, 866023.

23 **Remove the impeller shim** from the bearing at the compressor side.

24 **Remove the shaft thrust ring as follows:**

- Position the guide sleeve on the shaft and fix it to the compressor bearing flange with two M8-25 mm long screws.
- Lock the jack screw on the threaded end of the shaft.
- Fasten the dismantling tool extension tube to the inside thread of the thrust collar facing the compressor side of the turbocharger.
- Screw the adapter into the tool extension tube.
- Bring the tool and extension, nut and handle assembly up to the adapter.
- Fit the two M8-35 mm long screws to complete tool assembly.
- With the torque bar inserted into the end of the jack screw, turn the nut counter-clockwise to separate the thrust collar from the rotor shaft.
- As soon as the thrust collar is clear, carefully remove the rotor shaft from the main casing.
- The ring seals at the turbine end can then be seen and removed for inspection or cleaning if necessary.



Protect the turbine blades. After removing do not set the turbine wheel down on the blade tips.

Dismantling tools : 866002, 866003, 866004, 866005, 866006, 866007, 866009, 866013, 866018, 866023, 866025

25 **Remove the two "long loc" screws** fastening the diffuser ring seal to the main casing and remove the ring seal.

Dismantling tools: 866032

26 **Loosen and remove the six screws and tab washers** fastening the labyrinth seal plate to the main casing. Remove the shim and labyrinth seal plate at the same time, using three jack screws if necessary.

Dismantling tools: 866015, 866024.

27 **Undo partially the six bolts** fastening the closing plate at the compressor end and the outer cone at the turbine end. Do not remove the bolts at this stage. Position the main casing so that the external cone could be released (see Fig. 15-10).
A systematic light tap on each bolt heads will release the cone if jammed by carbon deposits.

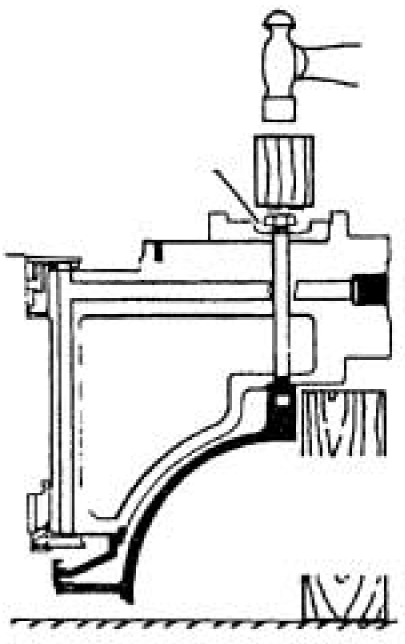


Fig. 15-10

CAUTION!

Make sure the supports are suitable and reliable before beginning. By using wood to support the main casing flange so the cone is held clear of the work surface, the cone can be separated by tapping in systematic order on each bolt head.
As the cone is released, unscrew the bolts further. Remove the bolts and separate the cone and ring gasket from the casing.

Dismantling tool: 866017.

28 Remove the main casing closure plate.

29 Extract the six screws and tab washers holding the ring seal bush at the turbine end of the main casing.

30 Remove the ring bush and seal.

Dismantling tool: 866015.

31 Remove the bearing from the turbine end as follows.
Undo and extract the four screws and tab washers fastening the bearing and bearing flange support to the main casing. If necessary use the jack screws provided to extract the bearing.

Dismantling tools: 866015, 866024.

32 Prepare to remove the turbine intake casing:

- Suspend the casing as shown in the figure below.
- Remove the nuts, spring washers and flat washers from the studs fastening the turbine intake casing to the turbine discharge casing.
- It may be necessary to separate the mating surfaces with jack screws. M12 tapped holes are drilled in the intake casing flange. The jack screws must be applied progressively and uniformly.
- Withdraw the turbine intake casing guiding it horizontally until the nozzle ring and turbine shroud assembly is clear of the turbine discharge casing.
- Maintain stability during removal by guiding the gas intake flange. Remove the intake casing gasket.

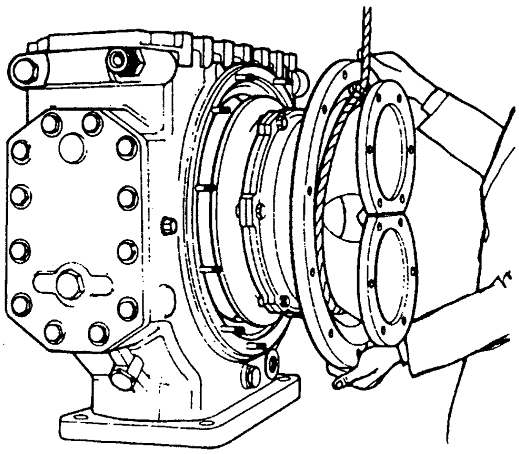


Fig. 15-11

Dismantling tools: 866015, 866017, 866024.

33 Undo the tab washers and remove the six screws fastening the turbine shroud and the turbine intake casing flanges. Remove the turbine shroud.

Dismantling tool: 866015

34 **Undo the tab washers** and remove the six screws fastening the nozzle ring to the turbine intake casing.

Dismantling tool: 866015

35 **Note and mark the position** of the cooling system connections and covers. If necessary, remove the turbine discharge casing. Remove the twelve M12-30 mm long screws and tab washers from the assembly leg.

36 **Remove the assembly foot,** the seal and alignment pegs.

Dismantling tool: 866017

15.5.3 Precautions after dismantling

15.5.3.1 Component cleaning

Except for the cooling system, the turbocharger components must be cleaned with lead-free engine fuel or washed with chlorinated hydrocarbons in a grease removal station. If none of these cleaning products is available, the parts may be washed in kerosene. The surfaces exposed to the exhaust gas heat must be sufficiently dry to ensure they are not flammable.

CAUTION! **Flammable mixtures. Protect against naked flames and use in a well ventilated area only.**

If necessary immerse the nozzle ring and turbine blades into boiling water to remove the resistant deposits resulting from the use of poor grade fuel or from additives in the cylinder lube oil.

CAUTION! **Do not use cotton shreds to clean the turbocharger components.**

CAUTION! **The coolant passages in the jacket may be cleaned with a weak solution of soda in hot water with a brush suitable for metal. The cleaning products of brands recommended by the engine manufacturer may also be used. Drain off the solution after cleaning and rinse the passages with hot soft water.**

CAUTION! **Do not let aluminium parts come into contact with soda solutions.**

If the engine runs under conditions where the turbocharger coolant inlet temperature is higher than average or if the cooling water contains sediments, the passages for coolant in the jacket must be cleaned more often. In such cases, check whether the deflector plates fastened to the covers need replacing. Check the zinc plugs, remove any scale from them or change them. If sea water is used as a coolant, the plugs deteriorate more rapidly. As already mentioned, it is important to make sure that the shims, thrust washers, rotor assembly components, etc. are handled with extreme care as their replacement involves re-machining and added expense. The bearing shells and thrust washers must be kept in a bath of clean oil until refitted, taking care AT ALL TIMES to protect them against dirt, dust and dampness.

15.5.3.2 Component inspection

After cleaning, check the operating condition of all the components.

Check all the dismantled components, in particular:

- excessive wear, corrosion or structural damage;
- security of fittings, studs, bolts and alignment pins;
- thread condition on the rotor shaft, in the lube oil threaded holes, in other holes, etc.;
- the condition of the bearings and thrust bearing faces.
- Make sure the oilways, air passages, drains and other passages are not fouled or obstructed.
- Change any damaged gaskets, seals, O-rings, etc.
- Change any damaged tab washers and unusable spring washers.

a) Air filter silencers

Check there is no damage or corrosion to the casing and accessories, check the condition and attachment of the seals, and the condition of the panel filter material. The seals must not be in contact with petroleum. Use White Spirit only. Clean and repaint external surfaces as required.

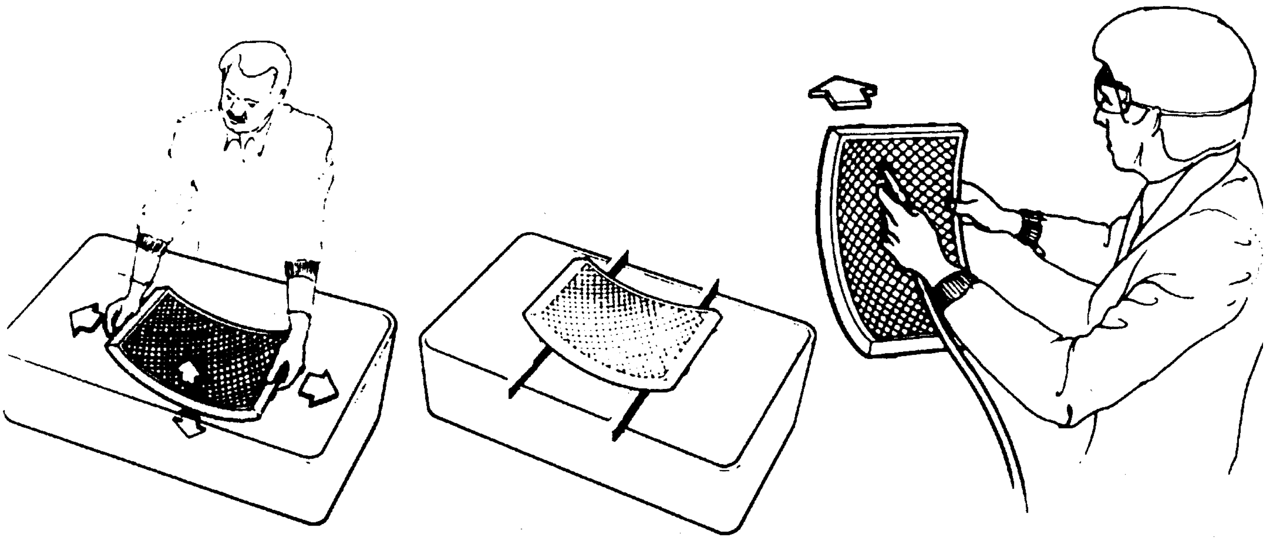


Fig. 15-12

b) Side inlet casing

Check there is no damage, corrosion, etc. and repaint.

c) Bearing surfaces

Check that the bearing bores are not worn and that the thrust bearing faces are not scratched. Make sure the two ring seal bushes are not scored in the bore. Wear tolerated on the shaft journals, on the bearings, and all other rotating surfaces must be concentric. Protect friction surfaces against dirt, abrasive particles and moisture AT ALL TIMES. Bearings that are waiting to be refitted must be kept in a bath of clean lubricating oil. Leave the new parts in their protective packing until ready for use.

d) Turbine

Individual turbine blades cannot be reconditioned. Both ends of the tie rod are folded inwards half-way between two adjacent blades. Any damage must be investigated and the parts replaced. Dynamic balance must be maintained.

15.5.3.3 Clearance table

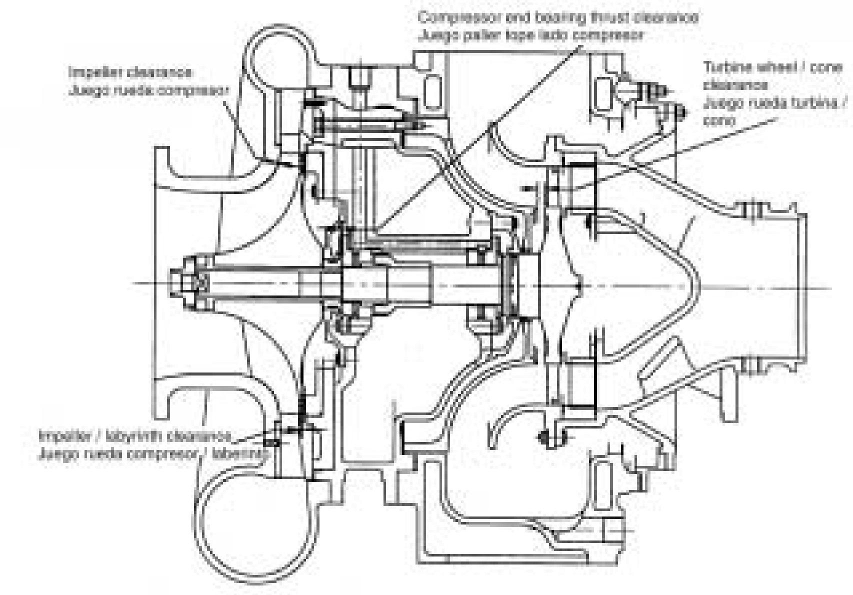


Fig. 15-13 jeux9748

Turbine wheel / cone clearance	3.25 - 3.90 mm	(0.128 - 0.154) "
Impeller axial clearance	0.61 - 0.81 mm	(0.024 - 0.032) "
Impeller / labyrinth clearance	0.28 - 0.33 mm	(0.011 - 0.013) "
Compressor end thrust bearing clearance	0.16 - 0.24 mm	(0.006 - 0.009) "
Clearances are measured with the shaft pushed towards the compressor end. See Section 07.		
Turbine end		
Bearing bore	50.00 - 50.025 mm	(1.9685 - 1.9695) "
Ring seal bore	83.06 - 83.11 mm	(3.270 - 3.272) "
Compressor end		
Bearing bore	42.275 - 42.291 mm	(1.6644 - 1.6650) "
Ring seal bore	63.50 - 63.55 mm	(2.500 - 2.502) "

15.5.3.4 Torque settings

The torque settings must be observed:

- Shaft end nut 102 Nm (75 lb.ft)
- Cone / sealing plate bolt 102 Nm (75 lb.ft)
- Sealing plate screw
- Labyrinth 29 Nm (21 lb.ft)
- Ring seal - set of screws at turbine end : 29 Nm (21 lb.ft)
- Ring seal - set of screws at compressor end : 29 Nm (21 lb.ft)
- Set of screws for nozzle : 15 Nm (11 lb.ft)

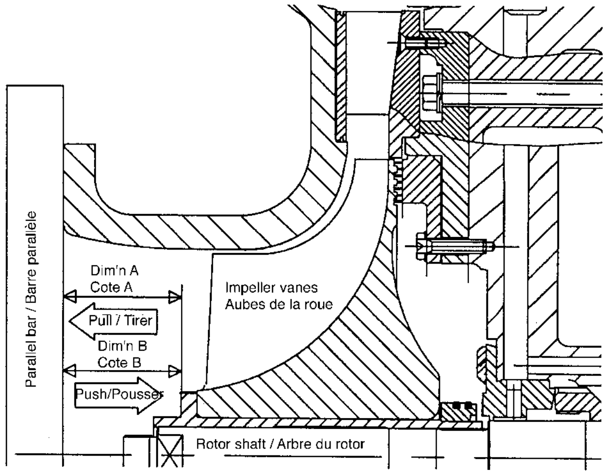


Fig. 15-14

15.5.4 Refitting

15.5.4.1 Refitting - preparation

Clearances must be checked in the course of refitting the turbocharger. There is no need to modify clearances after servicing during which no turbocharger part has been changed. However, if any particular clearance is found to be incorrect, the shims must not be modified until we have checked that the components are clean, in good condition and properly mounted. All tab washers will be changed when refitting as will any spring washers in poor condition. Special care is to be taken with the tightening of nuts, screws, etc. in particular when the screws are tightened in light alloy parts. Torque values are given as guidelines. Check that the components are clean, undamaged and free of burrs.

a) **Casing positioning:** If the markings made at the top of the casings during dismantling have been erased, the original position of each part must be checked and the casings marked again. Likewise, if a casing is to be refitted in a new position, it will be marked again in accordance with the instructions given in Section 02.

b) **Rotor assembly:** For the original dynamic balance to be maintained, the components that are not aligned by other means are marked with a letter “M”. The markings of these components must be aligned when refitting on the letter “M” engraved on the rotor shaft. The bores and diameters of the components such as the roller bearing cages and shells have close tolerances and it is essential to apply clean lube oil to these surface before assembly.

15.5.4.2 Refitting operations

1 Prepare the turbine discharge casing for refitting on the engine. Adjust the mounting leg, the covers, seals, studs, screws and tab washers. Hoist the casing and replace it on the engine.

Mounting tool: 866017

2 Prepare the turbine intake casing for refitting. Refit the nozzle ring and clamping ring in their correct positions, noting the location of the balance hole, with screws and tab washers. Tighten to 16.5 Nm torque.

3 Refit the turbine wheel shroud with the six bolts, twelve tab washers and six nuts. Tighten to 15 Nm torque.

4 Refit the ring gasket of the turbine intake casing.

5 Hoist the intake casing and bring it to its initial position relative to the engine exhaust manifolds, on the turbine discharge casing.

6 Fit the nuts and spring washers on the threaded studs in the turbine discharge casing, and then tighten them.

Mounting tool: 866015, 866017

7 Prepare the main casing for refitting. Reinstall the turbine end bearing. With the bearing correctly in place, refit the bearing support plate, the four screws and tab washers and then tighten them.

Mounting tool: 866017

8 Refit the ring seal bush at the turbine end and the packing. Check the air and coolant holes are not clogged. Fit the six screws after applying Loctite Pipe Sealant to the threads and folding down the lock tabs. Tighten to 29 Nm torque.

Mounting tool: 866017

9 Refit the seal plate on the main casing recess after applying silicone-based Loctite on the inner surface of the shim. The seal plate bolts are fitted during operation 6. The sealing air holes are aligned automatically on those of the main casing.

10 **Prepare the outer cone for refitting.**

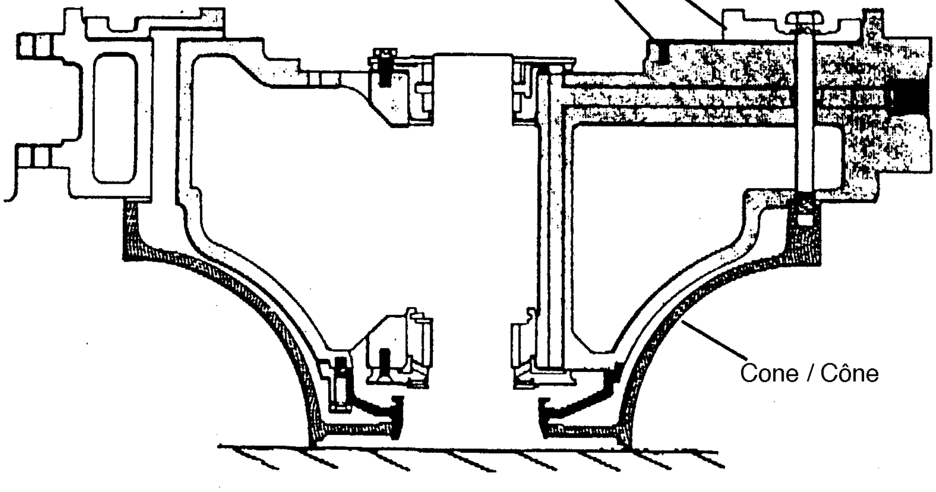


Fig. 15-15

For safety and convenience, place the cone on a flat, solid surface with the wider face upwards. Position the ring gasket on the cone. Line up the main casing with the cone carefully, making sure that the assembly remains stable.

11 **Refit the six screws and tab washers,** making sure that the ring gasket has not moved, thereby preventing the screws from fitting into the tapped holes on the cone.

12 **Tighten the screws and fold down the washer tabs.** Tighten to 102 Nm torque. The seal plate and cone are now fixed.

Mounting tool: 866017

13 **To avoid damaging** the turbine blades and compressor impeller, it is advisable to place the main casing on a prepared stand or to suspend it from a service hoist. The bearing centre line must be kept horizontal.

14 **Refit the airtight seals** at the turbine end of the shaft, the clearances should be facing each other relative to the horizontal axis.

15 **Then refit the rotor shaft as follows.**

- Insert the shaft, guiding it as it goes, through the turbine end of the main casing, keeping the assembly horizontal.
- As the disc and blades move closer to the end of the outer cone, raise this end of the shaft slightly, taking care not to damage the ring seals.

- Fit the ring seals in place in their bushes. Push the shaft gently to the compressor end until it is firmly in place.

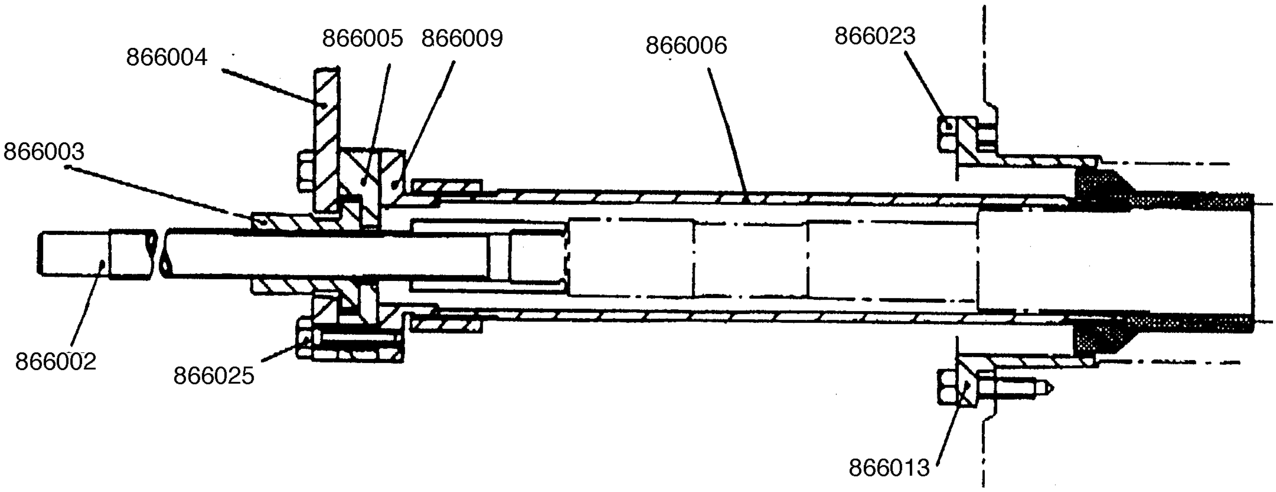


Fig. 15-16

16 **After applying Rocol anti-scoring compound** to the shaft, refit the thrust collar onto the shaft as follows.

- Position the guide sleeve on the shaft and fix it to the compressor end bearing flange with the two M6-25 mm long screws provided.
- Lock the jack screw to the threaded end of the rotor shaft.
- Fasten the mounting tool extension tube into the threaded part of the thrust collar. Position the assembly on the shaft, lining up the “M” markings.
- Screw the adapter into the tool extension tube.
- Bring the tool and extension, nut and handle assembly up to the adapter.
- Fit the two M8-35 mm long screws to complete the tool assembly.
- Insert the torque bar through the end of the jack screw and turn the nut clockwise to push the thrust collar onto the shaft.
- Remove the mounting tool and the guide sleeve, ready to fit the compressor end bearing.

Mounting tool: 866002, 866003, 866004, 866005, 866006, 866007, 866009, 866013, 866018, 866023, 866025

17 **Position the impeller shim** behind the compressor end bearing flange. Place the assembly into the main casing bore and together with the bearing flange support, fasten it with the four “long loc” screws.

Mounting tool: 866015

18 **Note and check the clearances.** The refitting operations involve actions for measuring the following

- compressor end thrust bearing clearance,
- clearance between the impeller and labyrinth,
- clearance between the turbine and cone.

Note: **Clearances may be measured with a suitable dial gauge, a depth gauge / micrometer or a set of feeler gauges.**

19 **If new parts have been fitted,** clearances may have to be adjusted to ensure:

- efficient turbocharger operation,
- proper turbocharger refitting.

Note: **The clearance adjustment instructions are specified at the appropriate points of the text.**

20 **Prepare to refit the impeller,** after fitting the ring seals in the corresponding grooves, the seal slots being on opposite sides of the horizontal axis.

21 **Lubricate the rotor shaft with Rocol compound** and refit the impeller by hand, making sure that it rests against the stepped part of the rotor shaft.

22 **If the impeller fits too tightly on the shaft,** use the tool used during dismantling to release it. Fit the drive washer and shaft end nut.

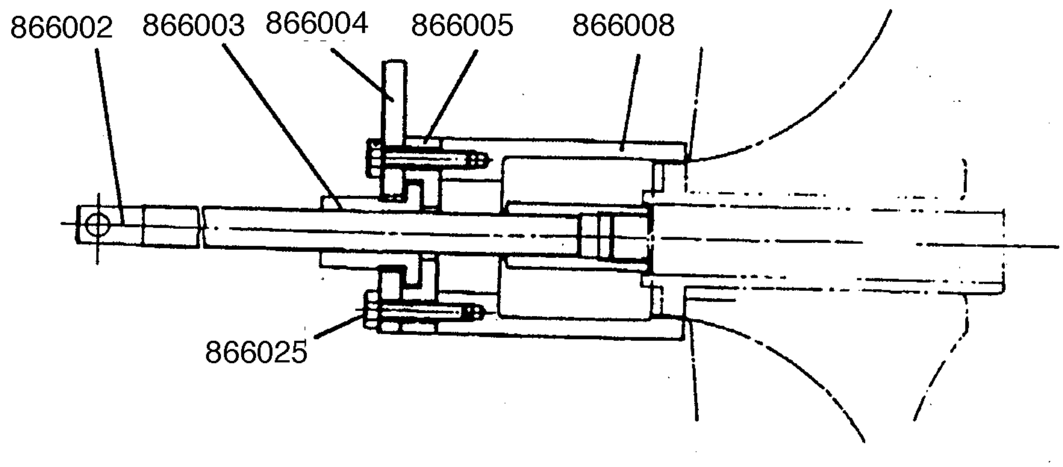


Fig. 15-17

Mounting tools: 866002, 866003, 866004, 866005, 866007, 866008, 866018, 866025.

23 **Check the total clearance** between the compressor end and the thrust bearing face, using a dial gauge or a depth gauge to measure the axial movement of the shaft. See Fig. 15-18.

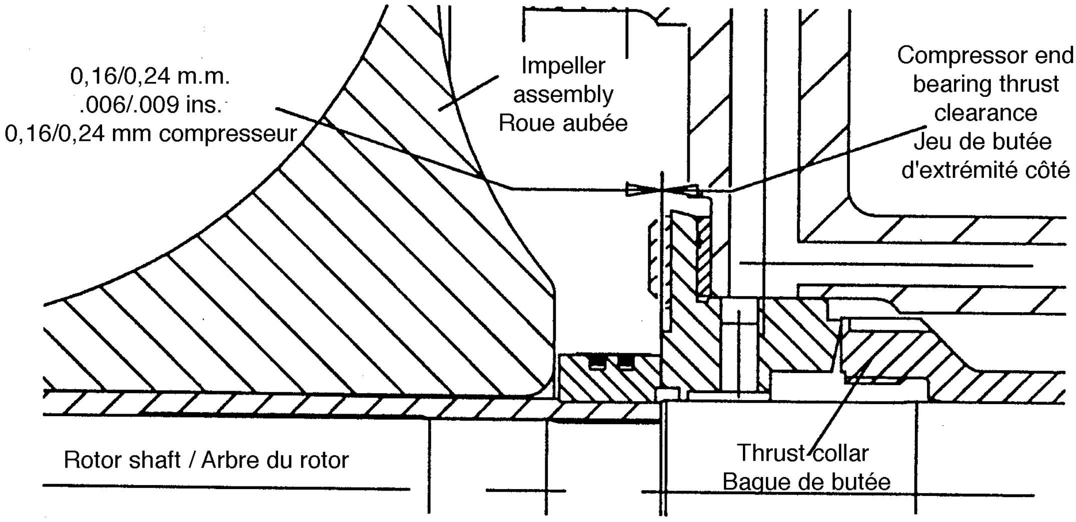


Fig. 15-18 jeuxbutco9748

24 **Prepare to measure the impeller clearances as follows:**

- Remove the impeller from the rotor shaft and the shim located behind the compressor end thrust bearing flange that were fitted previously.
- Refit the thrust bearing but do not fasten it.
  The impeller shim will be fitted later.
- Refit the labyrinth seal plate and shim.
- Fit the six screws and fold down the washer tabs.
- Tighten to 29 Nm torque.
- Refit the diffuser ring seal on the main casing and fasten it with the “long loc” countersunk screw.
- Refit the impeller on the shaft but, at this stage, DO NOT FIT the impeller drive washer, the lock washer and the rotor shaft end nut.
- Carefully refit the diffuser in place in the compressor discharge casing. Fasten it with the two “long loc” countersunk screws.
- Reposition the compressor discharge casing on the main casing.
- Fit four flat washers and four nuts spaced at 90°, and then tighten them.

25 **Check the impeller total clearance as follows:**

- Pull the impeller so that the blades rub slightly against the compressor discharge casing.
- Place a bar parallel to the open flange of the casing. See Fig. 15-19.
- Measure the distance between the flange face and the outside face of the impeller hub.

Nota : **This distance is Value A.**

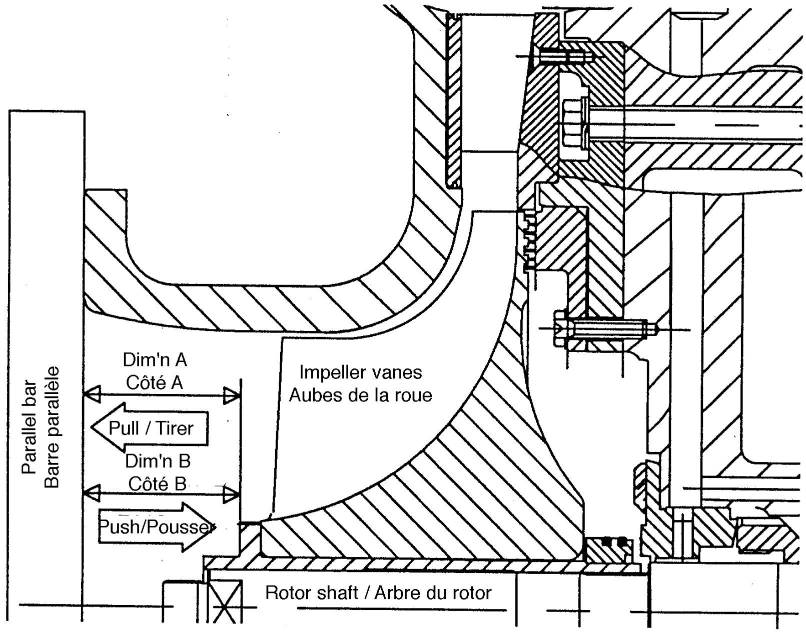


Fig. 15-19

- Push the impeller to the turbine end so that the rear face rubs lightly against the labyrinth plate.
- Measure the distance between the flange face and the outside face of the impeller hub.

Note: **This distance is Value B.**
Impeller total clearance = value A - value B

- Record the result of the calculation to check the clearance of the impeller / labyrinth later.

Note: **Notice that the impeller total clearance may also be measured directly with a dial gauge mounted in a suitable fashion.**

26 **Prepare to measure the clearance** between the impeller blades and labyrinth as follows.

- Remove the compressor intake casing with the diffuser and the impeller, using the extractor if necessary.
- Remove the compressor end thrust bearing.
- Refit the impeller shim behind the compressor end thrust bearing flange.
- Place the assembly in the main casing bore and together with the thrust bearing flange support, fasten with the four “long loc” screws.
- Refit the ring seal bush at the compressor end and the ring gasket in the main casing.
- Fit the six screws and fold down the washer tabs.
- Tighten to 29 Nm torque.
- Lubricate the rotor shaft with Rocol anti-scoring compound and refit the impeller on the rotor shaft, but, at this stage DO NOT FIT the impeller drive washer, lock washer, or rotor shaft end nut.
- Make sure the ring seals are correctly fitted in the bush bore.
- Line up the “M” markings on the rotor shaft and impeller.
- Apply an unbroken bead of Loctite Superflex R.T.V.2 silicone to the rabbet joint between the main casing and the compressor casing.
- Reposition the compressor discharge casing, complete with the diffuser, on the main casing rabbet.
- Refit the flat washers and spring washers as well as the nuts and tighten them.

27 **Check the clearance between the impeller blades and labyrinth as follows:**

- Pull the impeller so that the blades rub lightly against the compressor discharge casing.
- Set a bar parallel to the compressor casing open flange.
- Measure the distance between the flange face and the outer face of the impeller hub, as before.

Note: **This distance is Value C.**

- Replace and tighten partly the shaft end nut so that the impeller is against the shaft.
- Pull and hold the rotor shaft towards the compressor end.
- Measure the distance between the flange face and the outer surface of the impeller hub as before.

Note: **This distance is Value D. The impeller blade clearance = value D - value C and must be between 0.61 and 0.81 mm.**

- If the correct impeller clearance is not obtained, the shim must be modified as shown below.

Note: **A new thicker shim must be installed if the clearance obtained is greater than the value stated above.**

A suitable thickness of metal must be removed from the shim if the measurement is less than that specified above.

It is essential to maintain shim flatness and parallelism tolerance of 0.013 mm.

- After completing the clearance checks, remove the shaft end nut.
- Refit the drive washer on the impeller, the lock washer and the shaft end nut making sure that the “M” markings on the rotor shaft, impeller and impeller drive washer are aligned.
- Refit the shaft end nut. Lock the rotor with wrench flats on the turbine wheel and tighten the nut fully. Make two indents in the shroud at two diametrically opposite points. Tighten to 102 Nm torque.

28 **Check the clearance** between the impeller blades and labyrinth as follows:

- This clearance is calculated from the measurements made during operations 16 and 18.

It corresponds to the impeller blade clearance minus the total clearance of the impeller.

Note: **Clearance between the impeller and labyrinth = (B-A) - (D-C). The value must be between 0.28 and 0.33 mm with the shaft pushed to the compressor end.**

This setting ensures minimum clearance of 0.05 mm between the impeller and labyrinth when the shaft is pushed towards the turbine end. This clearance between the rear of the impeller and the labyrinth plate, i.e. the clearance between the impeller and labyrinth, is adjusted by peel-off film shims located behind the labyrinth plate. Each peel-off film is 0.05 mm thick.

29 **Check the clearance** between the turbine wheel and the cone as follows (see Fig. 15-20):

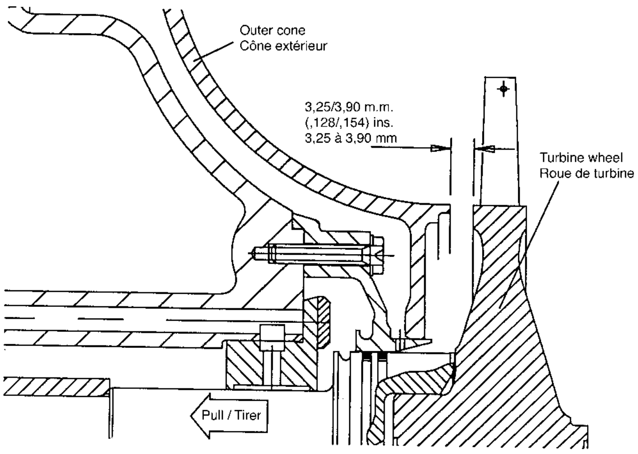


Fig. 15-20

- With the rotor shaft pulled towards the compressor end, use a feeler gauge to check the clearance between the cylindrical end of the outer cone and the turbine wheel disc.

Note: **The value must be between 3.25 and 3.90 mm. This clearance CANNOT be adjusted and if the above values are not obtained, check that the assembly has been mounted correctly.**

30 **Having completed clearance checks,** the cartridge made up of the main casing and the compressor discharge casing can then be fitted back on the turbine discharge casing making sure that the rotor shaft is horizontal and that the turbine wheel is concentric to the bore and its shroud which is fitted inside the turbine discharge casing.

31 **For this operation,** position the lifting brackets on either side of the main casing / in volute flange. Refit the nuts and washers.

Outil de montage : 866001

32 **Turn the speed measurement sensor clockwise,** without forcing, until the detector head comes into contact with the rotor shaft.

33 **To set the air gap** between the rotor shaft and the detector head, rotate the sensor half a turn counter-clockwise. The sensor is then correctly adjusted and the gap is about 0.7 mm. Lock the sensor in position by tightening the retaining screws on the lock plate.

Mounting tool: 866014

34 **Refit the air filter silencer** to the compressor discharge casing and once in place refit the three filter panel sections.

35 **Refit the compressor intake casing,** if it replaces the air filter silencer.

36 **Reconnect the compressor washing pipes** and the speed measurement connector to the turbocharger.

37 **Reconnect the turbine washing pipes,** if fitted.

38 **Remove the temporary protector plugs** from the lube oil inlet and the oil drain flange cover immediately before reconnecting the oil supply.

15.6 Turbocharger maintenance (W18V220 or W12V220 dual turbo)

15.6.1 Removing and installing the turbocharger

1 **Disconnect all air lines**from external filter (lub oil bath filter) and exhaust gas silencer.

2 **If provided :** Remove insulation.

3 **Check the lifting equipment.**

Turbocharger wihout gas outlet elbow :

Attach lifting equipment to bearing casing (see Fig. 15-21)

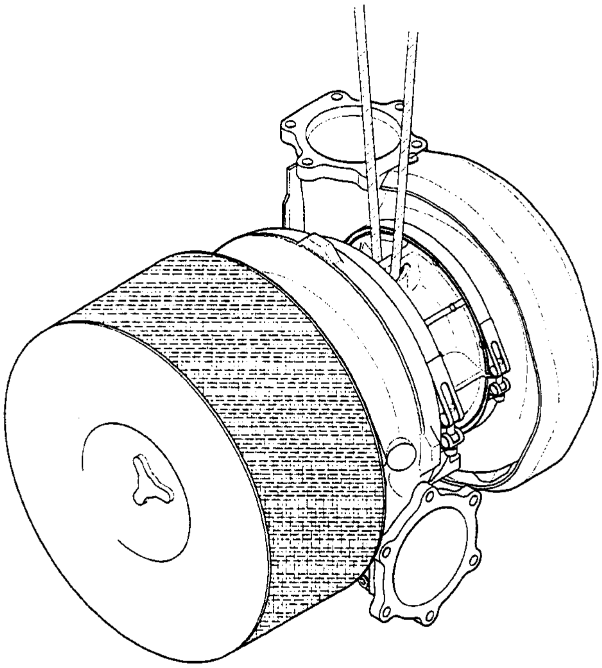


Fig. 15-21

Caution !

Take account of the weight of the turbocharger when selecting a suitable rope. Note centre of gravity.

4 **Relase fixing screws** on bearing casing.

5 **Lift the turbocharger** from the engine.

6 **Cover oil connections.**

To install the turbocharger follow the instructions in the reverse order.

15.6.2 Lubricating

15.6.2.1 Oil supply

A properly designed oil supply, suitable for all modes of operation, is an important prerequisite for trouble-free operation of the turbocharger. Lubrication of the TPS turbocharger is normally provided by oil from the engine oil circuit. If a separate lubrication system is used, emergency lubrication must also be provided.

Attention : **Please follow strickly the lub-oil characteristics and trade marks given by W. If not, no warranty should be taken into account.**

15.6.2.2 Oil Pressure

The oil pressure befor TC should lie between 2 to 4,5 bar at full load and at least 0,3 bar at part load.

15.6.2.3 Troubles, Causes, Remedies

Trouble	Due to	Cause	Remedy	See
Exhaust gas temperature too high, engine performance and speed unaltered	Turbo	Lack of air, e.g. filter blocked	Clean	TC Maintenance Contact Wärtsilä
		Compressor / turbine contaminated	Clean	
		Exhaust gas back pressure too high	Clean or repair boiler	
		Turbine damaged or eroded	Replace the rotor	
	Charge-air cooler	Dirt in the cooler	Clean	
		Insufficient cooling water	Top up	
		Cooling water inlet temperature too high	Check / clean cooling system	
		Insufficient ventilation	Improve ventilation	
Charge air pressure too low, engine performance and speed unaltered; air intake normal	Turbo	Manometer indication defective	Replace manometer	TC Maintenance Contact Wärtsilä
		Leaks in the line to the manometer	Repair leak	
		Dirt in the air filter causing, excessive pressure loss	Clean	
		Dirt in the compressor / turbine	Clean	
		Turbine / compressor damaged	Replace the rotor	
		Exhaust gas back pressure too high	Clean boiler or exhaust gas silencer	
Charge air pressure too high, engine performance and speed unaltered	Turbo	Manometer indication incorrect	Replace manometer	
Vibrations	Turbo	Rotor unbalance due to heavy contamination of compressor / turbine	Contact W	Contact Wärtsilä
		Turbine or compressor damaged	Replace rotor	
		Bearing defect	Replace bearing, seek possible cause	
Noise on running down, time too short reluctant starting	Turbo	Bearing damaged	Replace bearing	Contact Wärtsilä
		Rotor rubbing	Clean	
		Dirt in trubocharger		
		Foreign bodies in the turbocharger		
Pressure of lubrication oil too low	Turbo	Oil filter chocked with dirt	Replace filter	Turbo and engine maintenance
		Damaged pump for oil circulation	Check	
		Axial or radial play of rotor to large	Replace bearings	
		Manometer indication incorrect	Replace manometer	
Constant surging of the turbo	Turbo	Increased flow resistance due to : - dirt in the charge air cooler or silencer - heavy deposits of dirt in the compressor / turbine	Clean	

Call Wärtsilä France if the cause of the surging cannot be detected !

15.7 Maintenance (W18V220)

15.7.1 Daily Inspection

Inspection work during operation includes visual checks, as well as monitoring and measuring in order to ensure correct functioning of the turbocharger. This serves as an aid for the recognition of deviations during operation in order to prevent damage to the machine.

Note : **Control and measurement checks must be carried out on the listed inspection points at the intervals quoted below. See engine data sheet**

15.7.2 Cleaning Operation

Regular cleaning should ensure fault-free operation of the turbocharger and its fittings (see Fig. 15-22)

The external condition and the degrees of contamination of the cleaning points listed below must be established by visual checks at the intervals quoted in the maintenance schedule.

During all cleaning work the safety instructions must be observed.

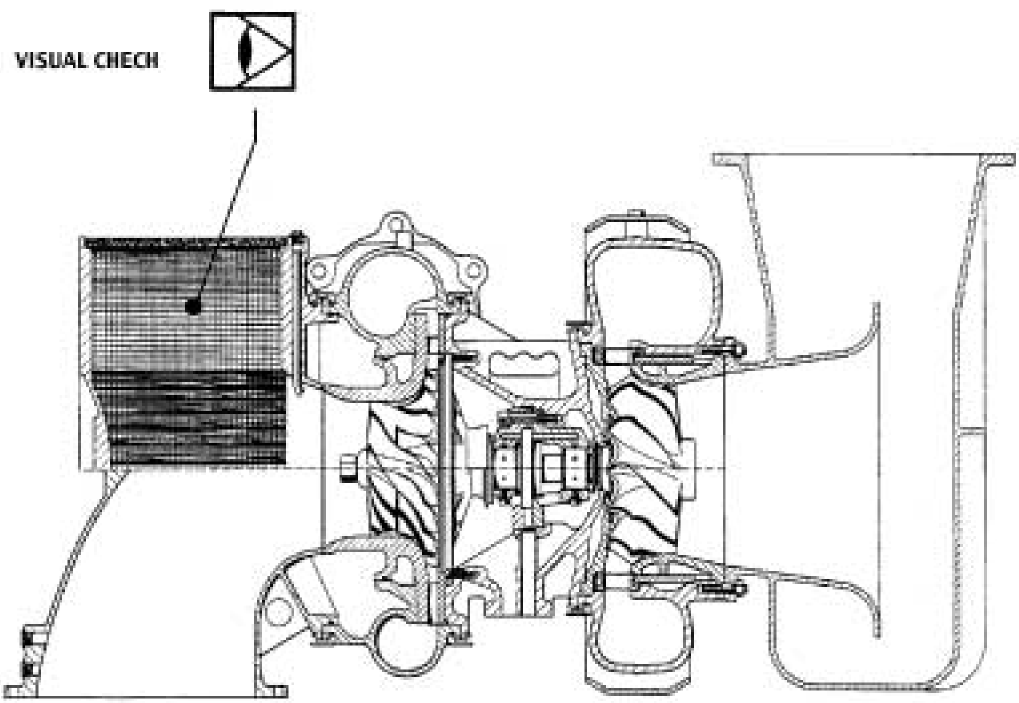


Fig. 15-22

15.7.3 Cleaning the silencer after removing

For cleaning dismantle the silencer.

1 **Remove the filter ring (1)** and loosen the tension bands (2).

2 **Withdraw the cover sheet-metals (3 & 4)** bend them and remove the felt segments (5).

Caution ! **During cleaning take care that the filter ring and the felt segments does not become wet.**

3 **Remove dirt with a soft brush** or dry compressed air.

4 **Heavily soiled felt segments and filter ring** should be replaced (see Spare Part Catalog, Chapter 15).

Note : **Mount the extended cover sheet-metals (4) over the ribs (A).**

Caution ! **Damaged tension bands must be replaced by new ones.**

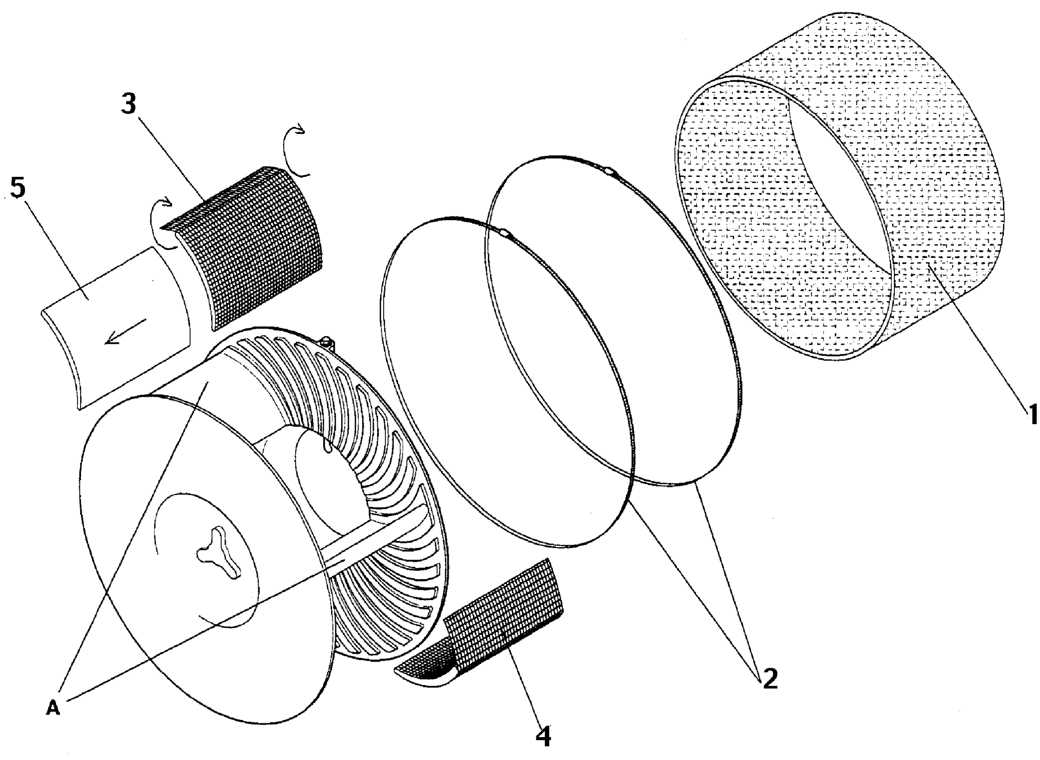


Fig. 15-23

15.7.4 Maintenance work

Maintenance work includes inspection and function checks of wearing parts with or without changing process materials, parts or modules. It must be carried out in accordance with the intervals as set out int Chapter 04 : Maintenance Schedule of this Manual.

Caution !

Failure to carry out the maintenance work within the prescribed intervals can lead to damage and inoperation of the turbo.
The safety instruction in the respective chapters must be observed for all maintenance work.
Damage parts which could impair correct function must be replaced.
Scew fastenings must be tightened with a torque wrench.
If retightening is no longer possible, replace the screw fastenings.
Keep lubrication and process materials ready.

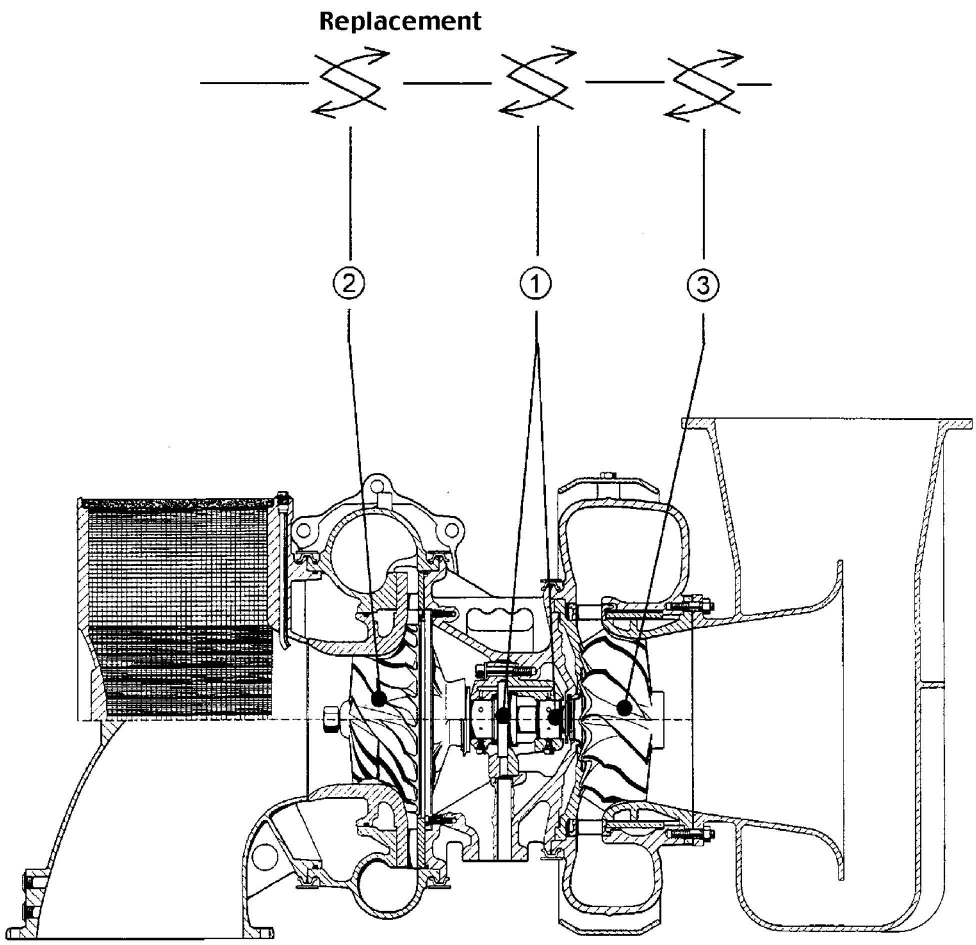


Fig. 15-24

15.7.5 Dismantling / assembling the turbocharger

15.7.5.1 Removing and installing the compressor or casing

1 **Disconnect all air lines.**

2 **Release V-clam (1)** and remove silencer, air suction branches or air inlet flange (see Fig. 15-25).

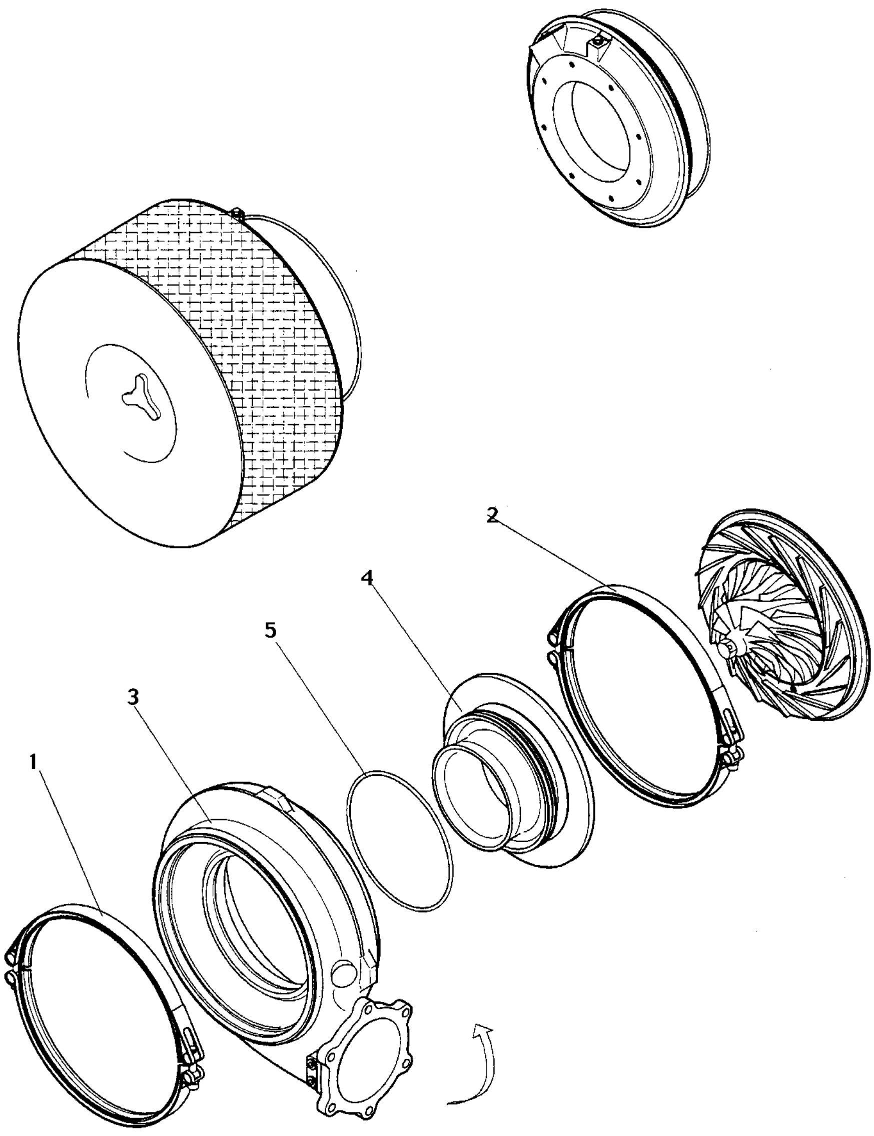


Fig. 15-25

Caution ! **Take account of the weight of the turbocharger parts when selecting a suitable rope.**
Check lifting equipment and secure properly.

3 **Release V-clamp (2)** slightly and turn flange of compressor casing upwards.

4 **Attach lifting equipment to flange.**

5 **Release V-clamp fully (2)** and remove compressor casing with wall insert (4) and O-ring (5).

6 **Fit compressor casing** in the reverse sequence.

Note : **Check gasket rings for damage and replace of there is any doubt about their condition.**

Clean V-clamps thoroughly with a steel brush before fitting.

Lubricate thread and internal part of profile with Antiscuff (or similar high temperature lubricating paste).

15.7.6 Removing and installing the cartridge group

1 **Check lifting equipment** and fix bearing casing (see Chapter 15.1.4 : Removing and installing the turbocharger and Fig. 15-26-1).

Caution ! **Take account of weight of cartridge group when selecting the rope.**

2 **Apply penetrating oil** to screw thread of V-clamp (1) and allow to take effect.

3 **Release V-clamp (1)** with hexagonal socket insert (2).

4 **Release and remove fixing screws (A)** of bearing bracket.

5 **Remove cartridge groupe** and gasket.

6 **Cover oil connections**

7 **Remove nozzle ring (4).**

8 **Measure axial and radial clearances** (see following section).

9 **Release screw (5)** and remove diffuser (6) and O-ring.

The cartridge group is fitted in the reverse sequence

Note : **Check gasket rings for damage and replace if there is any doubt about their condition.**
Clean V-clamp (1) thoroughly with a steel brush before fitting.
Lubricate thread and internal part of profile with Antiscuff (or similar high temperature lubricating paste).

Caution ! **Do not damage or displace gasket rings (B) in the fixing support during assembly (see Fig. 15-26-2).**

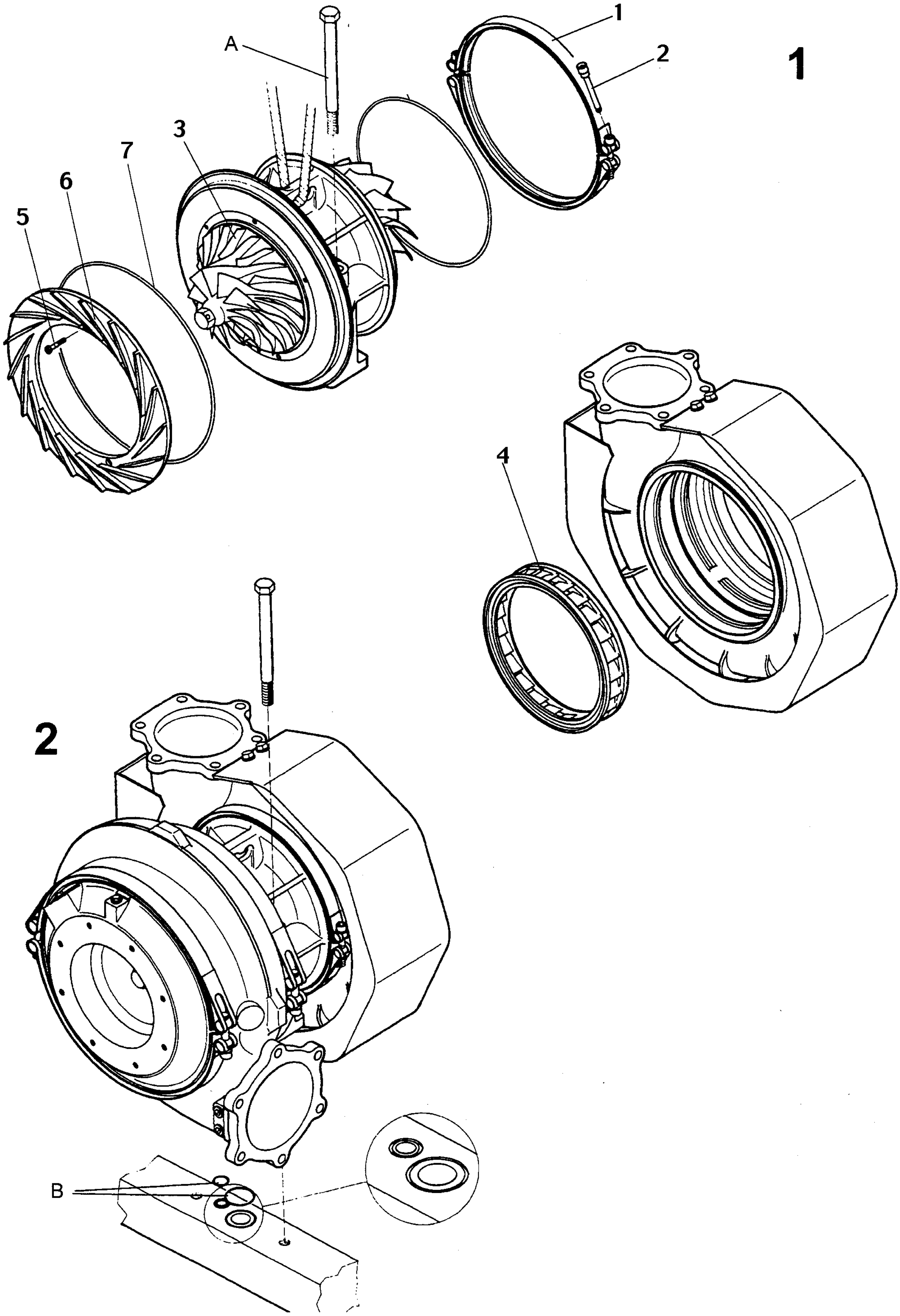


Fig. 15-26

15.7.7 Axial and radial clearances

After removing and before fitting the cartridge group the axial clearance “A” and radial clearance “B” must be measured (see).

Note : **The diffuser must be mounted and tightened to measure the clearances.**
Raise turbine slightly for correct measurement of axial clearance “A”.

Clearance (mm)	
A max	0,21
B max	1,26

Caution ! **Measure and note the axial and radial clearances.**
If the clearances are out of tolerance, please contact Wärtsilä France.

15.7.8 Maintenance work

15.7.8.1 Replacement

Caution : **Must be done by authorized engineer from Wärtsilä France.**

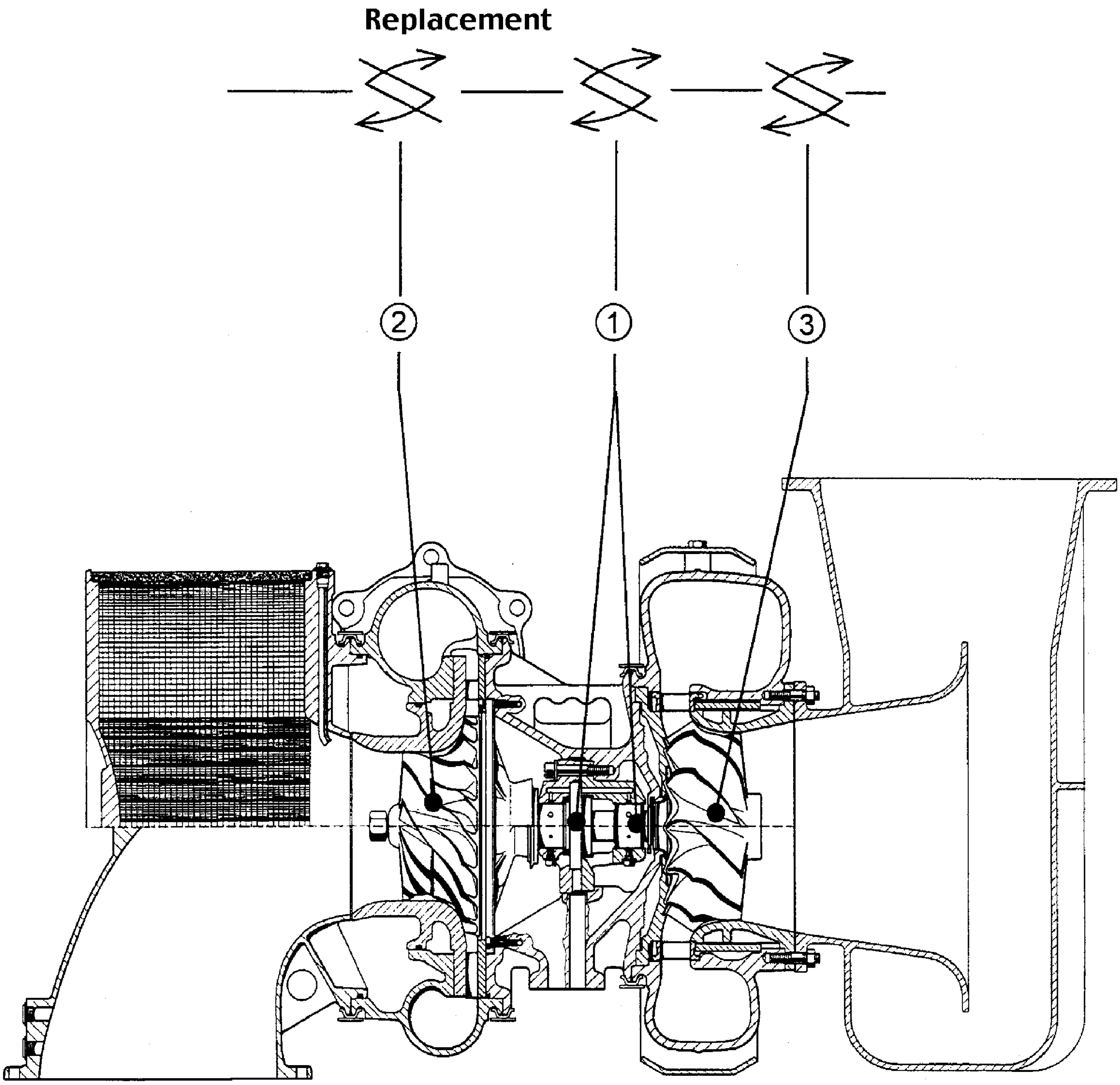


Fig. 15-27

15.7.8.2 Replacing the bearings

The bearings must be replaced if damaged or at the latest in accordance to the instructions of the rating plate and/or Maintenance Schedule.

The operation period of the bearings depends on the operation conditions.

The bearings have to be replaced if the axial and radial clearances are exceeding or if high wear has been detected.

Note : **See previous chapter to check clearances.**

15.7.8.3 Replacing the compressor wheel

The compressor must be replaced if damaged or at the latest in accordance to the instructions of the rating plate and/or the Maintenance chedule.

15.7.8.4 Replacing the bladed shaft

The bladed shaft must be replaced if damaged or at the latest in accordance to the instructions of the rating plate and/or the Maintenance Schedule.

Note : **For more information, please contact Wärtsilä France.**

15.7.9 Table of tightening torques

For the screws in the table below (see Fig. 15-28), the following tightening torques must be applied :

Location	Part n°	Tightening torques (Nm)
1	See Chap 15 : TC of the Spare Parts Catalog for the SPC	60
2		19
3		65
4		60
5		65
6		19
7		220
8		10

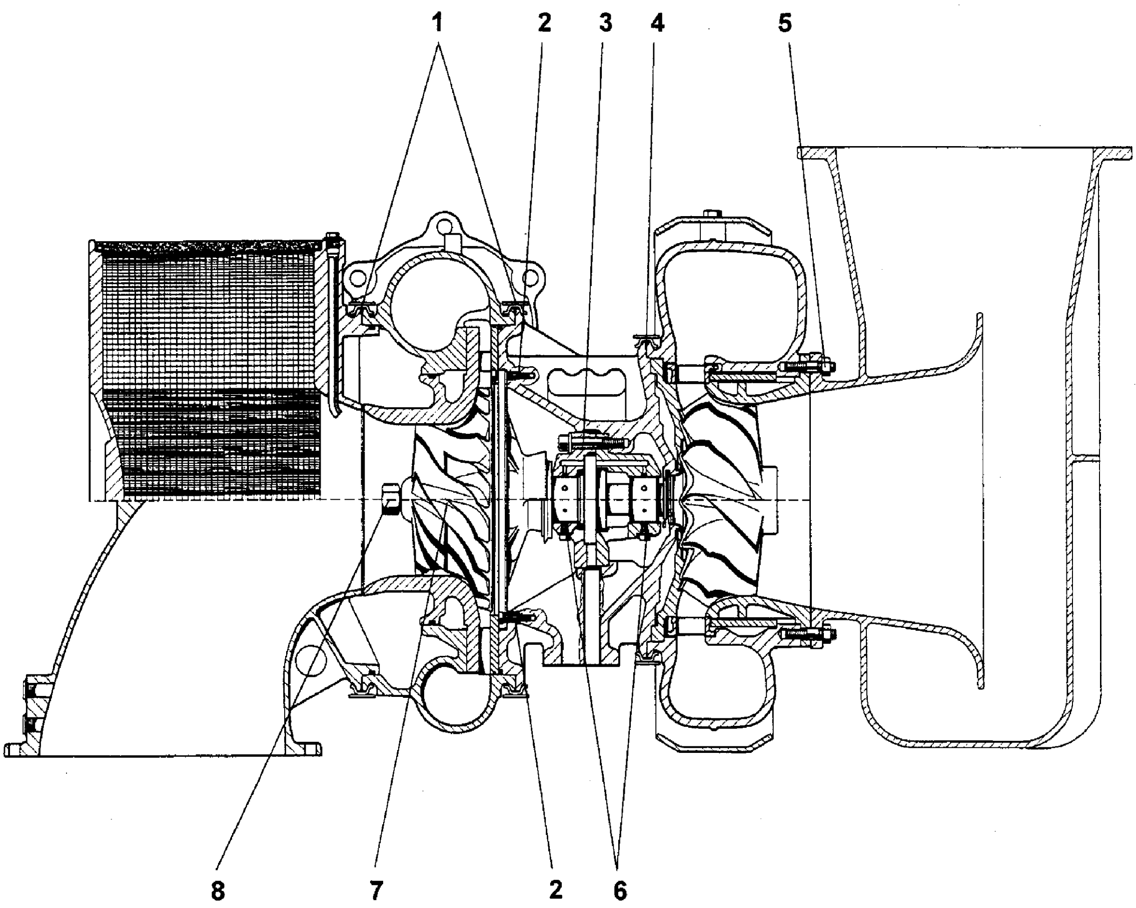


Fig. 15-28

15.8 Charge air cooler Maintenance

15.8.1 General maintenance

1 **Condensation from the air is drained** through a small hole/pipe at the bottom of the cooler housing after the insert, and at the opposite end of the air manifold. Examine regularly that the draining pipes are open by checking the air flow when running.

Caution : **If water keeps on dripping or flowing from the draining pipe for a longer period (unless running all the time in conditions with very high humidity) the cooler insert may be leaky and must be dismantled and pressure tested.**

2 **At longer stops,** the cooler should be either completely filled or completely empty, as a half-filled cooler increases the risk of corrosion. If there is a risk of sinking water level in the system when the engine is stopped, drain the cooler completely. Open the air vent screw (3) to avoid vacuum when draining.

3 **Clean and pressure test the cooler** at intervals according to chapter 04. or if the receiver temperature cannot be held within stipulated values at full load.

4 **Always when cleaning,** check for corrosion.

15.8.2 Cleaning of air cooler insert

Cleaning of the water and air side heat exchange surfaces is imperative for a long and trouble free operation of the engine and must be done at regular intervals.

1 **Remove the cooling water pipes** when the cooling water is drained.

2 **Remove the side cover** of the air cooler housing.

3 **Remove at least four of the cooler flange screws** on each side of the air cooler.

4 **Apply the lifting tool.**

5 **Remove the top flange** of the air cooler housing.

6 **Remove the remaining cooler flange screws.**

7 **Lower the insert** until it is clear from the cooler housing.

8 **Clean the air side of the cooler** by immersing it in a chemical cleaning bath for at least 24 hours. We recommend that the detergent is circulated for the best cleaning effect. When cleaning is completed, the cooler should be flushed by applying a powerful water jet.

Note! **If the water jet attacks the cooling tubes vertically, i.e. in parallel to the fins, a pressure of 120 bar is suitable to be applied at a distance of two meters from the fin surface.**

Caution! **Wrong use of water jet may cause damage to the fins, which results in an increased pressure drop over the air cooler and an decreased efficiency.**

9 **Clean the water side** by detaching the headers and from the cooler bundle and immersing the tube bundle into a chemical cleaning bath for at least 24 hours.
Upon completion, follow the recommendations given for the air side.

10 **Check the gaskets** before reassembling the headers.

11 **Mount the cooler on the engine.**

12 **Vent the cooler** and check the tightness when starting up.

16. Ignition system

16.1 General information

The W 220 SG engine is a four-stroke gas engine with prechamber ignition working to the “lean burn” principle.

In the lean burn gas engine, the air-gas mixture in the cylinder is very “sparing”; i.e. there is more air in the cylinder than is needed for combustion. To improve ignition and combustion of this lean mixture, a prechamber is used in which there is a rich mixture.

Ignition is started by a spark plug mounted in the prechamber. The resulting combustion provides the energy required to ignite the lean mixture in the main chamber.

The prechamber is located in the centre of the cylinder head.

16.1.1 Operating principle

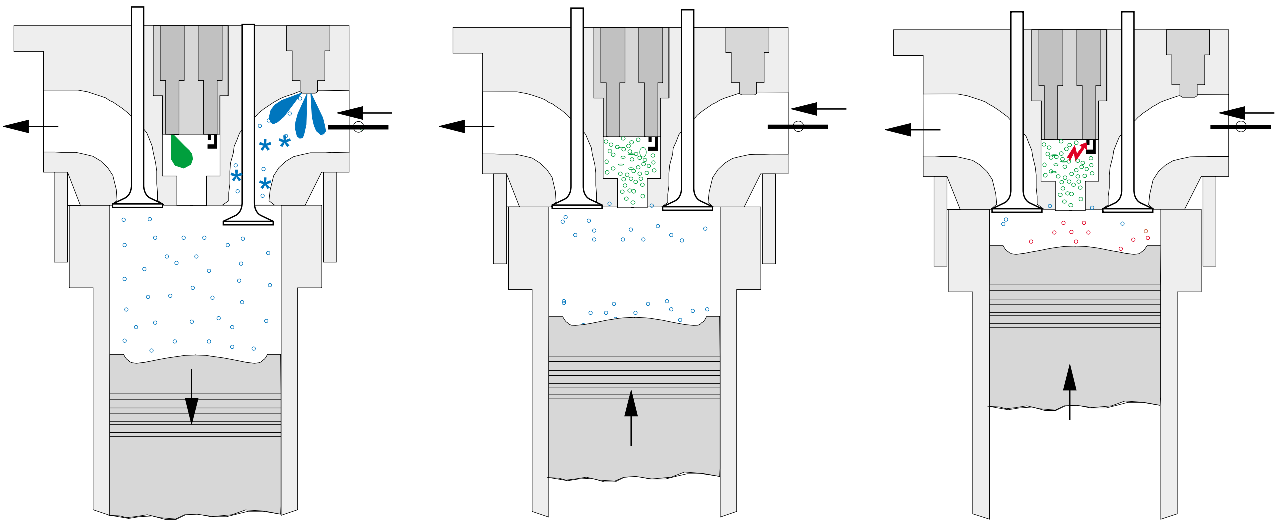


Fig. 16-1

16.2 Prechamber

16.2.1 Description

1. Rocker bracket
   Support de culbuteur
2. Rocker
   Culbuteur
3. Valve yoke
   Palonnier de soupape
4. Prechamber flange
   Bride de préchambre
5. Cylinder head
   Culasse
6. Rotocap
   Rotateur
7. Coil
   Bobine
8. Spark plug sleeve
   Fourreau de bougie
9. Spark plug extension
   Prolongateur de bougie
10. Gas supply manifold
    Tubulure arrivée gaz
11. Nut
    Ecrou

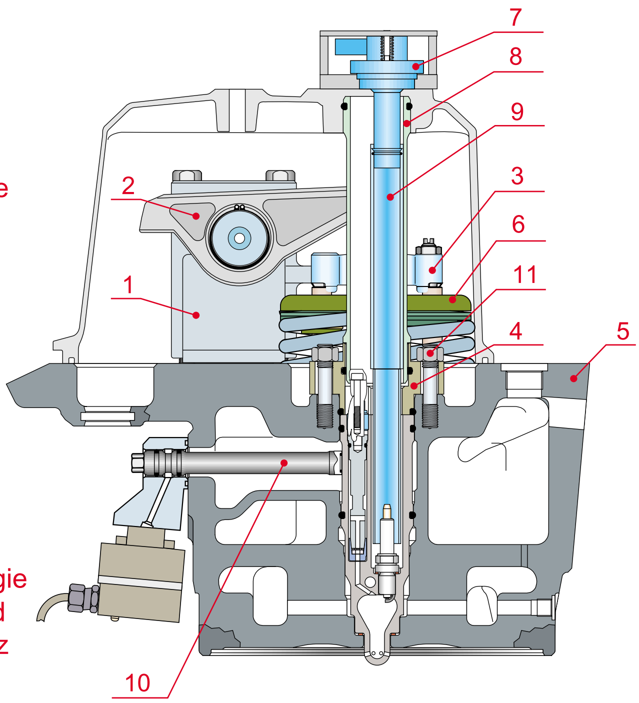


Fig. 16-2

The prechamber is made from a high thermal resistance alloyed steel. Chamber cooling is optimised to obtain the best service life from the spark plug.

A sleeve (8) mounted in the prechamber seals it from oil from the rocker system and is also used to insert the spark plug extension.

16.2.2 Prechamber - removal

1 **Drain the engine coolant circuit.**

2 **Disconnect the coil cable.**

3 **Remove the locking cover of the coil (7)** and the spark plug extension (9).

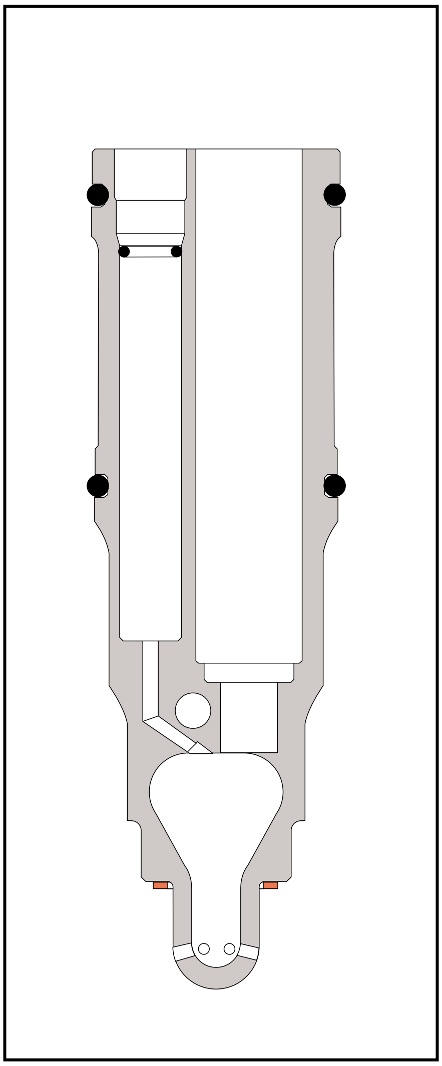
4 **Remove the cylinder head cover** and the spark plug sleeve (8).

5 **Remove the gas supply manifold (10).**

6 **Unscrew the nuts (11) of flange (4)**

7 **Remove the flange (4).**

8 **Remove the prechamber** using special tool 837001.



16.2.3 Prechamber overhaul

Clean the prechamber, paying special attention to the thread of the spark plug. Make sure that there are no cracks or wear around the holes. Check that the mating surface is clean and flat.

16.2.4 Prechamber reinstallation

1 **Check that the mating surface** at the bottom of the cylinder head is clean.

2 **Replace the O-rings (9) and (10)** on the prechamber (see Fig. 16-3)

3 **Lubricate the seals** with oil or vaseline.

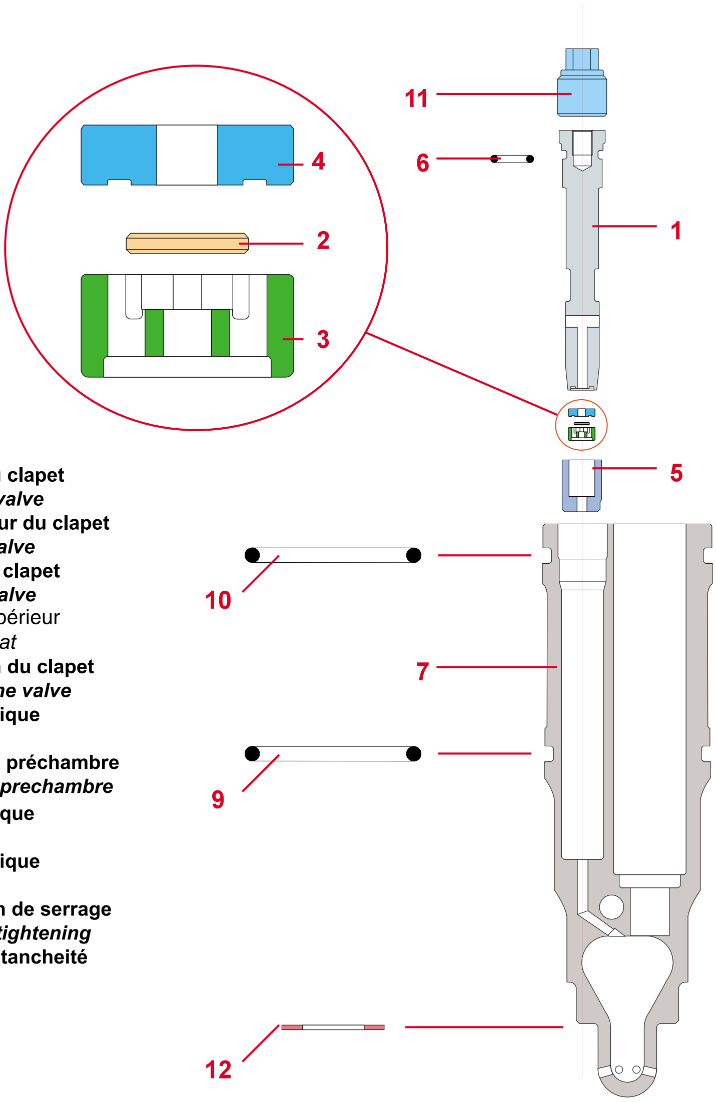
4 **Replace the sealing washer (12).**

5 **Install the prechamber and the flange (4)** and tighten nuts (11) to the prescribed torque (see Section 07).

16.3 Prechamber check valve

16.3.1 General description

A check valve is installed in the gas supply piping to prevent compression or combustion pressure from entering into this piping.



1 Corps du clapet
1 Body of valve
2 Obturateur du clapet
2 Seal of valve
3 Siège du clapet
3 Seat of valve
4 Siège supérieur
4 Upper seat
5 Manchon du clapet
5 Muff of the valve
6 Joint Torique
6 O-ring
7 Corps de préchambre
7 Body of prechambre
9 Joint torique
9 O-ring
10 Joint torique
10 O-ring
11 Bouchon de serrage
11 Cork of tightening
12 Joint d'étancheité
12 Gasket

Fig. 16-3

16.3.2 Check valve - removal

1 **Disconnect the coil cable.**

2 **Remove the coil** and the spark plug extension.

3 **Remove the cylinder head cover** and the spark plug sleeve (12).

4 **Unscrew the locking plug (11).**

5 **Extract the valve** using the threaded section provided for this purpose at the end of the valve.

6 **Blank the hole in the prechamber.**

16.3.3 Check valve - overhaul

1 **Unscrew the sleeve (5) at the end of the valve.**

2 **Remove the seat (3), the valve seal (2)** and the upper seat (4).

3 **Carefully clean all parts,** as well as the gas supply port in the valve body (1).

4 **Re-assemble the valve in the reverse order of disassembly.**

5 **Tighten the sleeve to the specified torque** (see Section 07).

Note: **The valve should be overhauled in accordance with the maintenance schedule (Section 04).**

16.3.4 Check valve reinstallation

1 **Remove the plug from the prechamber hole** and check that the mating surface is clean.

2 **Replace the O-ring (6)** and lubricate it with oil or vaseline.

3 **Install the check valve** and tighten the locking plug to the given torque (see Section 07).

4 **Install the spark plug sleeve** and the cylinder head cover.

5 **Install the spark plug extension** and the coil.

6 **Connect the cable to the coil.**

16.4 Ignition system

16.4.1 General information

The ignition system has been especially designed for this type of engine and is built into the engine control system. The control system (WECS) sets ignition advance which can be adjusted separately cylinder by cylinder. The ignition coil is located on the top of the cylinder as close as possible to the spark plug.

The spark plug extension mounted between the coil and the spark plug is made of Teflon to ensure good high-voltage conductivity.

The industrial spark plug with platinum electrodes provides for a long service life.

16.4.2 Ignition coil

16.4.2.1 Removal and refitting

See Sections 16.2.2. and 16.2.4.

16.4.2.2 Coil - reconditioning

The ignition coil does not require any maintenance.

If defective, the coil has to be replaced.

16.4.3 Spark plug

16.4.3.1 Spark plug - removal

1. **Remove the coil** and the spark plug extension.
2. **Unscrew the spark plug** using special tool DLP758120.

16.4.3.2 Spark plug - reconditioning

The spark plug does not require any reconditioning. If defective, it has to be replaced in accordance with the maintenance schedule (see Section 04).

16.4.3.3 Spark plug - refitting

1. **Check the gap of the electrode.** This gap must be 0.4 mm.
2. **Tighten the spark plug** using special tool DLP758120 to the correct torque (see Section 07).
3. **Install the spark plug extension,** the coil and the locking cover.

Caution: **Never lubricate the spark plug thread. Grease reduces the cooling efficiency of the spark plug.**

16.4.4 Spark plug extension

16.4.4.1 Extension - removal and installation

(See Sections 16.2.2. and 16.2.4.).

16.4.4.2 Extension - reconditioning

Clean the extension and replace it if cracked or if signs of high-voltage arcing are found (burning).

17. Gas System

17.1. General Description

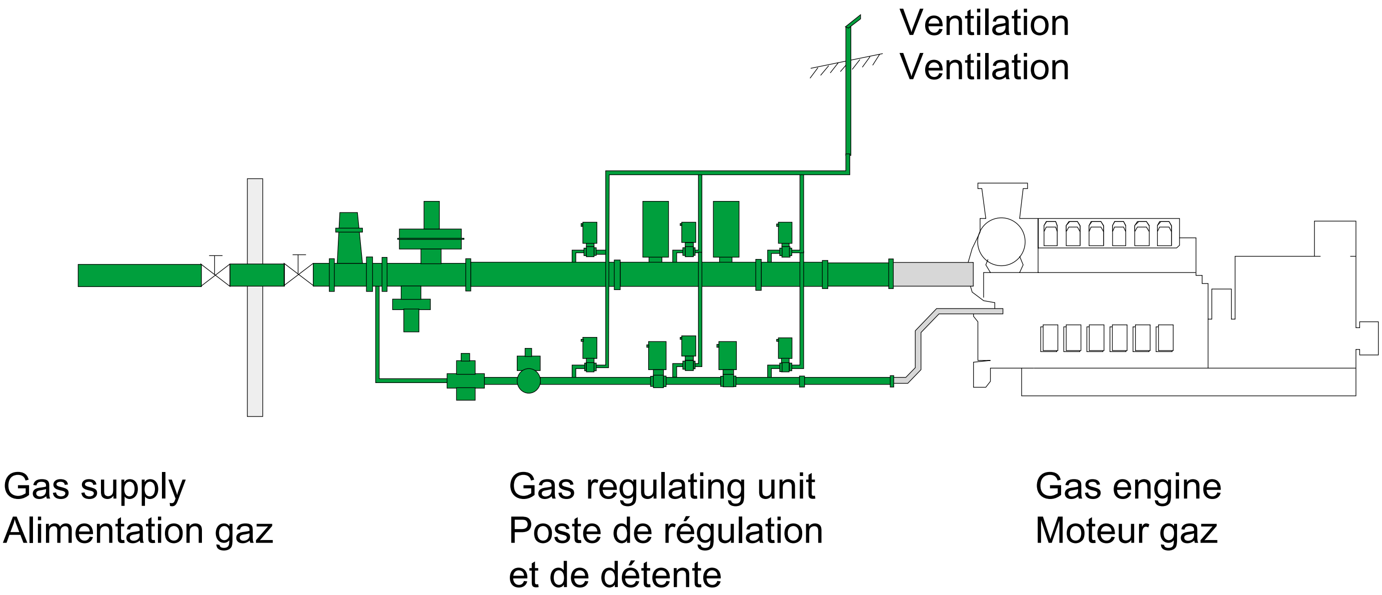


Fig. 17-1

The gas is fed through a control and expansion unit before it enters the engine.

This unit includes the filters, pressure regulators, solenoid stop valves and solenoid vent valves. The unit is made up of two separate gas outlets: one for the prechamber supply and one for the main chamber supply. The gas outlet pressures are controlled by the WECS 3000 system depending on engine power. Because the unit may vary from one installation to the next, it is not described in this Section (see appended instructions).

On the engine, the gas is supplied via a common manifold which branches off with intake pipes to each cylinder. A separate supply pipe is used to feed the prechambers.

Gas intake is controlled by main gas valves to provide power and prechamber valves for prechamber supply.

The two types of valves are direct-acting solenoid valves controlled by the WECS 3000 system. A check valve is also fitted in the prechamber to prevent any returns along the supply circuit.

The WECS 3000 system controls the two gas pressures (prechamber and main chamber). These pressures are read by the monitoring system (MONITOR).

The prechamber is described in Section 16.

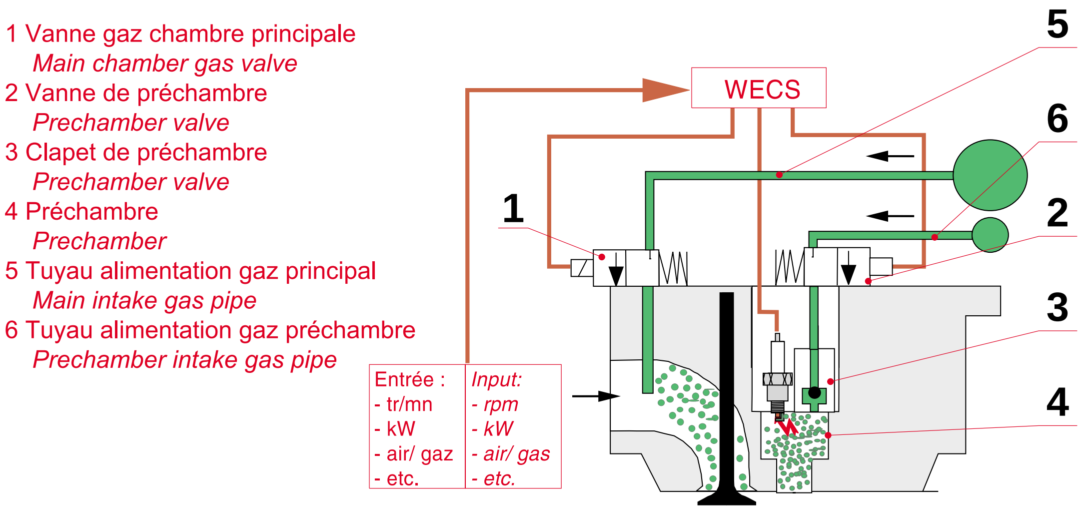


Fig. 17-3 wecs019748

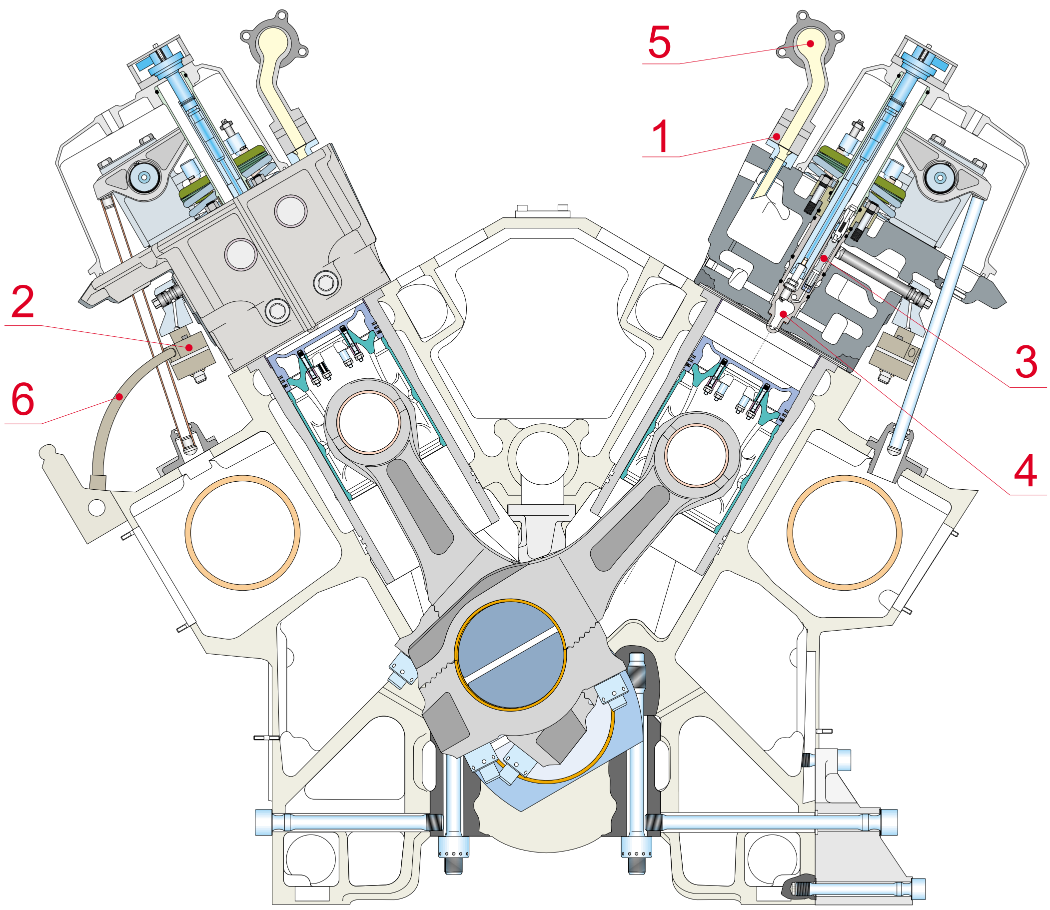


Fig. 17-2 bati29748

17.2. Maintenance

It is essential for all components to be clean for the system to operate correctly.

The pipes, valves, check valves and expansion unit components must be thoroughly cleaned before use.

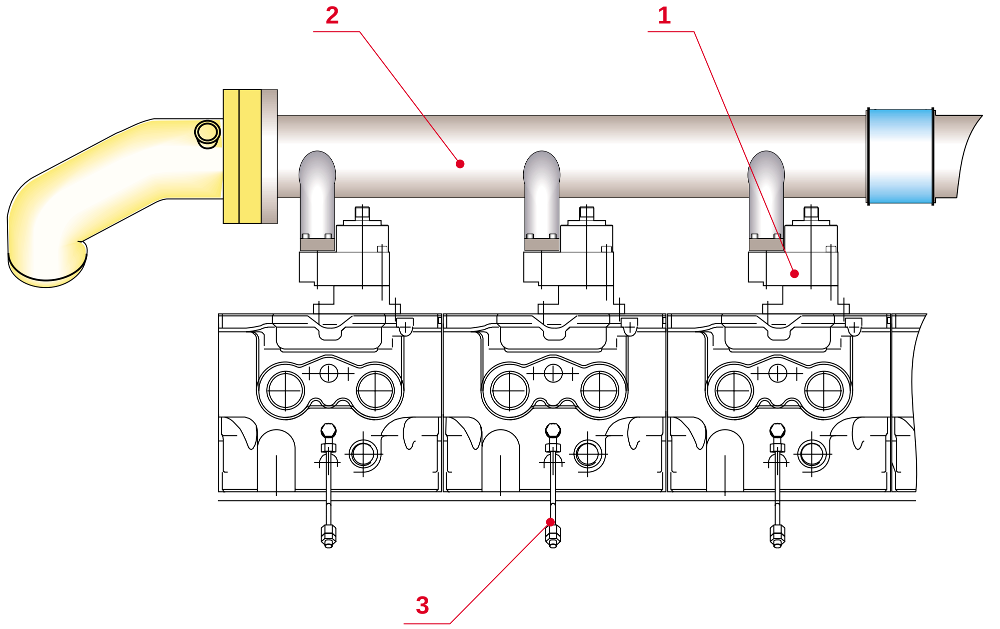
Caution: **Before carrying out any work on the gas line, check that all the gas stop valves are closed, that the vent valves are open and that the gas pipes have been vented.**

17.3. Gas pipes on engine

The gas pipes on the engine are partly integrated to supply the pre-chambers in the hot box supports.

A symmetrical manifold for each bank branching off with feed pipes supplies the main gas valves.

O-rings provide gas tight seals. Change the O-rings whenever the assembly is dismantled.



1 Vanne Gaz principale
Main Gas Valve
2 Collecteur Gaz
Gas manifold
3 Tuyau alimentation préchambre
Prechamber intake pipe

Fig. 17-4 17-39748

17.4. Main gas valve

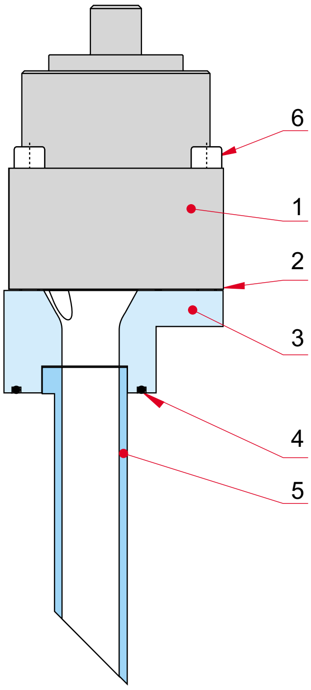


Fig. 17-5 17-49748

17.4.1. Description

The main gas valve controls the amount of gas to be admitted into each engine cylinder. The valve is located on the cylinder head and the gas is fed into the intake chamber via a bevelled pipe which improves the gas / air mix. The prechamber gas valve is a solenoid valve.

The WECS system regulates the supply of gas by adjusting the opening time of the solenoid valve.

17.4.2. Main Gas valve - removal

1 **Check that the gas supply stop valves** are closed and the gas pipes are vented.

2 **Disconnect the electrical power supply** to the valve.

3 **Remove the gas intake pipe.**

4 **Undo the four screws (6)** and remove the valve.

5 **Protect the openings to the cylinder head** and intake pipe.

17.4.3. Gas valve - reconditioning

The gas valve is maintenance free. It must be changed if it does not operate properly.

17.4.4. Main Gas valve - refitting

1 **Remove the protections from the openings** and check that the mating surfaces are clean.

2 **Change the O-ring (2)** on the valve.

3 **Fit the valve** and tighten the four screws to the specified torque (see Section 07).

4 **Fit the gas supply manifold** and tighten the screws.

5 **Connect the electrical power supply.**

17.5. Prechamber solenoid valve

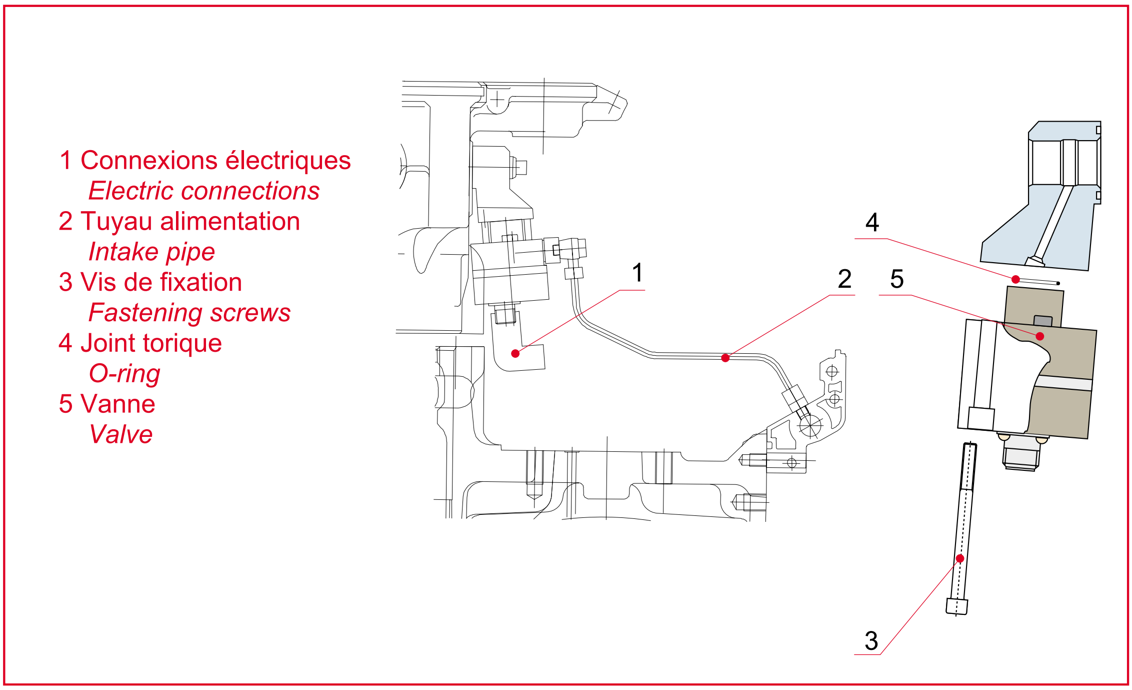


Fig. 17-6 17-59748

17.5.1. Description

The prechamber solenoid valve controls the amount of gas admitted into the prechamber of each cylinder.

The WECS system controls this valve by regulating the opening time.

17.5.2. Prechamber valve - removal

1 **Check that the gas stop valves are closed** and that the gas pipes have been vented.

2 **Remove the hot box covers.**

3 **Remove the prechamber valve supply pipe (2).**

4 **Unscrew the electrical connection.**

5 **Undo the two retaining screws (3)** and remove the prechamber valve (5).

6 **Protect the openings of the cylinder head** and the supply pipe.

17.5.3. Prechamber valve - reconditioning

The prechamber valve is maintenance free. It must be changed if it does not operate properly.

17.5.4. Refit the prechamber valve.

1 **Remove the protective covers** and check that the mating faces are clean.

2 **Change the O-ring (4).**

3 **Fit the prechamber valve** and tighten the two screws to the specified torque (See Section 07).

4 **Refit the gas supply pipe.**

5 **Connect the electrical supply.**

18. Lubricating Oil System

18.1 General design

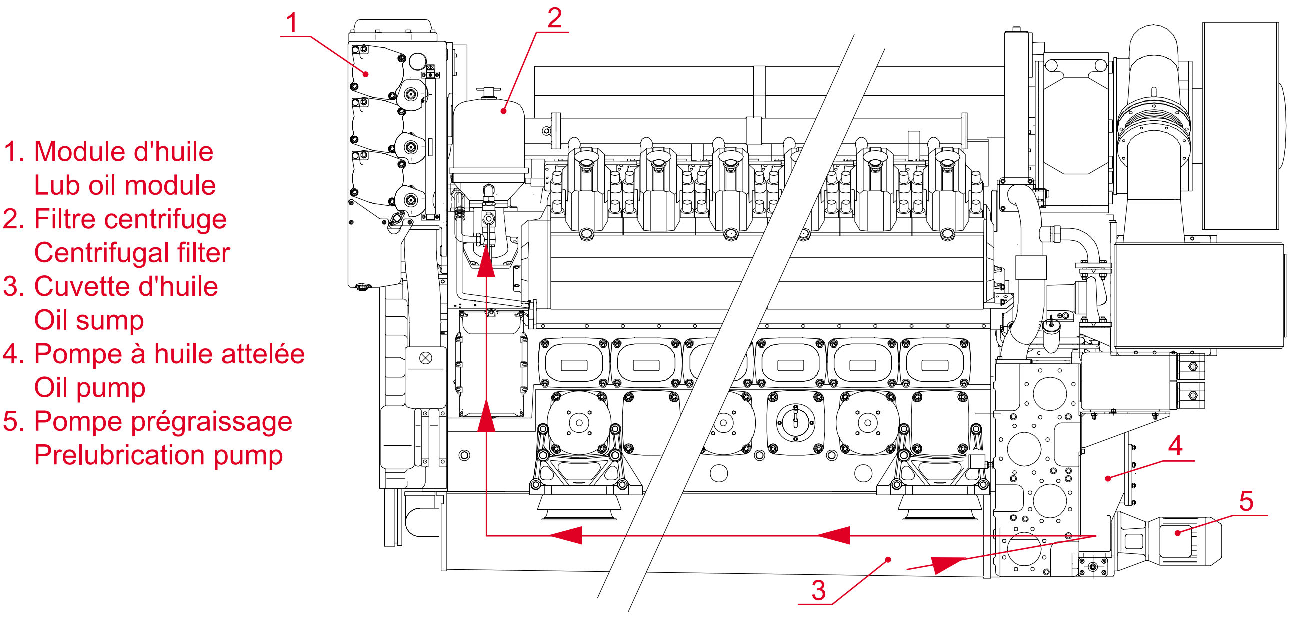


Fig. 18-1

The lubricating oil system includes the oil sump, the oil pump, the by-pass centrifugal filter and the lubricating oil module.

The oil is drawn up from the sump through the suction pipe into a channel integrated in the free end cover. The pump unit is located externally and is mounted directly on the free end cover. It comprises the engine driven lubricating oil pump and the electric prelubrication oil pump.

From the oil pump, the oil is fed into another channel integrated in the free end cover, then into a welded steel pipe located in the sump for transfer to the other end of the engine (the flywheel end). At this end, the oil is directed toward a channel integrated in the engine block and then to another channel integrated in the flywheel cover.

From the flywheel cover, the oil is fed by a pipe to the lubricating oil module.

From the oil pump, part of the oil flows to the centrifugal filter, which is mounted in a by-pass arrangement.

The lubricating oil module comprises the oil temperature regulating, cooling and filtering devices. The module is made of several aluminum castings assembled at the flywheel end of the engine, and above the flywheel. The filters treating the full oil flow are of the paper cartridge type, installed horizontally in the module.

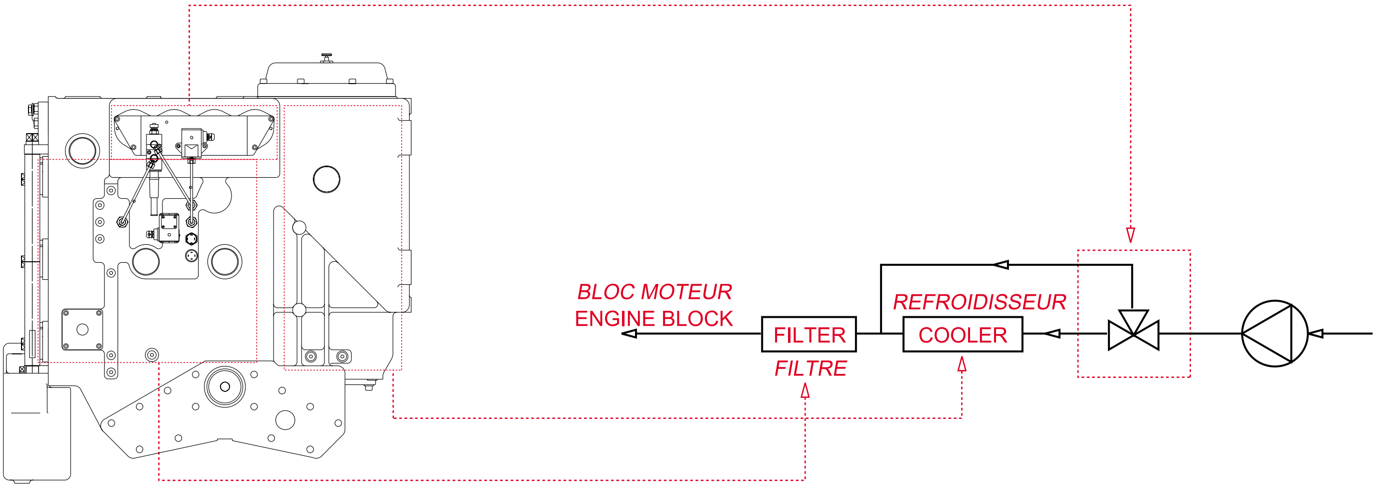
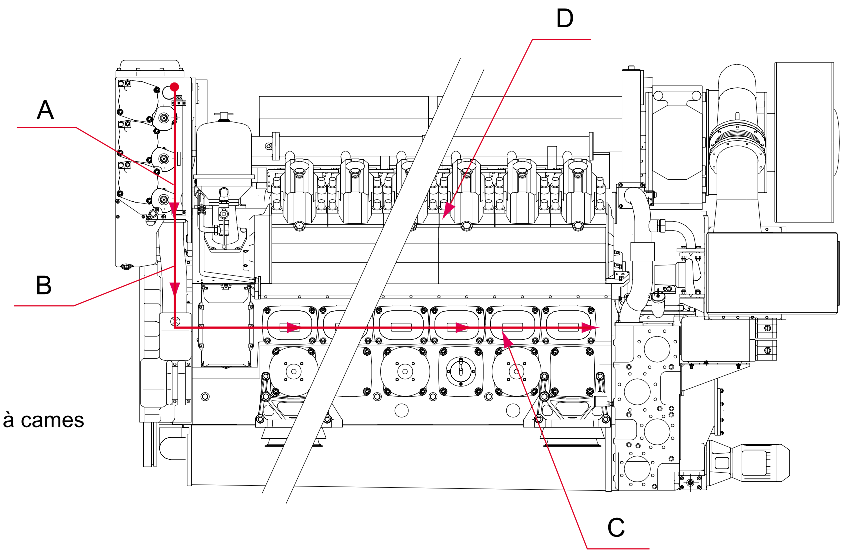


Fig. 18-2

From the lubricating oil module, part of the oil is pumped to the lubricating pipes of the camshaft and its bearings, the valve tappets and the cylinder head valve mechanism. To lubricate the gear drive, two other pipes supply oil jets mounted in the flywheel housing.



A. Vers distribution
To timing gear
B. Vers arbre à cames
To camshaft
C. Vers coussinets d'arbre à cames
To camshaft bearings
D. Vers culbuteurs
To rocker arms

Fig. 18-3

The remaining oil is pumped into the main channel integrated in the engine block.

The oil in the main channel supplies three groups of major components:

- the crankshaft bearings,
- the connecting rod big and small end bearings,
- the piston pin bushes, by means of a channel machined in the connecting rods.

A small part of the oil is used for pressurized lubrication of the cylinder liners.

The piston head gallery is cooled by oil sprayed from the oil jets.

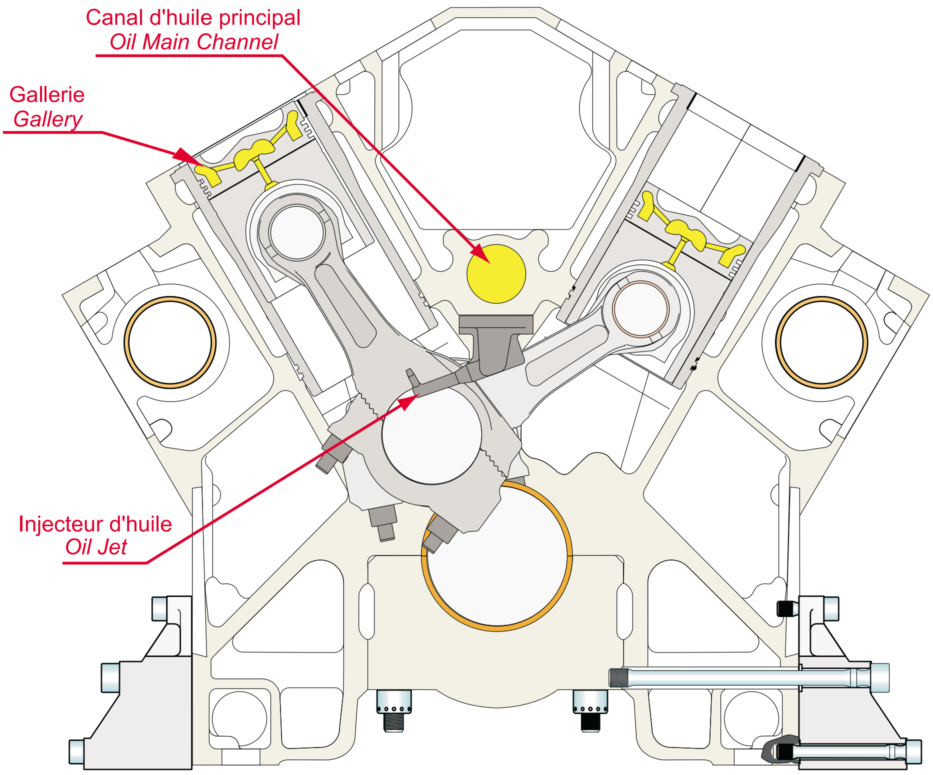


Fig. 18-4

The turbocharger is lubricated via a pipe mounted on its bracket.

The oil pressure in the turbocharger is provided by a diaphragm in the turbocharger bracket.

Another pipe is connected to the pressure regulating valve in the pump unit to provide a constant lubricating oil pressure in the engine, under all running conditions (oil temperature, engine speed, etc.). It is very important to keep the pressure correct to ensure efficient lubrication of bearings and piston cooling. The pressure is adjusted at the Wärtsilä France s.a.s. facility using a set screw located on the regulating valve.

Caution: **Adjustment of this set screw is reserved for Wärtsilä France personnel. When the oil is cold, the pressure may increase beyond its nominal value during start-up, but it should return to its nominal value when the oil reaches its normal service temperature.**

18.2 General maintenance

Use only high quality oil recommended by the manufacturer as specified in Section 02. Always ensure that there is a sufficient quantity of oil in the system. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level close to the maximum and never let it drop under the minimum. These limits apply to the oil level in a running engine. One side of the dipstick is graduated in centimeters. This scale may be used to verify oil consumption. Replace the oil on a regular basis at the frequency given in Sections 04 and 02, Section 02.2.3. When the oil is still hot, drain the oil circuit as well as the filter and cooler. Clean the crankshaft casing and oil sump using a clean cloth (no cotton waste). Clean the main filter and the centrifugal filter. Replace the filtering cartridges of the main filter, unless they were replaced recently.

Caution: **Utmost cleanliness is required when working on the lubricating oil system. Dirt, deposits, or metal particles may seriously damage bearings. When dismantling pipes or parts of the circuit, cover all openings with blanking seals, adhesive tape or clean cloths. When storing or transporting oil, take care to prevent dirt or foreign matter from contaminating the oil. Use a filter screen when refilling with oil.**

18.3 Lubricating oil pump module

18.3.1 Description

The lubricating oil pump module comprises the main pump and the pre-lubricating pump.

Both pumps are of the gear drive type.

The main oil pump is driven by the gear train, which is fitted with an additional roller bearing.

The main oil pump and the pre-lubricating oil pump have a common inlet and outlet. A check valve stops the oil from flowing through the pre-lubricating pump gears when the main pump is running.

A combined pressure regulating/safety valve is integrated in the pipe of the pump.

18.4 Combined oil pressure regulating and safety valve

18.4.1 Description

The pressure regulating valve is integrated in the oil pump housing and controls the oil pressure ahead of the engine by returning the surplus oil directly to the suction side of the pump.

A pipe in which the pressure is constant when the engine runs at a constant speed is connected to the engine distribution pipe. This pressure actuates a regulating piston and a spring is compressed to balance this force at the required pressure. In this way, pressure is held constant in the distribution pipe independently of pressure at the pump outlet and the loss of head in the circuit. A higher pressure is obtained in the circuit by tensioning the spring more.

In engines designed to run at varying speeds, the valve is designed to provide a pressure in function of the engine speed, in compliance with the recommended values (Section 01).

If for any reason the pressure rises substantially in the circuit, for example due to a blockage, a ball opens allowing the oil to flow to the regulating piston. This ball acts as a safety valve.

18.4.2 Maintenance

1 **Remove the moving parts.** Check wear and replace worn or damaged parts with new parts.

2 **Clean the valve carefully.**

3 **Refit all components.**

Note **Check that no moving part is blocked during assembly.**

18.4.3 Oil pressure regulating valve - adjustment

Whenever the oil pressure regulating valve is disassembled, it is necessary to follow the procedure below to adjust the valve (see fig. 18-5).

1 **Adjust the threaded rod (3)** so that it protrudes 16.5 mm from the edge of the side plate.

2 **Carefully increase the engine speed, then the load.** The engine inlet pressure after the filter should not exceed 4.5 bars. At full load, adjust the threaded rod to obtain an engine inlet pressure between 4.2 and 4.5 bars after the filter.

3 **Once the adjustment is made,** check that the screw protrudes between 10 and 18 mm. If this is not the case, inform Wärtsilä France.

4 **Fit the nut** as well as the brass lock nut.

5 **Check** that the engine inlet pressure after the filter is still between 4.2 and 4.5 bars.

A. Preadjusting size
Côte de préréglage
1. Counter nut
Contre écrou
2. Nut
Ecrou
3. Threaded rod
Tige filetée
4. Governor valve
Vanne de régulation
5. Pipe
Tube

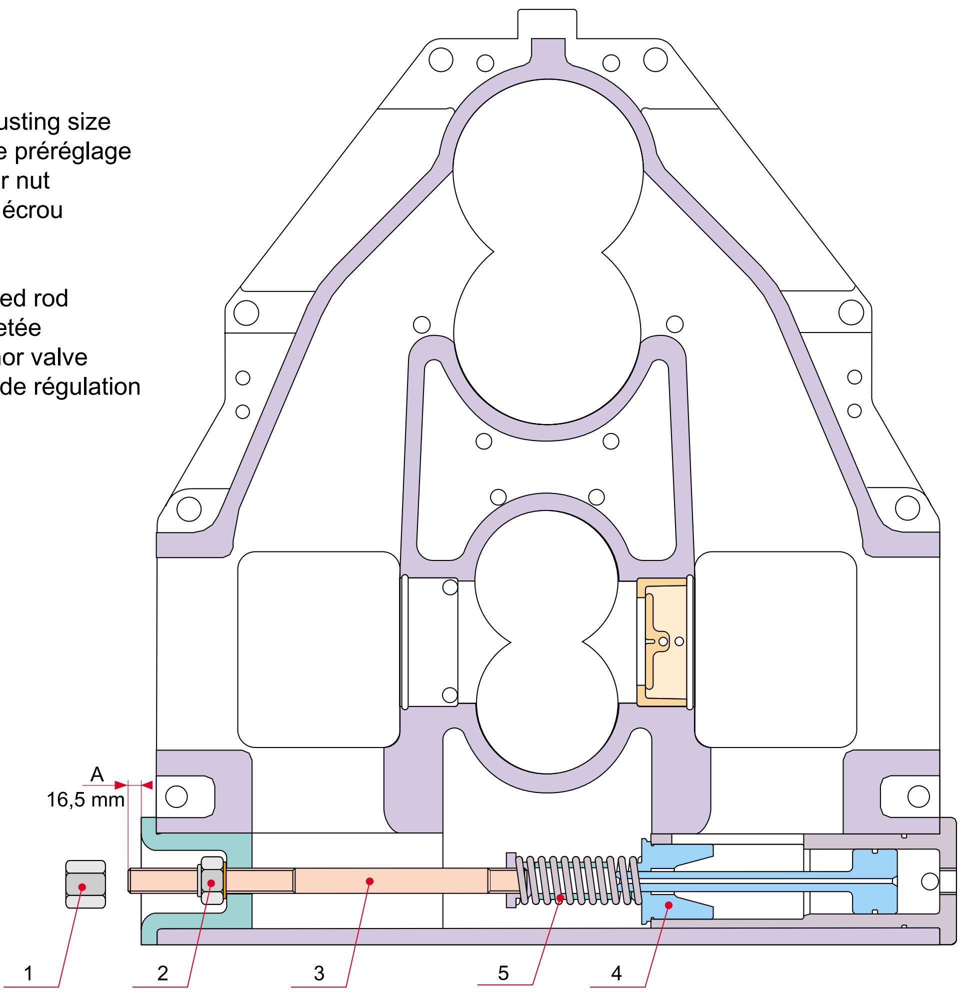


Fig. 18-5

18.5 Lubricating oil cooler

18.5.1 Description (see Fig. 18-6)

A tube stack (1) is inserted in a jacket (2) also comprising the filter housing.

The tube stack is only secured at one end. The other end can move longitudinally to allow for expansion.

Both ends are fitted with two O-rings.

The oil flows around the tubes and the coolant flows inside the tubes.

The tube stack is made of cupronickel and the water box is of aluminum.

1. Faisceau tubulaire
   Tubular bundle
2. Enveloppe
   Body
3. Couvercle réfrigérant
   Cooler cover
4. Vis de fixation faisceau
   Bundle fixing screw

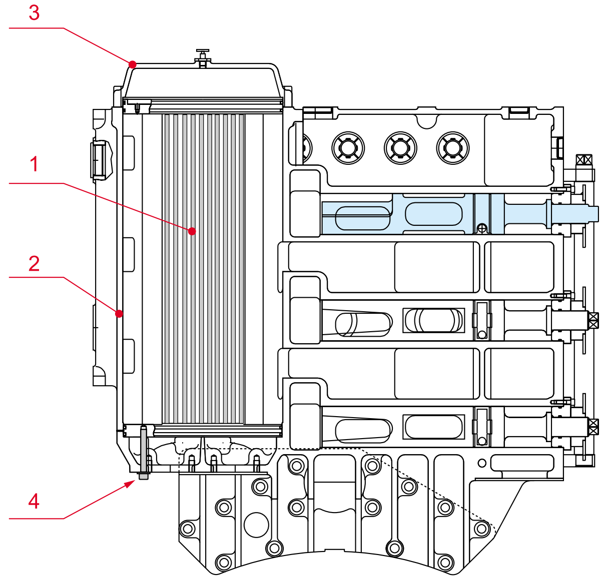


Fig. 18-6

18.5.2 General maintenance

1 **Regularly clean and test** the cooler by hydraulic pressure (12 bars), in compliance with the instructions given in Section 04, or when the oil temperature tends to rise abnormally.

2 **The water side can be cleaned** by removing the water box (3). Remove the tube stack to clean it thoroughly.

3 **When cleaning,** check for corrosion and test under hydraulic pressure.

Caution : **It is better to replace the tube stack too early than too late. Leakage of water into the lubricating oil would have very serious consequences.**

18.5.3 Cooler - removal and refitting

18.5.3.1 Removal

1 **Open the filter drain valve.**

Caution: **Be careful when opening the lubricating oil cooler. In spite of draining, there is always a small amount of oil in the covers and in the housing.**

2 **Drain the water circuit** as far as necessary.

3 **Remove the top cover (3).**

4 **Mark the position of the tube stack** in relation to the casing.

5 **Remove the stack retaining screws (4).**

6 **Extract the stack** vertically with a lifting ring and taking care not to get it jammed during removal (risk of damage to fins).

18.5.3.2 Refitting

1 **Check the sealing surfaces** for cleanliness and for scratches.

2 **Recondition,** and use new O-rings.

3 **Smear the O-rings** with a suitable lubricant.

4 **Fit the tube stack** in its casing.

5 **Check the position of the tube stack** using the marks previously made and refit the retaining screws (4).

6 **Refit the top cover.**

7 **Connect the coolant pipes** and lubricating oil pipes.

18.5.4 Oil side - cleaning

Normally, clogging of the oil side is insignificant. However, any clogging could severely affect the efficiency of the cooler. By design, the tube stack cannot be cleaned mechanically on the outside. Slight clogging may be removed by spraying steam through the tube stack.

If there is a considerable amount of dirt, use a commercially available chemical cleaning solution.

a) Alkaline degreasing agents:
These agents are suitable for normal degreasing. However, they are not very effective on heavy grease, sludge and oil coke. They require high temperatures. Always pour the degreasing agent slowly into hot water, never the reverse procedure. Carefully rinse with water after treatment.

b) Hydrocarbon solvents:
Solvents include an entire range of products, from light petroleum solutions to chlorinated hydrocarbons such as trichloroethylene. These products should be handled with care as they are often extremely volatile and have a toxic or narcotic effect.

c) Dissolving emulsions:
Heavy sludge, for example oil coke, can often only be dissolved with solutions of this type. Numerous brands are available on the market.

Note: **Follow the manufacturer's instructions to obtain the best results.**

18.5.5 Water side - cleaning

Cleaning shall be carried out so as not to damage the natural protective layer on the pipes.

Note: **Use Nylon brushes as metal brushes are likely to damage the protective layer.**

Remove sludge and deposits with a brush. Rinse with water.

If deposits in tubes are hard, e.g. calcium carbonate, such deposits may be chemically removed using commercially available agents. After this treatment, the tube should be rinsed and, if necessary, treated with a solution to neutralize the residual washing agents. Otherwise, follow the manufacturer's instructions.

18.6 Thermostatic valve

1. Eléments thermostatiques
   Thermostat elements
2. Piston de vanne
   Valve unit
3. Bride fermeture
   End flange

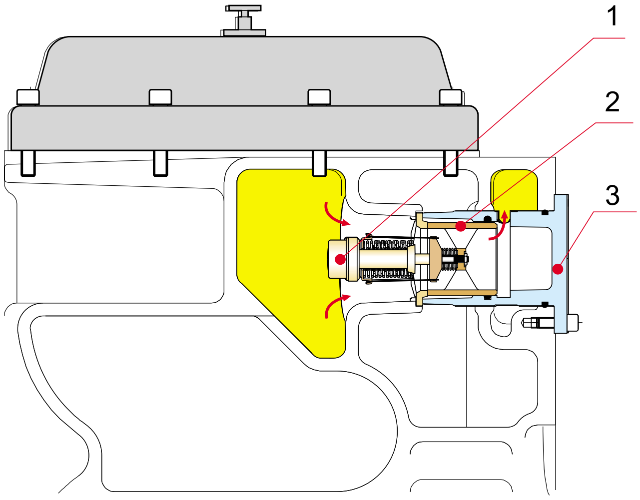


Fig. 18-7

18.6.1 Description

Fig. 18-7 illustrates the valve in closed position (left). When the temperature exceeds the set value, the contents in the elements (1) expand and force the valve (2) towards its seat, thus allowing part of the oil to be by-passed to the cooler.

This movement continues until the set temperature of the mixture is reached once again.

When the cooler becomes dirty, the temperature may rise by a few degrees, which is practically normal as the valve needs a certain rise in temperature inorder to open to a given position and increase the oil flow through the cooler.

The oil module is equipped with four thermostat elements.

18.6.2 Maintenance

Normally, no maintenance service is required. Insufficient oil temperature is caused by a defective thermostat. Excessive oil temperature may stem from the same cause, although it is most frequently caused by the cooler becoming clogged.

Replace the thermostatic valve at the intervals shown in Section 04.

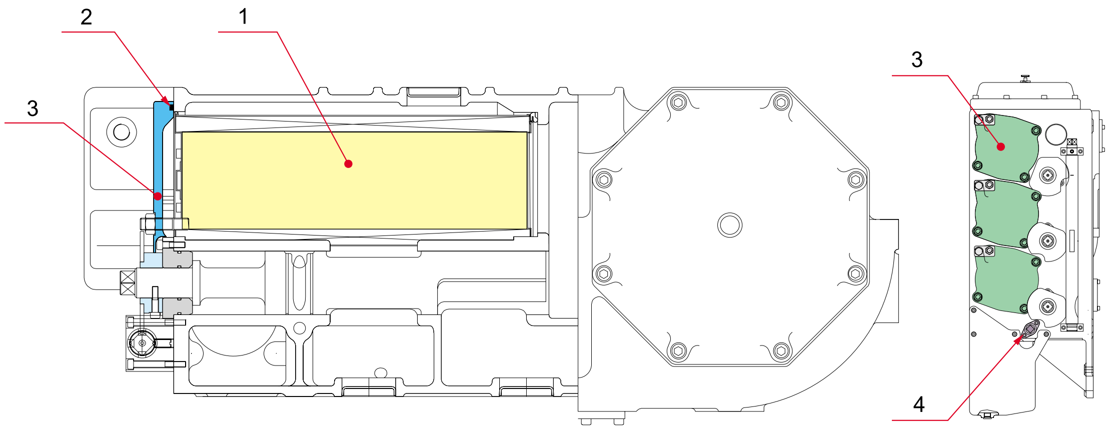
1 **Remove the oil thermostat cover.**

2 **Remove the support** of the thermostatic elements, then remove the elements.

3 **Check the element** by heating it slowly in water. Record the temperature at which it starts to open and the temperature at which it is fully open. Correct values are given in Section 09. The lowest oil temperature value corresponds to the beginning of opening, and the highest value corresponds to full opening of the valve.

4 **Replace any defective element.** Check the O-rings and replace if necessary.

18.7 Main oil filter



1. Cartouche filtrante / Filter cartridge
2. Joint torique / O-ring
3. Couvercle de filtre / Filter cover
4. Robinet de vidange / Draining cock

Fig 18-8

18.7.1 Description

The filters provided are full-flow filters, i.e., the entire oil flow goes through the filters. Normally, all filter elements should be in service to provide maximum filtration.

The oil passes through three cartridges (1) made of special paper, pore size 15 µm.

The filter is provided with a combined visual indicator or a pressure differential indicator connected to the automatic alarm system (WECS 3000), indicating a high loss of head through the filter. The paper cartridges must be replaced as soon as possible if high losses of head are recorded.

18.7.2 Filter cartridge replacement and filter cleaning

Rigorous maintenance of filters reduces engine wear. Replace cartridges on a regular basis (see Section 04) and, if the alarm is given by the clogging indicator, replace filters as soon as possible. As the service life of filters depends largely on the quality of the fuel used, the load, the quality of the oil, the use of a centrifugal filter, experience feedback from the system will indicate the appropriate frequency for cartridge replacement.

Note: **We recommend that you replace the filters at the maintenance times given in Section 04.**

Note: **Open the decompression screw to bring the filter to atmospheric pressure before opening the drain valve.**

1 **Filter draining:** Open the drain valve (4), and drain the oil (see Fig 18-8).

2 **Remove the covers (3).**

3 **Remove the paper cartridges (1).**

4 **Clean and rinse the filter casing carefully** with fuel oil.

5 **Change the paper filters.** These filters cannot be cleaned. Therefore, always keep a sufficient stock of cartridges.

6 **Change the O-rings (2).**

7 **Refit the covers (3)**

Note: **Never re-use drained oil to fill up the system as this oil is very dirty.**

18.8 Centrifugal filter

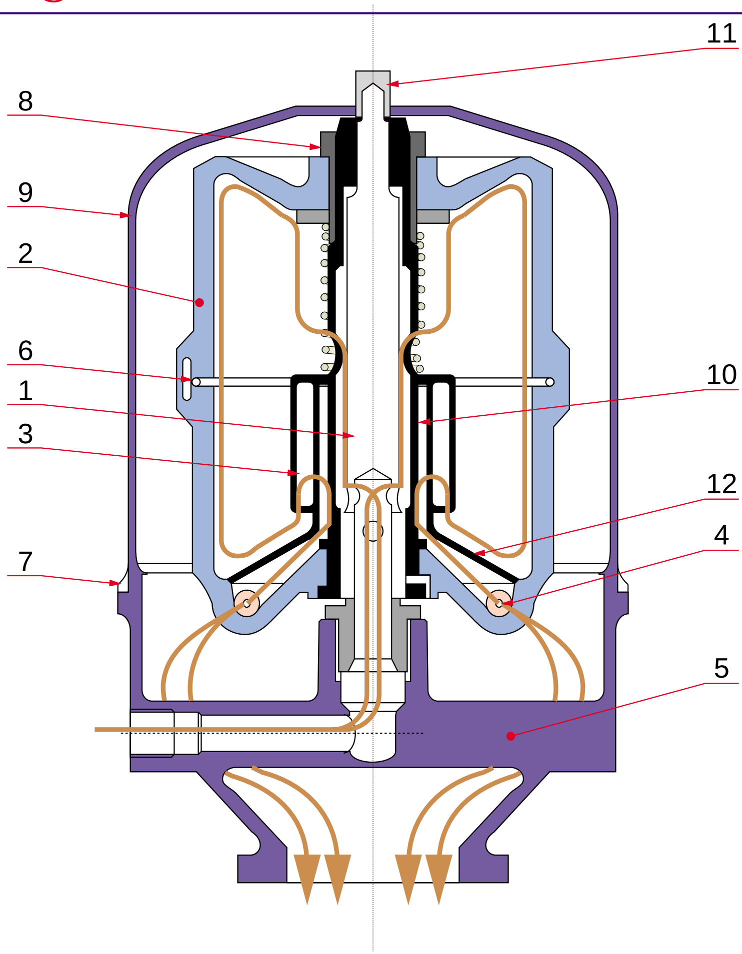


Fig. 18-9 glacier9748

18.8.1 Description

A centrifugal by-pass filter is fitted to the engine, in addition to the main filtration system.

The filter comprises a housing (5) with a hardened steel pivot (1) on which a dynamically balanced rotor (1) runs freely. The oil crosses the housing and rises towards the center pivot, and into the rotor.

The rotor comprises two compartments, one cleaning chamber and one drive chamber. The oil flows from the center pipe (10) to the top part of the rotor where a high centrifugal force is applied to it. Thus, dirt is deposited on the walls of the rotor in the form of thick sludge.

The oil then flows from the cleaning-separting compartment into the drive compartment including the central tube support (19) and the lower part of the rotor which has two jet nozzles (4). The clean oil jetting from the nozzles torque drives the rotor. The oil returns to the engine sump via the housing.

18.8.2 Cleaning

Regular cleaning of the centrifugal filter is very important (Section 04) as it collects enormous quantities of dirt, and lessens the load on the main filter (consequently, paper cartridges have a longer service life). If a large quantity of dirt is found on the filter (corresponding to an 8 mm thick layer) at the recommended cleaning frequencies, the filter must be cleaned more frequently.

Clean the filter as follows. Do not forget to close the oil supply valve to the filter.

1 **Remove the attachment brackets** of the filter cover (11).

2 **Remove the filter cover.** Check thrust bearings and shell bearings for wear. Also inspect the O-ring (7). Replace it if necessary.

3 **Remove the rotor assembly from the pivot** and allow the oil to escape from the jet nozzles before removing them from the filtering body. Hold the rotor body and unscrew the rotor cover lifting nut (8). Separate the rotor cover from the rotor body and remove the center pipe support.

4 **Remove the sludge from inside the cover** and from the rotor body using a wooden spatula or suitably shaped piece of wood and then wipe. Wash all components, in fuel oil for example.

5 **Clean jet nozzles with a compressed air blow gun.** Make sure that the bore of the pivot is not plugged with sludge.

6 **Examine the wear of the bearing surfaces of the pivot.**

7 **Inspect the O-ring (6). Replace it if required by its condition.**

8 **Clean the support pipe,** making sure that the holes in the mesh are not plugged.

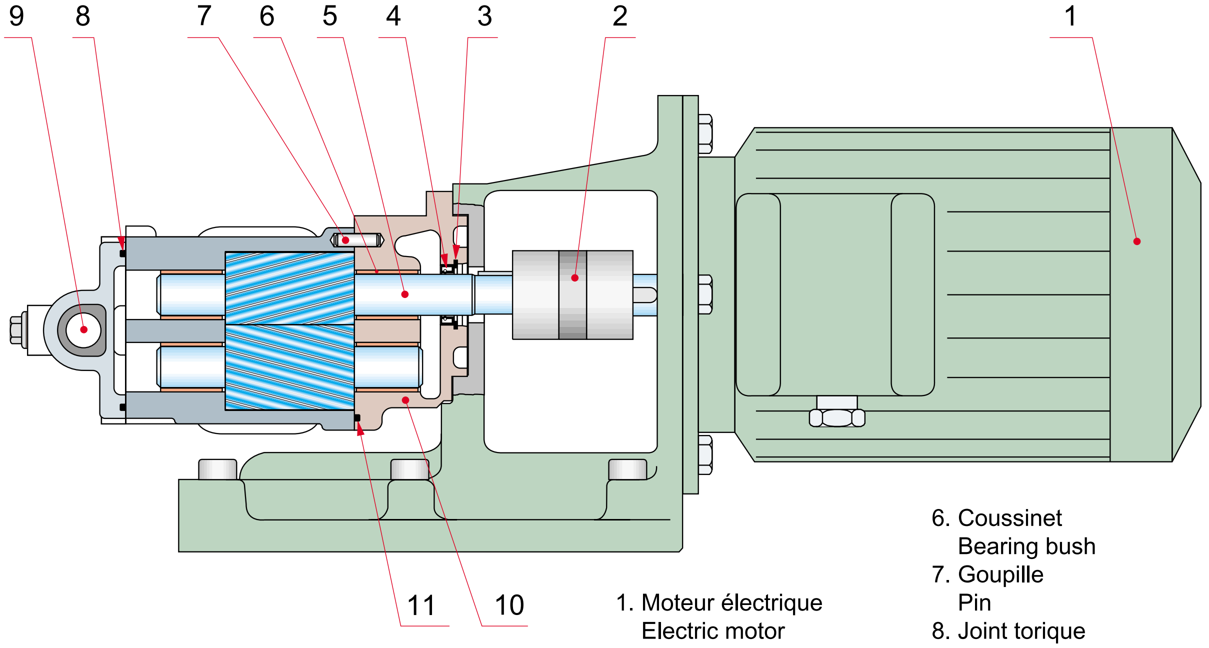
9 **Fully re-install the rotor** and the tighten nut (8) to a 10 Nm torque.

Bad nut (8) tightening may cause rotor imbalance, which has an effect on filter performance.

10 **Examine the bearings** located in the body of the filter. Replace them if necessary.

11 **Fully re-install the filter.** Check that the rotor runs freely, then fit the filter cover and re-attach the attachment bracket of the filter cover.

18.9 Pre-lubricating oil pump



1. Moteur électrique
   Electric motor
2. Accouplement élastique
   Flexible coupling
3. Circlips
   Retaining ring
4. Joint d'étanchéité
   Shaft seal
5. Arbre de commande
   Drive shaft
6. Coussinet
   Bearing bush
7. Goupille
   Pin
8. Joint torique
   O-ring
9. Soupape de régulation de pression
   Pressure regulating valve
10. Carter de pompe
    Pump casing
11. Joint torique
    O-ring

Fig. 18-10

18.9.1 Description

The pump is of the screw type, driven by an electric motor.

The pump is fitted with an adjustable pressure regulating valve (9). The pressure must be limited to the minimum pressure, approximately 2 bars, by unscrewing the adjusting screw (14) to its final position so that the electric motor is not overloaded when it operates with very cold oil.

18.9.2 Maintenance

See the pump manufacturer's maintenance manual. Normally, no regular maintenance is required.

After 3 to 6 years use, the shaft seal must be replaced. Oil leaks indicate that the shaft sealing is insufficient and the seal must be replaced. Be careful not to damage the sealing faces of the bushes. A slight scratch can be detrimental to sealing. Avoid touching sealing surfaces with your fingers.

19. Cooling System

19.1 Description

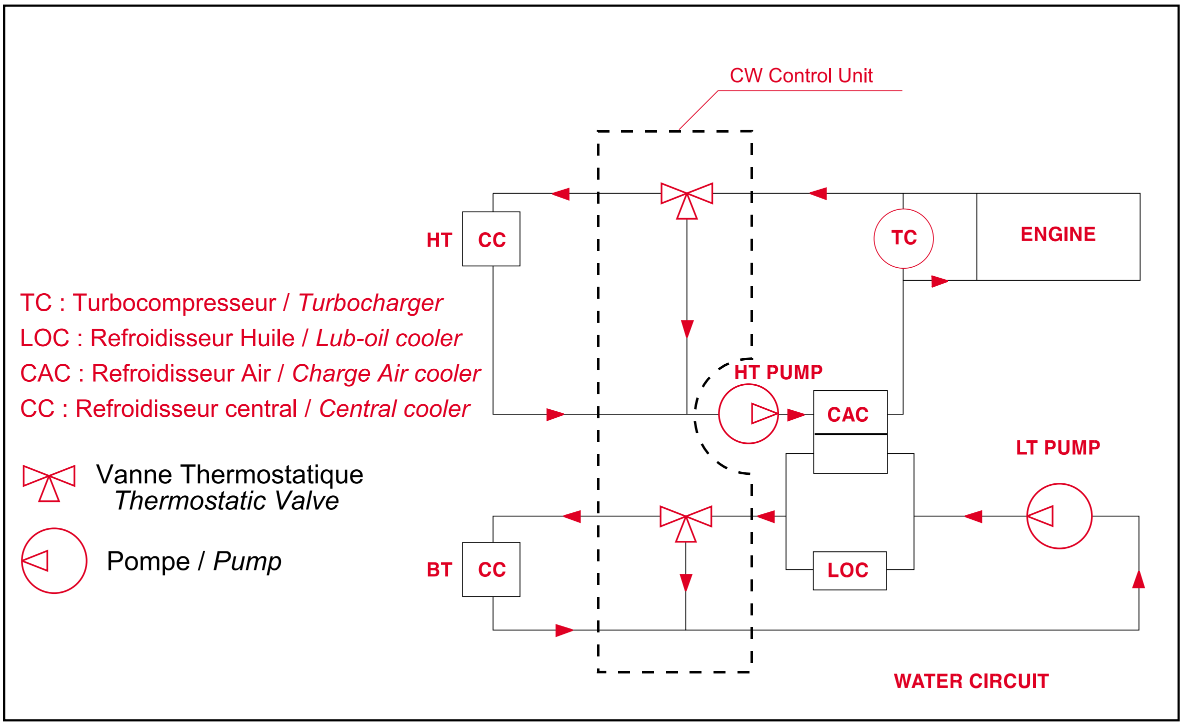


Fig. 19-1

19.1.1 General information

The cooling system comprises two cooling circuits: the low-temperature circuit (LT) and the high-temperature circuit (HT). The water in the low-temperature circuit cools the air cooler and the oil exchanger in parallel. The water in the high-temperature circuit cools the cylinders (liner water), the cylinder heads and the non-insulated part of the exhaust system. The dual pump allows the coolant to circulate in both circuits. The dual pump is a centrifugal pump fitted with two rotors, one for the LT circuit and the other for the HT circuit. The temperatures of the coolant are controlled by sensitive, bulb type element, thermostatic valves. The thermostatic valves of the two circuits are mounted on the same bracket. The body of the coolant regulating unit is mounted on the bank B side of the free end of the engine and is fitted with one outlet and one return to the external cooling system only. The HT coolant circuit may optionally be fitted with a preheating system comprising one of the heating resistors, an electric circulating pump and check valves.

19.1.2 Low temperature circuit

From the body of the coolant regulating unit, the coolant is pumped from the LT pump to the free end cover. Part of the coolant is pumped to the second stage of the air cooler and returns to the free end cover via the water manifold and the two external pipes. The remaining LT water is pumped to the free end via a channel machined in the engine block, bank A. From the block, the water then circulates in the oil heat exchanger of the lube module. The water returns via a pipe in the flywheel cover then, through bank B of the engine block, returns to the free end cover. The W 220 SG cooling system is a dual water system (see fig. 19.1). If the temperature is low (less than a nominal temperature), the water returns to the pump but, if the water temperature is high (greater than a nominal temperature), it is directed to an external air cooler.

19.1.3 High-temperature circuit

From the body of the coolant regulating unit, the high-temperature water is drawn by the HT pump through the free end cover. From the HT pump, through the free end cover and the water manifold, the high-temperature coolant is directed to the cylinder liners and cylinder heads. In the cylinder head, the water cools the hot part in contact with the combustion prechamber, the seats of the exhaust valves and all other components efficiently. From the cylinder head, the water goes to the multiduct to cool the non-insulated part of the exhaust gas manifold. From the multiduct, the HT coolant returns to the regulating unit body via the water box and a pipe. If the temperature is low, the water is returned directly to the HT pump but, if the temperature is high, the water is pumped to an external air cooler.

19.2 Coolant regulating unit body

19.2.1 General information

The regulating unit body controls the temperature of the HT and LT coolant by means of two sets of thermostatic valves. The thermostatic valve is of the three-way type to direct the water in the required direction. When the engine is started and cold, the thermostatic valve lets all the water return to the engine without passing through the central cooler. This keeps the warm-up time as short as possible. When the engine is hot, part of the HT water returns directly to the pump and the remaining water is directed to the central cooler. If the water temperature is too high, the thermostatic valve directs all water to the central cooler to enhance cooling. This valve does not require any adjustment. The temperature setting is adjusted once and for all by the engine manufacturer. The valve is fully enclosed in its casing and there are no fragile external components that may be damaged. No parts need lubricating and no packing glands have to be tightened.

The operating principle of the valve is the expansion of a substance in the elements. This substance is always in a relatively pasty state and is very sensitive to temperature changes. Each group of thermostatic valves comprises four elements. If one element is damaged, the others perform the function with only a slight temperature difference. Water flow is directed either to the by-pass or to the cooler. Failure of an element does not entail a drop in engine power.

19.2.2 Thermostatic valve maintenance

Normally, no maintenance is required. An excessive drop in water temperature is caused by a defective element. An excessively high temperature may be caused for the same reason, even though in most cases this is caused by a clogged cooler.

1 **Drain the water from the circuit.**

2 **Loosen the flange (1) and remove the element.**

3 **Test the element** by heating it slowly in water. Record the temperature threshold when it starts to open and the temperature when it is fully open. The correct temperatures are given in Section 6.4. The lower number is the beginning of opening temperature and the higher number the full opening temperature.

4 **Replace the element if it is defective.** Check sealing and replace sealing parts if necessary.

19.3 Different types of water cooling systems

The different types of external cooling systems are:

- radiator,
- tower,
- raw water.

19.3.1 Cooling with a radiator

The radiator is often selected when the ambient temperature is between +5°C and +35°C and when untreated water is not readily available. During cold weather (ambient temperature less than 0°C), the engine cooling system has to be filled with an antifreeze solution and must be appropriately designed. The radiator cooling system comprises the following modular units:

- radiator,
- expansion tank.

19.3.2 Cooling with a tower

The cooling tower is selected when the ambient temperature is high and the amount of untreated water available low. This system makes it possible to use treated soft water in the engine circuit at the same time as non-treated soft water in the cooling tower circuit. The advantage of the cooling tower is that the cooler may reach a temperature less than the ambient temperature due to forced evaporation of the water. Losses due to evaporation must be compensated for by adding fresh water.

The system comprises:

- the cooling tower,
- the expansion tank,
- the heat exchanger,
- the pumping module.

19.3.3 Cooling with untreated water

In general, the untreated water cooling circuit represents the most economic solution when untreated water is available in sufficient quantities and is of good quality.

The system comprises:

- a pump module,
- a heat exchanger,
- an expansion tank.

The untreated water is pumped from a supply tank or directly from the sea, a lake or a river.

19.4 Preheating

For fast loading of the engine after starting, the coolant circuit may be fitted with a preheating system. This system preheats the coolant to a temperature as close as possible to the 50°C operating temperature in the HT circuit. The preheating system consists of a 12 kW immersion heater unit set to 60°C and an electrical circulating pump.

19.5 Design of the external cooling system

Correct operation of an installation depends on the auxiliary systems.

Environmental conditions must be taken into account from the outset and it is particularly important that auxiliary devices should taken into account and optimised right from the design phase of the project. Piping shall be fitted in compliance with the following rules:

1 **All pipes shall be installed** with a 1 cm/m slope to facilitate fluid drainage.

2 **The low points of fluid circuits and gas circuits** shall be fitted with drain valves or plugs.

3 **Untreated water heat exchangers** are also inclined at 1 cm/m. The assembly may be drained in freezing weather conditions.

4 **The circuit filling points** shall be located at low points, and top points shall be fitted with automatic or manual venting systems.

5 **If required by the quality of the water,** circuits shall be made of an anti-rust material, PVC or bronze.

6 **Connections between the system and the generating set** are flexible to absorb vibrations and alignment faults due to expansion or relative movements.

19.5.1 Bleeding air from the water circuit

The engine is fitted with connections for continuous venting of the system.

19.6 Expansion tank

The expansion tank is designed to compensate for changes in the volume of water in the coolant circuit and also to vent the circuit and to provide sufficient static pressure in the water circuit.

a) **Static pressure** provided by the expansion tank: minimum 0.5 bar at the crankshaft.

b) **Volume :** Approximately 10% of the volume of water in the cooling circuit.
The vent pipes of each engine may be connected separately to the expansion tank. Do not use trap type elbows and the end of these pipes must be located beneath the surface level of the water.

19.7 Drainage tank

The purchase of a drainage tank in which treated coolant can be stored after draining from the engine or from the cooling circuit during maintenance work or a general overhaul is recommended.

19.8 Maintenance

19.8.1 General information

To obtain good results without any operating problems, the system (expansion, venting, preheating, pressurising, etc.) must comply strictly with the engine manufacturer's instructions. See sections 02 for more information on coolant treatment. If freezing could occur, drain all water and keep it treated to put back in the circuit later.

19.8.2 Cleaning

Clogging will be low in this fully-closed circuit if the water is appropriately treated in compliance with the instructions given in Section 02. Over time, clogging may occur to varying degrees depending on the initial quality of the water and the efficiency of the water treatment. As soon as deposits are found in cylinder liners, in cylinder heads and in cooler pipes, they are to be removed if they impede heat exchange with coolant. These deposits may cause serious damage. In principle, deposits may be removed chemically or mechanically as described below. For further information, see the cooler cleaning instructions in Section 18.5.

a) **Mechanical cleaning**

Most deposits are free sludge or solid particles that can be brushed and rinsed away with water. Where access is easy (liners), the hardest deposits may be removed by mechanical means. In certain cases, deposits which are dissolved by chemical means but which still remain attached have to be removed by mechanical means.

b) **Chemical cleaning**

Narrow holes and pipes for water (cylinder heads, coolers) can only be chemically cleaned. If the deposits are greasy, it is necessary to use a degreasing product (Section 18). The deposits, especially if of the lime scale type, can be removed with an acid solution. On the other hand, deposits comprising calcium sulphate and silicates resist chemical treatment, which nonetheless may have a dissolving effect making brushing efficient if access to the surfaces is possible. Numerous brands of products are commercially available (Section 02.3). Cleaning solutions must contain corrosion-inhibiting additives. To obtain the best results, always follow the product manufacturer's instructions. Carefully rinse to remove all residue from chemical treatment. If possible, brush surfaces. Rinse again with water, then with a 5% sodium carbonate crystal solution to neutralise remaining traces of acid.

19.9 Monitoring

Pressure sensors and temperature probes are installed to monitor the pressure and the temperature in the LT and HT cooling system.

a) Temperature probes to monitor

- LT temperature, central cooler outlet,
- LT temperature, central cooler inlet,
- HT water temperature, engine outlet,
- HT water temperature, turbocharger outlet.

b) Pressure sensors to monitor

- LT pressure, central cooler outlet,
- LT pressure, central cooler inlet,
- HT pressure, after the pump,
- LT pressure, before the air cooler.

Sensors and probes are connected to the engine main control unit (MCU). Engines are fitted with alarms monitoring the low and high temperature and pressure thresholds on HT and LT circuits.

19.10 Water pump

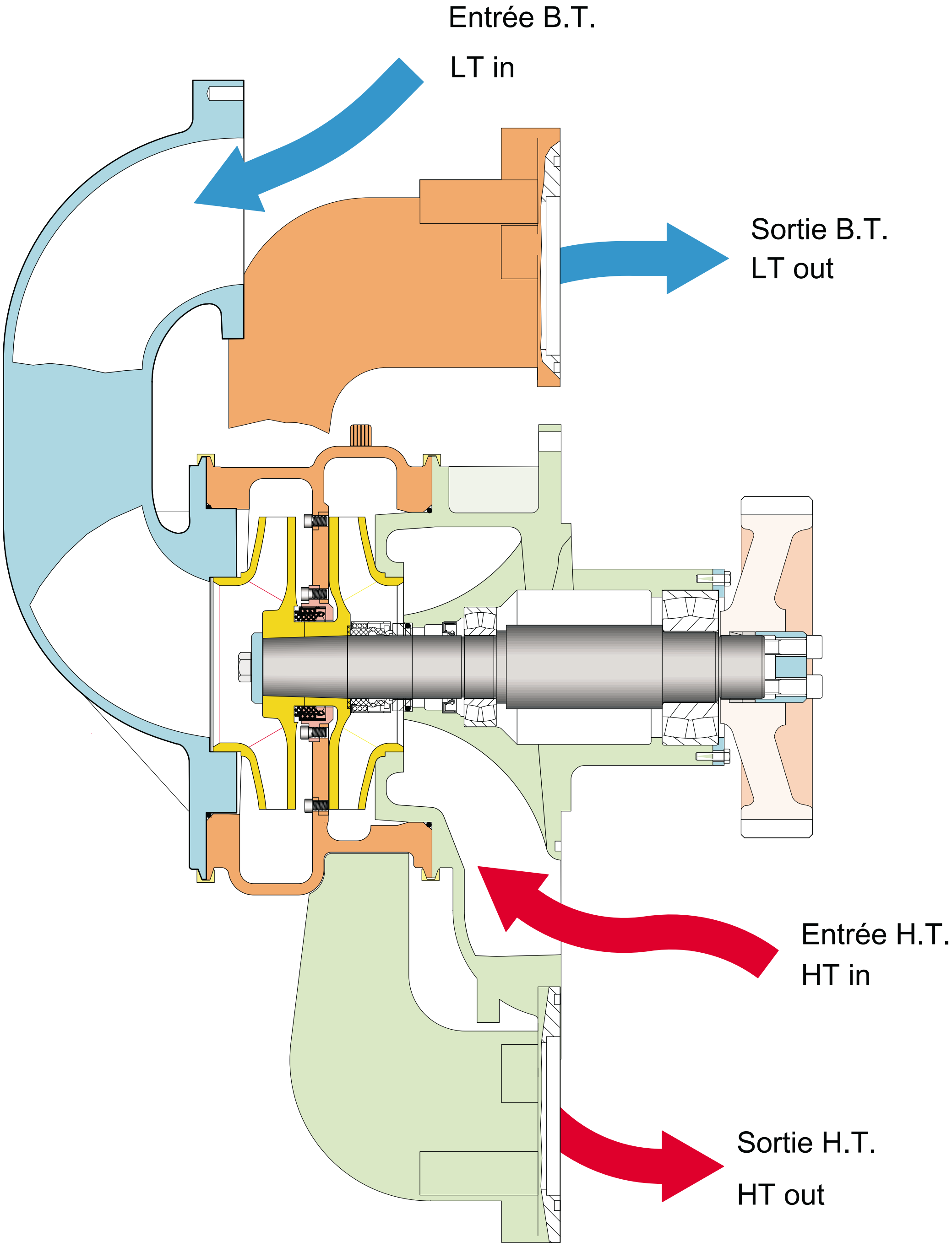


Fig. 19-2

19.10.1 Description

See Fig. 19-3

The dual pump is a centrifugal pump fitted with two rotors,fitted on the same shaft by a mechanical packing.

The pump is driven by a gear drive located at the free end of the engine.

The pump impellers, the pump body, the bearing support and the LT water inlet pipe are machined from iron castings.

The shaft in contact with the cooling fluid is made of non-chromium-plated, acid-resistant steel alloy. The shaft is machined from steel bar.

The shaft is mounted on two ball bearings (9) and (10) lubricated by splashing oil entering the bearing housing.

The shaft seal (12) stops oil from leaking out and, at the same time, dirt and water from entering.

The impellers are force-fitted to the shaft. The mechanical seal (11) rotates with the shaft and with its O-ring ensures proper sealing.

The shaft seal HT/LT ensures proper sealing between the 2 circuits.

19.10.2 Maintenance

Check the pump at the frequencies recommended in Section 04, or as soon as oil or water leaks are noticed.

19.10.3 Water pump assembly

19.10.3.1 Tooling

- Heating means making it possible to reach approximately 100°C.
- Engine oil
- Radial shaft seal assembly tool
- Front and rear bearing assembly tool
- Mechanical seal assembly tool
- Soapy water
- Torque wrench for tightening up to 115 Nm.

19.10.3.2 Assembly

1. Volute
   Pump housing
2. Rouet BT
   LT Impeller
3. Tube d'aspiration BT
   LT suction pipe
4. Corps de pompe
   Bearing housing
5. Couvercle de roulement
   Bearing cover
6. Arbre
   Shaft
7. Vis
   Screw
8. Rondelle
   Washer
9. Roulement
   Front bearing
10. Roulement
    Back bearing
11. Joint d'arbre
    Mechanical seal
12. Bague d'étanchéité
    Radial shaft seal
13. Joint torique
    O-ring
14. Joint torique
    O-ring
15. Vis
    Screw
16. Collier de serrage
    V-clamp
17. Rouet HT
    HT impeller
18. Plaque intermédiaire
    Intermediate plate
19. Joint d'arbre HT/BT
    Shaft seal HT/LT
20. Corps de joint
    Seal body
21. Vis
    Screw

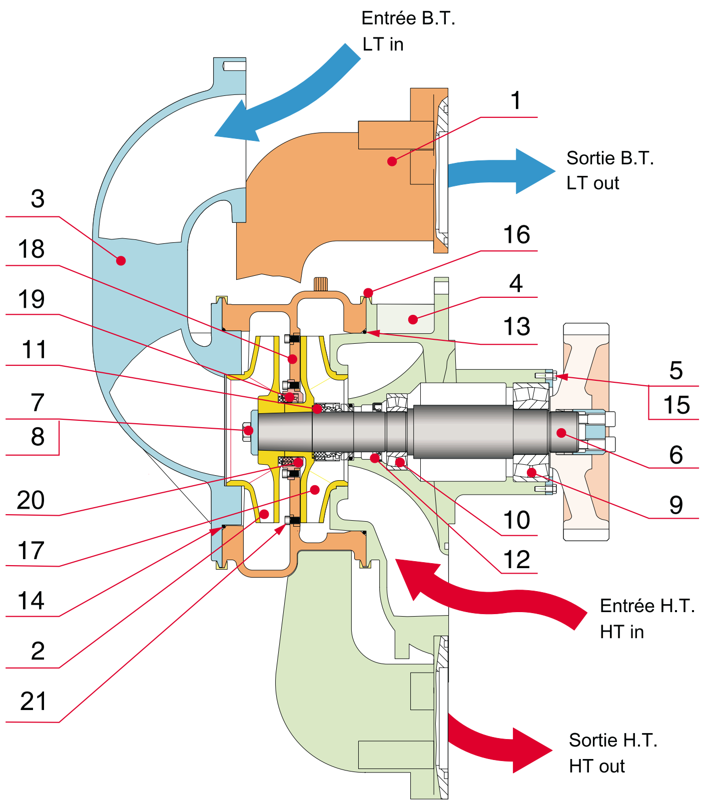


Fig. 19-3

1 **Lubricate the radial shaft seal (12)** with engine oil. Install the seal in the bearing housing (4) using tool no. 846007.

2 **Heat the front bearing (30)** to 80°C, then install it on the shaft (6).

3 **Install the front bearing** + shaft assembly in the bearing housing using tool no. 846008.

4 **Install the rear bearing (10)** on the shaft and in the bearing housing using tool no. 846009.

5 **Install the bearing cover (5).** Put Loctite 2701 thread lock on screws (15) and tighten screws to 10 +/- 0.5 Nm.

6 **Lubricate the O-ring of the mechanical seal (11)** with soapy water.

7 **Fit the O-ring and mechanical seal set** in the bearing housing.

8 **Lubricate the mechanical seal gussets and the shaft** with soapy water.

9 **Fit the seal on the shaft** with tool no. 846001.

10 **Install the HT impeller (17)** on his taper

11 **Fit the O-ring (13) on the housing (4)** and secure the pump housing (1) using the V collar (16).

12 **Install the intermediate plate (18),** put Loctite 2701 on the screws (21) and thighten the screws at 6 Nm;

13 **Fit the shaft seal HT/LT on his support** after lubricating with soapy water

14 **Mount the set on the impeller (17)** and fit it with the screws (21) coated with Loctite 2701 and tighten at 6 Nm

15 **Install the impeller LT (2),** washer (8) and screw (7). Tighten the screw to 200 Nm, then loosen and remove the screw. Put Loctite 2701 thread lock on the screw, and tighten the screw to 250 Nm.

16 **Install the O-ring (14)** in the LT water inlet pipe (3) and secure the pipe to the pump housing using the V collar (16).

19.10.4 Removal

Removal is the reverse procedure to fitting.

20. Exhaust System

20.1 Exhaust manifold

Characteristics and dimensions

Multiduct
Material: nodular cast iron
Mass: 8 kg
Test pressure: 10 bars
(water side)

Exhaust pipes:
Material: Special heat-resistant spécial résistant nodular cast iron

Bellows: Multi-ply thickness
Material: Heat-resistant steel

20.1.1 General description

The exhaust manifold is fitted between the cylinder heads and the turbocharger. The manifold consists of multiducts (3) and exhaust pipes (2). The exhaust pipes are connected together by expansion bellows (1). The manifold is enclosed in an insulation box made of panels sandwiched between 2 steel sheets.
The turbocharger operates in accordance with a constant pressure concept. By this concept, the branch exhaust pipes of the entire cylinder bank are joined to a common pipe as far as the turbocharger.
The multiducts between the cylinder heads and the exhaust manifolds support the entire exhaust system, as well as the insulation box. The multiducts are cooled by the coolant from the cylinder heads and they are vented by a pipe mounted along the engine.
The multiducts also connect the supercharging air manifold to the air intake channel in the cylinder heads. All connected surfaces between these parts and the engine block, the cylinder heads and the exhaust pipes are sealed.

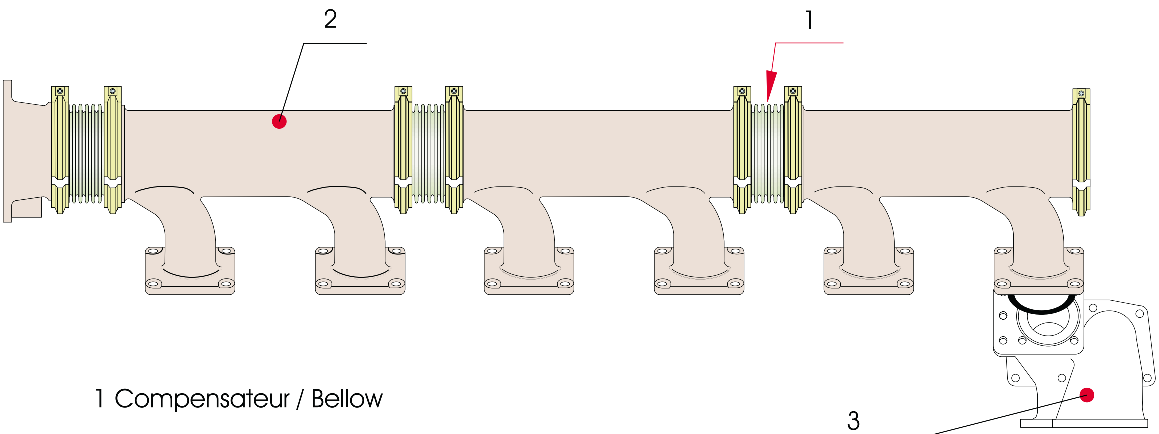
The multiduct is secured to the cylinder head and, consequently, is automatically aligned. The connection with the engine block is flexible to allow for small movements of the cylinder head.
The exhaust pipes are made of special alloy nodular cast iron. The pipes are cast with an individual branch for each cylinder. The wall of the metal bellows is made of a multiply material ; they are expansion joints.

The complete exhaust system is enclosed in an insulation box made of panels sandwiched between steel sheets.

Caution! **The outside surfaces of the box get hot.**

The exhaust gas temperature of each cylinder, as well as the temperature ahead of and after the turbocharger, are checked by means of sensors.

W12V220 exhaust system



1 Compensateur / Bellow

2 Collecteur d'chappement / Exhaust pipe

3 Multiduct / Multiduct

Fig. 20-1

W18V220 exhaust system

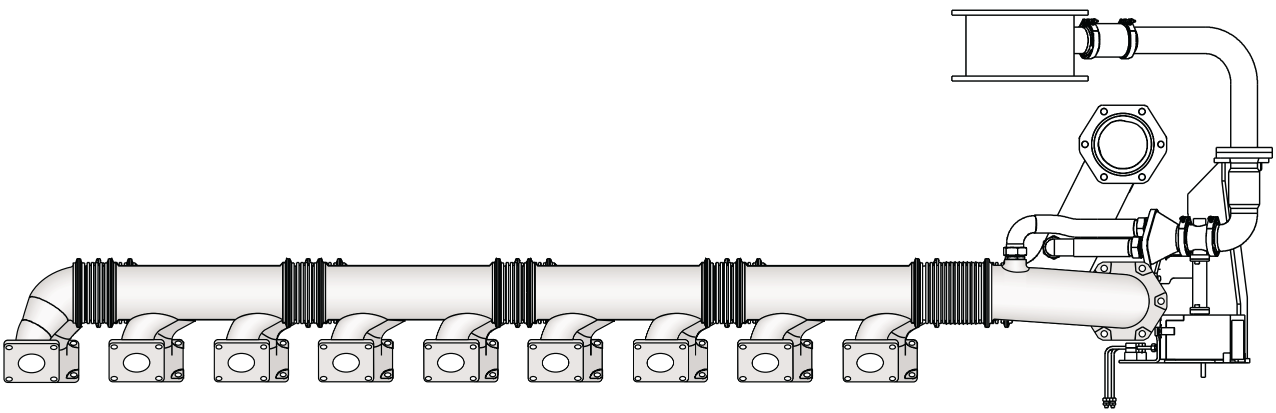


Fig. 20-2

20.1.2 Expansion bellows - replacement

1 **Remove the relevant panels** of the insulation box.

2 **Remove the screw fittings** and remove the expansion bellows.

3 **Check that the exhaust pipe flanges** are parallel and coaxial to stop lateral forces from being applied on the bellows.

20.1.3 Re-installation of Multiducts

Exhaust system

1 Multiduct / *Multiduct*
2 Joint / *Gasket*
3 Joint / *Gasket*
4 Capotage / *Insulation box*

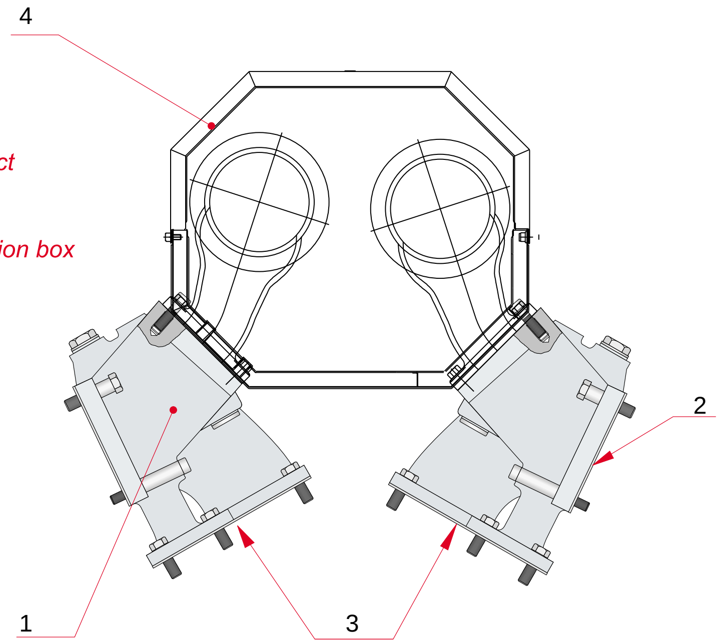


Fig. 20-3

When cylinder heads and multiducts have been removed.

a) **For bank A :**

1 **Install cylinder heads** A1, A6

2 **Tighten** the cylinder head attachment nuts by hand.

3 **Fit seals under Multiducts A1, A6.** Tighten the Multiducts to the block (6 washers per screw) until the washers are completely crushed (80 Nm), then loosen the screws one quarter of a turn.

4 **Remove** cylinder heads A1, A6.

5 **Using a metal rule** placed between cylinders A1 and A6, align the other multiducts and tighten them against the block until the washers are fully crushed (80 Nm), then loosen the screws one quarter of a turn.

6 **Fit on place** one cylinder head.

7 **Coat the clamping screws** between the cylinder head and the multiduct with high-temperature grease.

8 **Bring the cylinder head** and the multiducts into contact.

9 **Tighten the cylinder head** as per Section 12.2.3.

10 **Tighten the multiduct** on the cylinder head.

11 **Repeat operation 7** on another cylinder head.

b) For bank B :

Same as bank A using cylinder heads and multiducts B1 and B6.

20.2 Waste Gate

20.2.1 General description

The Waste Gate regulating valve is mounted as a by-pass between the gas inlet manifold and the turbocharger outlet.

This valve regulates the gas/air ratio by controlling the air flow provided by the turbocharger.

This valve is electrically controlled by the "WECS" system.

W12V200 Waste gate location

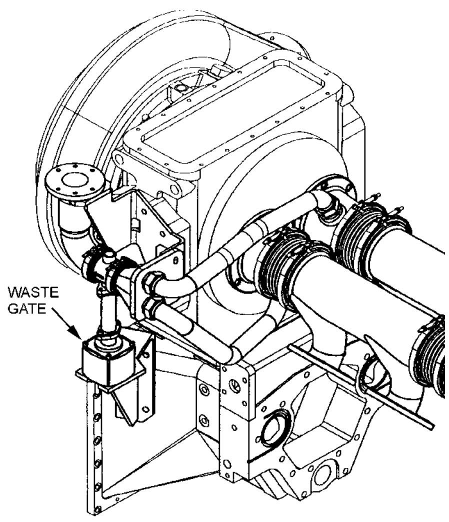


Fig. 20-4

W18V220 Waste gate location

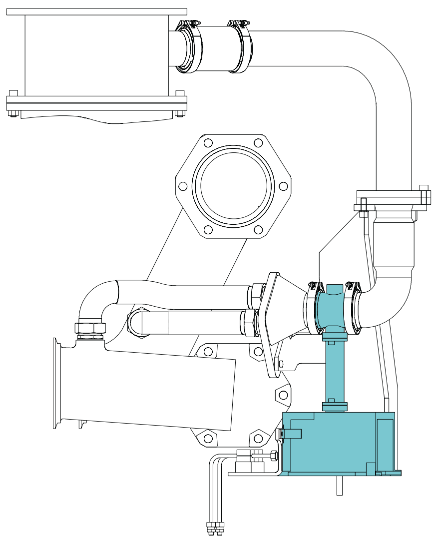


Fig. 20-5

21. Starting Air System

21.1 Description

The engine is started by compressed air held at a :

- 11 bar static pressure for a 12V,
- 22 bar static pressure for a 18V,

at the pressure regulating valve. A pressure gauge on the instrument panel gives a pressure read-out before the engine is started.

When starting the engine, the main starting valve can be activated either by a push-button for manual starting or pneumatically via a solenoid valve mounted on the air tank of the overspeed stoppage device for automatic starting.

As a safety measure, the air that controls start-up is fed through a start blocking valve (7) which prevents the engine from starting when the turning gear is engaged.

A by-pass line on the same circuit feeds the throttle valve pneumatic control.

Pneumatic starter system diagram

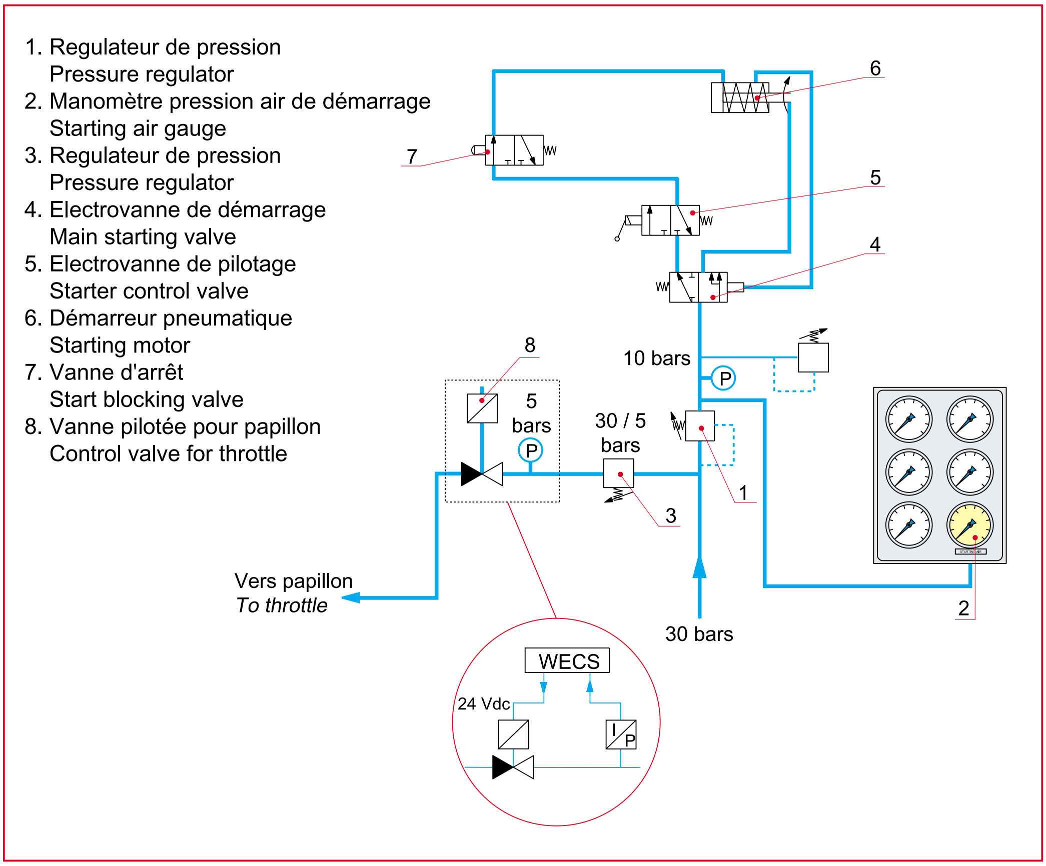


Fig 21-1

21.2 Starting Devices

21.2.1 Description

The engine is provided with a turbine type pneumatic starter motor. The turbine works with air. Very small amounts of foreign matter or fluid in the air supply should not normally affect the starter motor, and lubrication is not required. The pneumatic starter motor can be broken down into four basic parts:

- air intake casing,
- turbine casing,
- first stage of gear drive,
- reducing gear casing.

When the engine reaches a speed of 150 rpm, the current is cut out by a relay (5) of the electronic tachometer and the starter motor is automatically disengaged.
In the event of a power failure or malfunctioning of the regulation devices, the starter motor can be activated in emergencies by a manually controlled valve. Notice that the automatic disengagement of the starter is then not operative and accordingly, when the engine starts, the valve must be closed to prevent the starter motor running at overspeed.
The start blocking valve (7) prevents the engine from starting when the cranking gear is engaged (as with emergency starting with the start control valve (5)).

21.3 Air starting motor lubricator

21.3.1 Description

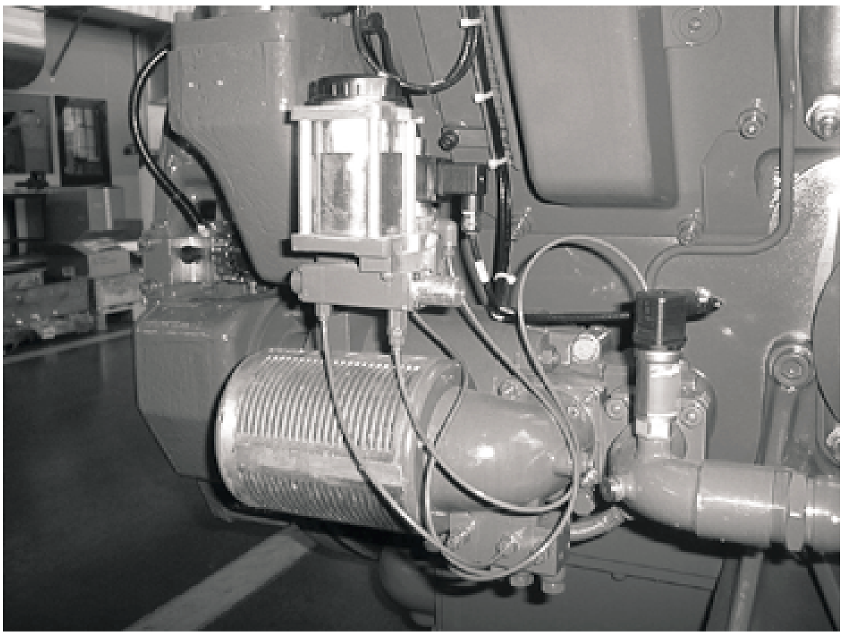


Fig. 21-2

21.3.2 Operation of the servolubricator

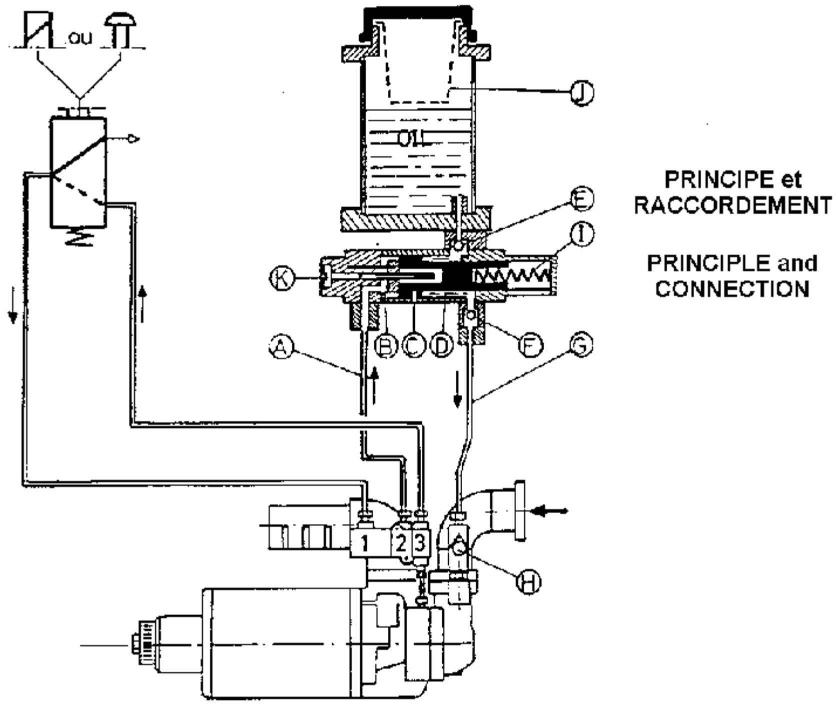


Fig. 21-3

When the starting motor begins to operate, the air is fed by pipe (A) in chamber (B) and actuates piston (C).

The oil in chamber (D) closes valve (E), passes by (F) and pipe (G) and is injected in the starting motor supply pipe via valve (H).

At the end of the starting operation, pipe (A) is vented by the control system and the pressure drops in chamber (B). Spring (I) then pushes piston (C) while closing valve (F) sucks oil from the tank by valve (E). Chamber (D) is filled with oil which will be injected during the next starting operation.

21.3.3 Oil filling

Screen (J) must be fitted when filling the tank to eliminate any possible impurities in the oil.

- Capacity: 200 cm3.

The characteristics of the oil as well as a table of cross-references between different brands are included in chapter 21.3.7.

21.3.4 Priming

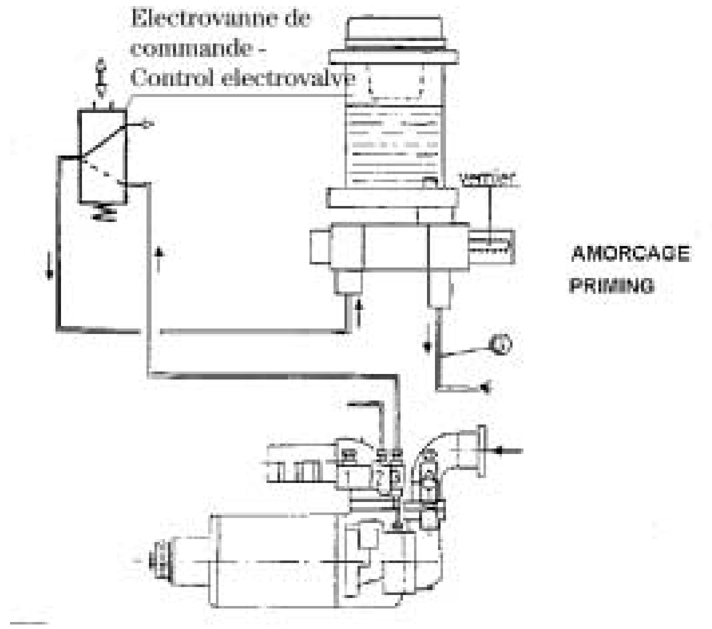


Fig. 21-4

Connect the servolubricator as per Fig. 21-3. Adjust flow rate to maximum (Screw (K) cf. Fig. 21-3).

Operate the control (cf. Fig. 21-4 and Fig. 21-5) several times until oil flows from pipe (G). Then connect as per Fig. 21-3 and adjust to the required flow rate (cf. chap. 21.3.5).

Fig. 21-5

21.3.5 Flow rate adjustment

The servolubricator is used to inject, at each cycle, a quantity of oil varying from 0 to 6 cm3.

The flow rate is adjusted using a screw (K) modifying the capacity of chamber (D) by adjusting the stroke of piston (C).

Fully tighten screw (K) to obtain maximum flow. Gradually unscrew to decrease this flow rate.

The recommended adjustment for a starting motor operating under normal conditions is approximately 2 cm^3 per start-up. The quantity of oil injected can be seen, in cm^3, on the vernier located on the servolubricator body, opposite the adjustment screw (cf. Fig. 21-6).

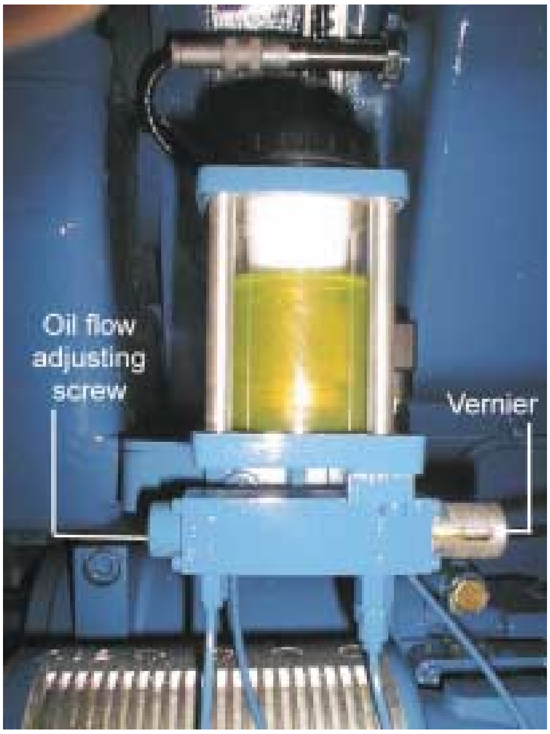


Fig. 21-6

21.3.6 Maintenance

No special maintenance is required by the servolubricator.

However, occasionally check that it operates correctly (movement of the piston in the vernier - cf. Fig. 21-6).

Caution: **Make sure that the oil level is always above the minimum. Top up the oil every 80 start-ups approximately.**

Remark: **Proper lubrication eliminates the detrimental effects due to condensation.**

21.3.7 Recommended certified oils

21.3.7.1 Oils

Type	Mineral	
Viscosity at 40°C	31.1	cSt
Viscosity at 50°C	22	cSt
Viscosity at 50°C	3.1	°Engler
Viscosity at 100°C	6.75	cSt
Viscosity index	180	

21.3.7.2 Cross-references

Brand name	Cross-reference
GALI	ETG 10
BP ENERGOL	HLP 32
ELF	OLNA ou VISGA 32
ESSO	NUTO HP 32 ou OLEO FLUID HM 32
FINA	HYDRAU HV 32
MOBIL	DTE 13M
MOTUL	RUBRIC 32
SHELL	TELLUS 32
TOTAL	EQUIVIS ZS 32

21.4 Implementation and maintenance of the reservoir pressure regulating valve

21.4.1 Operation and characteristics

21.4.1.1 Operating principle

The dome cap reservoir must be charged with neutral gas at a pressure corresponding to what is required downline. To increase the pressure downline, simply increase the pressure in the reservoir. To decrease the pressure, reduce the pressure in the reservoir (the latter mentioned operation must be carried out during operation or after having previously bled the circuit downline from the pressure regulating valve).

21.4.1.2 Characteristics

- Standard die cast brass construction.
- Balanced valve (fully tight when closed).
- Tapped connection ports (BSP).
- Reservoir control port, tapped, ¼ “ BSP.
- Permissible upline pressure 100 bar.
- Downline pressure 0.5 to 40 bar.

21.4.2 Installation on piping

The unit must be connected to the piping in compliance with the fluid flow direction indicated by an arrow on the body of the unit.

The input and output ports are tapped (BSP).

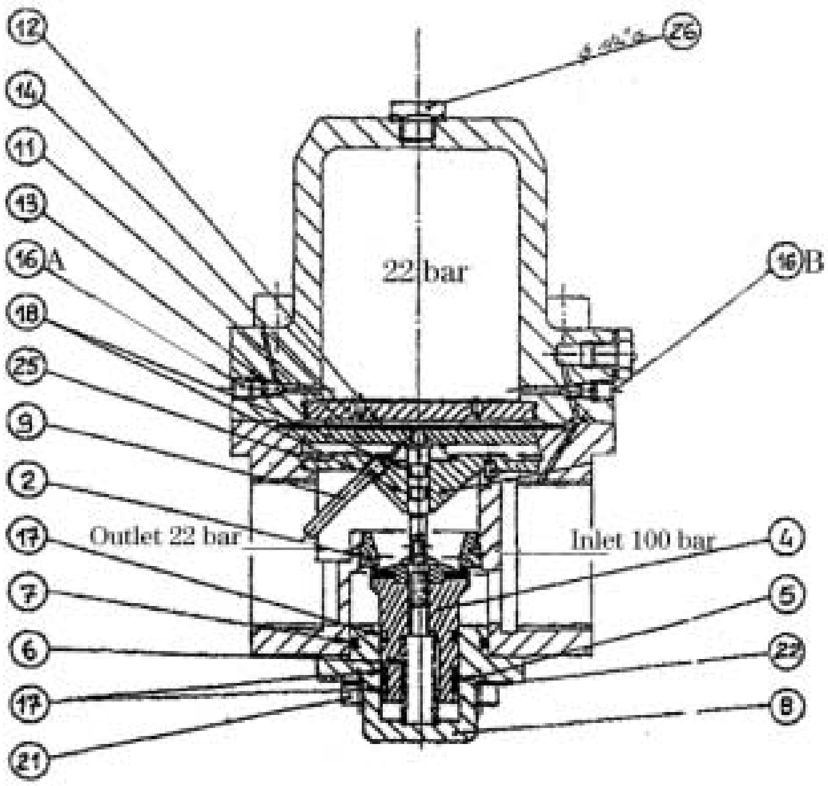


Fig. 21-7

Item	Description	Quantity
2	O-ring	1
5	O-ring	1
6	Spring	1
7	O-ring	1
12	Membrane	1
13	O-ring	3
17	Teflon bush	3
18	Teflon bush	2
16A	Discharge needle	1
16B	Discharge needle	1
26	Pressure gauge connector	1

21.4.3 Different methods of charging the reservoir (see fig. above)

a) Using upline pressure: (40 bar maxi) and dowline pressure (22 bar)

- Slightly open the upline and downline valves so that the pressure regulating valve is in flow position (downline, disconnect the electrovalve and press the pushbutton).
- Slightly open the charge needle item 16B using a hex head key until the required expanded pressure is read out on the downline pressure gauge. Close the needle.

If the downline pressure is greater than the required pressure, open the discharge needle. When the required pressure is reached, close the needle.

The unit is ready to operate.

b) Using an external pressure source which must be connected to the 1/4" BSP port of the reservoir.

Remark: **The pressure indicated by the reservoir pressure gauge is very close to the actual output pressure (plus or minus 1 bar).**

21.4.4 Special precautions

- Excessive torquing to charge and discharge needles during closing can be detrimental. The maximum torque to apply is 0.25m-Kg.
- Depressurise the reservoir when there is no upline or downline pressure from the pressure regulating valve (inspection or maintenance operation).
- Before replacement if required, check the type of O-rings, the membrane and the valve seat indicated on the technical data sheet appended to the unit.

21.4.5 Possible failures - Causes - Remedies

Possible failure	Causes	Remedies
No downline pressure when the reservoir is pressurised	Membrane item 12 damaged.	Replace the membrane
Upline /downline sealing fault when the pressure regulating valve is closed.	Foreign body between valve item 4 and seat item 3	Remove the seat and valve assembly by removing housing item 8. Examine parts, clean them, and replace if necessary.
	Valve or seat damaged	
	Valve gummed (fault due to prolonged period of non operation)	
	Seat seal item 2 or valve seal item 5 damaged.	
Dome cap reservoir sealing fault	Leakage from one of the needles, through the pressure gauge connector or the membrane.	Locate the leak using a “snoop” type foaming product.
		If the leak is at the needle or the pressure gauge connector: use Loctite or Teflon.
		If the leakage is through the membrane: replace the membrane.

21.4.6 Prolonged storage

a) **Before storage :** depressurise the reservoir and the air circuit.

b) **Return to service :** if storage is greater than 6 months, disassemble the unit, replace the seals and slightly lubricate with appropriate grease (Oxigenoex for Oxygen).

21.4.7 Verification and testing after maintenance work

1 **Do not forget to slightly lubricate the seals** and especially the moving seals.

2 **Check valve tightness.**

3 **Check for external leaks** with “snoop”.

21.5 Compressed air container and pipes

The starting system is designed to prevent explosions.

An oil and water separator and a check valve must be installed on the supply pipe between the compressor and the compressed air container. A bleed valve must be installed at the low point of the circuit. A check valve and a safety valve are installed immediately upline from the circuit.

Bleed condensation from the container before starting.

Prior to installation, carefully clean the piping between the compressed air container and the engine. During use, protect it from dirt, oil and condensation.

Inspect the compressed air container and clean it on a regular basis, then coat it with an anti-corrosion product and allow to dry for a sufficient amount of time. At the same time, inspect valves: excessive tightening may damage the valve seats, causing leaks. Leaking worn valves, including the safety valve, must be ground. Test the safety valve under pressure.

22. Governor linkage

22.1 Throttle valve (following equipment)

The engine is equipped with an electro-pneumatically controlled throttle valve governed by the WECS control system.

This throttle valve regulates the air flow for all the cylinders. It is mounted in the hood between the air cooler and engine frame.

A 4-20 mA signal controls throttle valve position depending on engine speed and load.

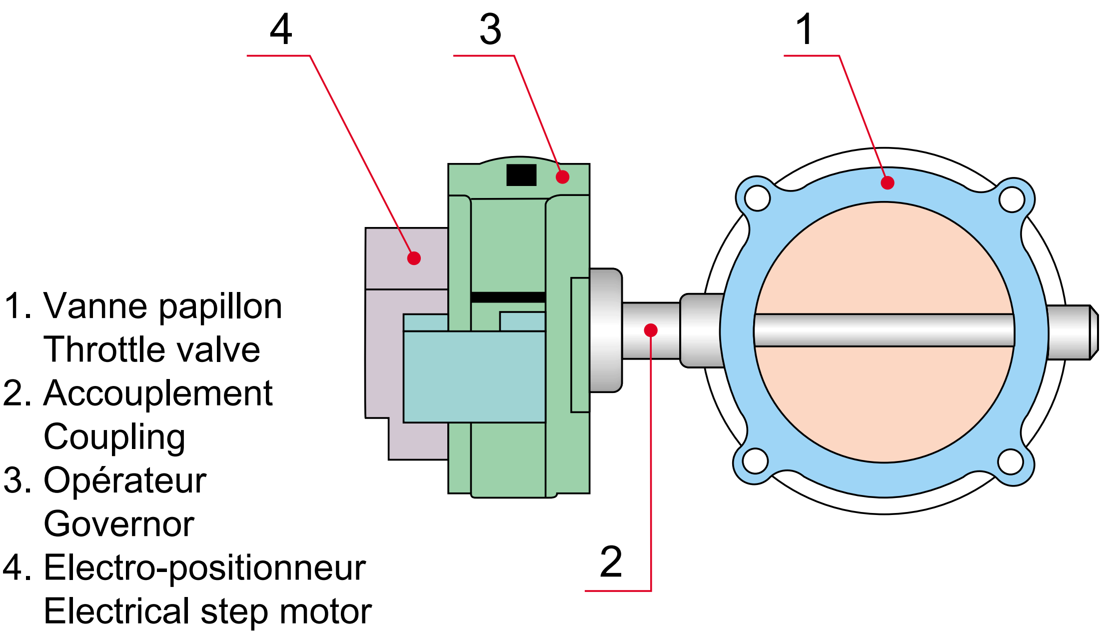


Fig. 22-1

22.2 Removal - maintenance

The throttle valve is maintenance free in principle. However, to check the throttle valve condition, it is necessary to remove the air inlet hood (1) and the charge air cooler (2).

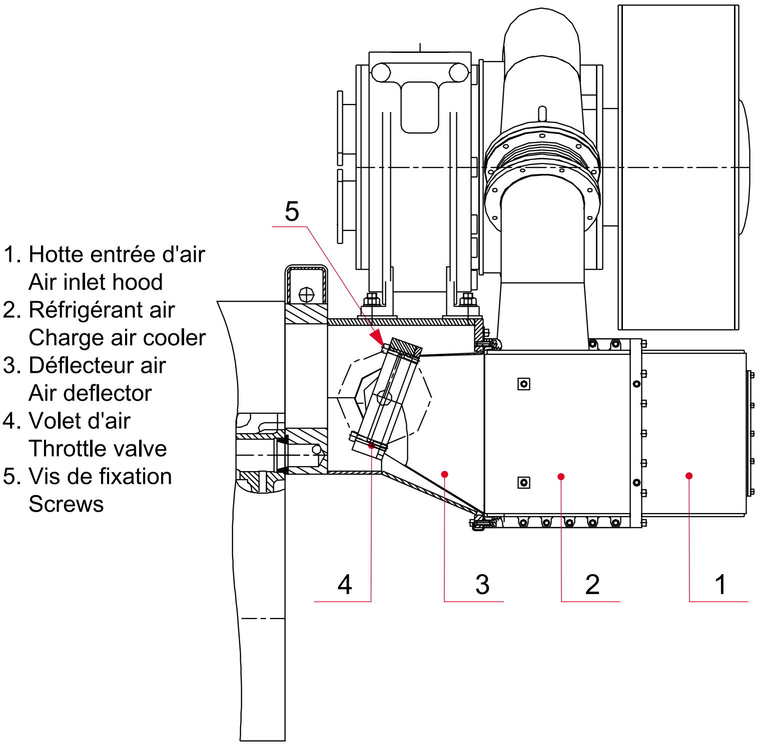


Fig. 22-2

The throttle valve electro-pneumatic control may be removed for testing and maintenance. The control drive bar has an index mark to prevent positioning errors.

The positioning settings are defined in the component supplier's instructions.

23. Instrumentation and automatic control devices

23.1 Introduction

This Section covers the operation of the WECS 3000 System (engine testing / control system).

23.2 WECS 3000 set-up

This Section describes the main components of the system and the way they communicate with each other and with external systems.

23.2.1 General information

The WECS 3000 system comprises five different types of unit located at various points on the engine. They can all communicate with each other via the CAN bus (an RS485 serial link is provided in the event an SMU is used). See Section .

WECS 3000 main components

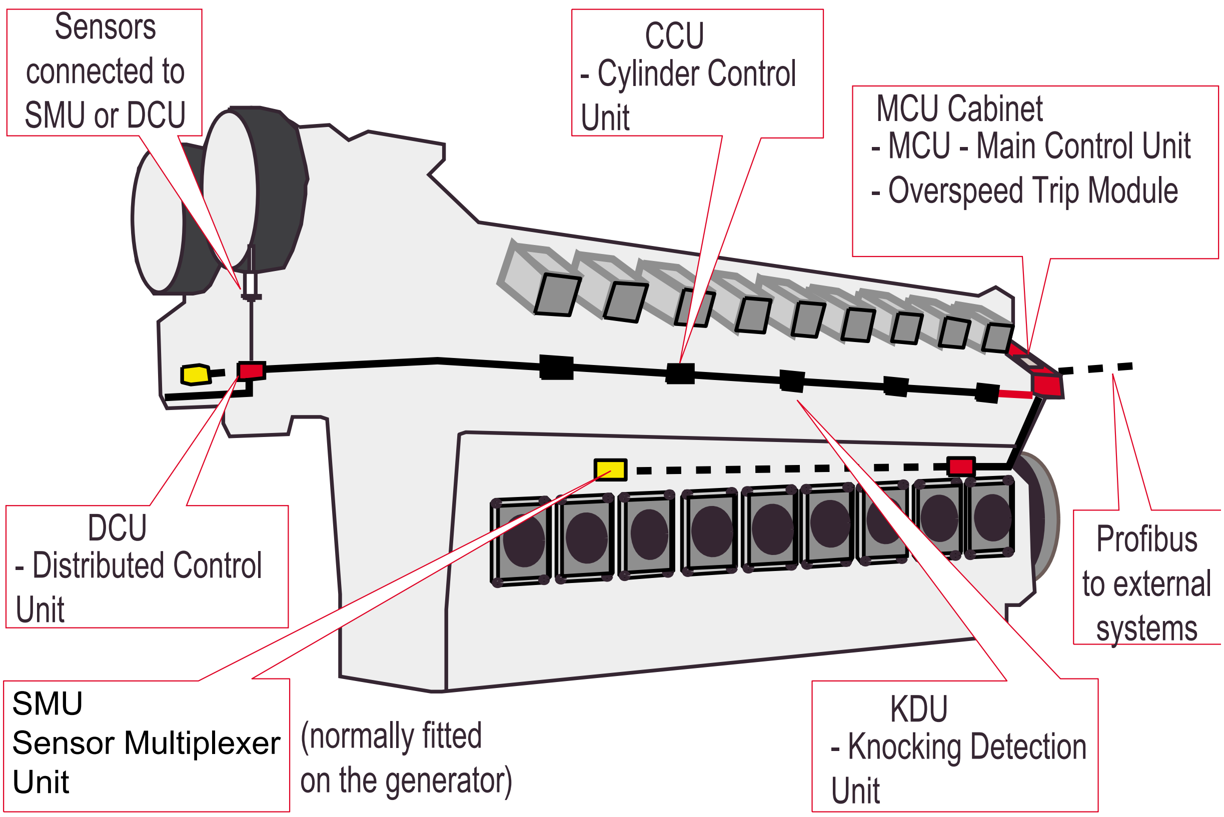


Fig 23-1 3223889601

The five different types of unit that communicate with each other are:

- MCU: Main Control Unit,
- CCU: Cylinder Control Unit,
- SMU: Sensor Multiplexer Unit,
- DCU: Distributed Control Unit
- KDU : Knocking Detection Unit

Each engine has a single MCU, enclosed in its cabinet fitted on shock-absorbing mountings at the flywheel end of the engine.

The CCUs, DCUs and SMUs are fixed at various locations on the engine, comparatively close to the sensors or control items they are designed to monitor or operate.

The MCU is the mainstay of the system as it provides the reference values for ignition, gas pressure, timing (point and duration of injection). It also controls such functions as speed synchronisation versus load, supercharge air regulation, start-up sequences, safety devices, monitoring devices, etc. It is the MCU that communicates with the external systems (Profibus) and the incoming and outgoing digital and analogue signals.

The CCU is in charge of all actions relating to the cylinders and cylinder monitoring, such as ignition and injection in the main combustion chambers and precombustion chambers. It also measures the exhaust gas temperature. It operates the ignition module and gas intake solenoid valves in accordance with timing data from the MCU. The CCU calculates the angular position of the engine and its speed from pulses emitted by an encoder mounted on the camshaft. Each CCU controls and supervises two cylinders.

The DCU and SMU measure various signals from sensors and convert them into digital data transmitted over a network to the MCU to monitor processing.

23.3 Speed measurement

Methods for measuring engine and turbocharger speeds.

23.3.1 Engine speed

In the WECS 3000 system, speed measuring components process signals from two types of sensor :

- an incremental encoder mounted on the end of the camshaft. This is the main device, which calculates the engine's angular position and speed.
- an inductive proximity sensor mounted on the camshaft pinion. It also serves as a redundant (back-up) protection in the event of overspeed.

The speed indicated by the encoder is compared in the MCU with the speed signal from the sensor. The overspeed device is tripped if there is a discrepancy of 50 rpm between the two sets of data. See (Tripping).

Engine speed measurement

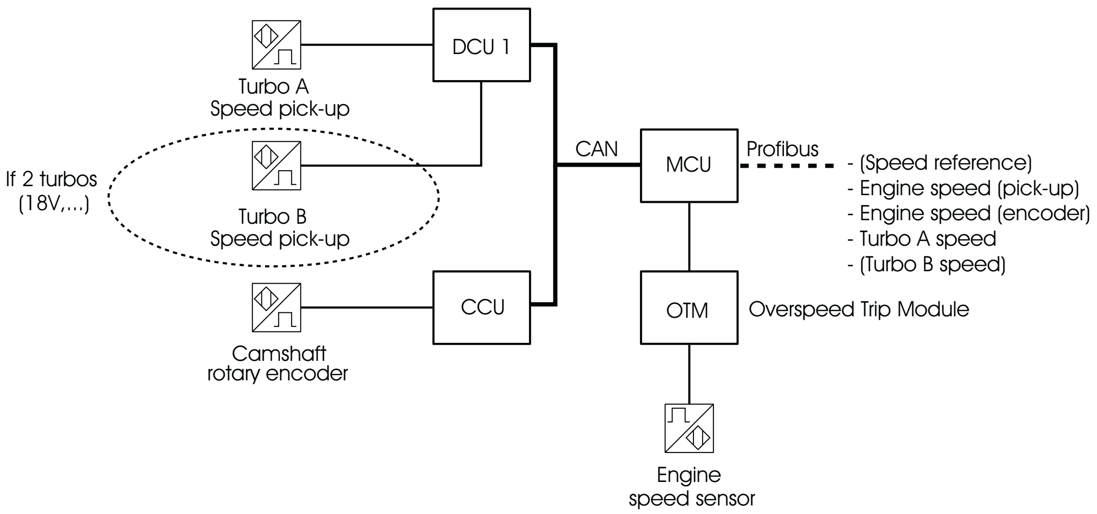


Fig. 23-2

23.3.1.1 Camshaft rotary encoder

This is an incremental optical encoder with pulse marker. It has two outputs: one giving 900 pulses per shaft rotation and the other one synchronisation pulse per shaft rotation. One turn of the camshaft corresponds to two turns of the crankshaft, making 450 pulses per turn of the crankshaft, i.e. 0.8 encoder pulses.

The encoder has a 24 Vdc supply. Its output is protected against short-circuits and reverse polarity.

Encoder signals (speed pulse train and synchronisation pulse) are transmitted to each CCU (wiring). These signals are electrically isolated from the CCU electronic circuits by an optical coupling circuit at the input to each CCU input/output board. Each CCU calculates engine speed from the encoder pulse trains and sends the result via the CAN bus to the MCU. The engine is stopped if one of the CCUs sends a signal that is different from the others.

Rotary encoder: physical appearance and signal definition

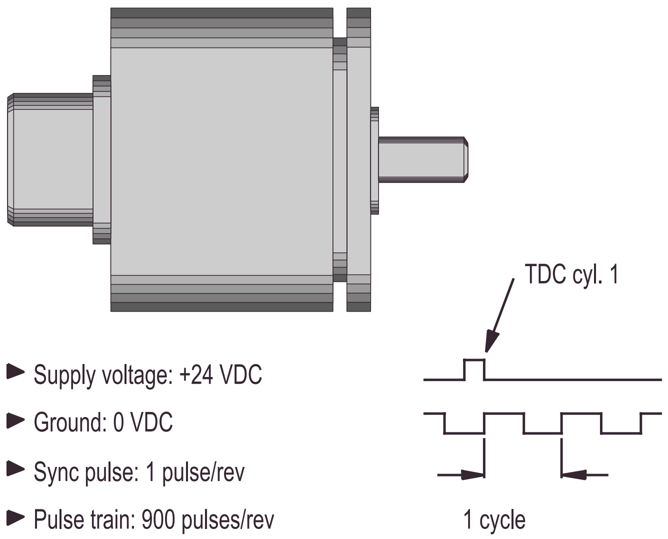


Fig. 23-3

The encoder is mechanically set so that the synchronisation pulse is given when piston A1 passes through TDC during its power stroke. This pulse synchronises ignition timing and duration of the intake valves for all the cylinders.

The MCU ensures that the encoder gives 900 pulses per revolution: it trips an alarm or emergency stop if the number of pulses deviates from 900 by more than a prescribed number. The thresholds at which alarms and shutdowns are tripped are defined in Section .

23.3.1.2 Engine speed sensor

The speed measurement made by this sensor is used redundantly to protect the engine redundantly against overspeeds and to check the camshaft encoder speed signal. This inductive proximity sensor with an integrated amplifier produces a square-wave signal. It is connected directly to the overspeed module in the MCU cabinet, from which it receives its 24 Vdc supply. A pulse is produced for each camshaft pinion tooth that passes by the sensor head. A pulse train proportional to engine speed is therefore produced, and relayed by an optical coupler and transformed by a transducer into a 4 - 20 mA analogue signal in the overspeed relay. This signal is connected to the MCU, which monitors the signal and compares it with the speed calculated by the CCU. If there is a discrepancy between the two speeds, the MCU trips an alarm.

Engine speed sensor

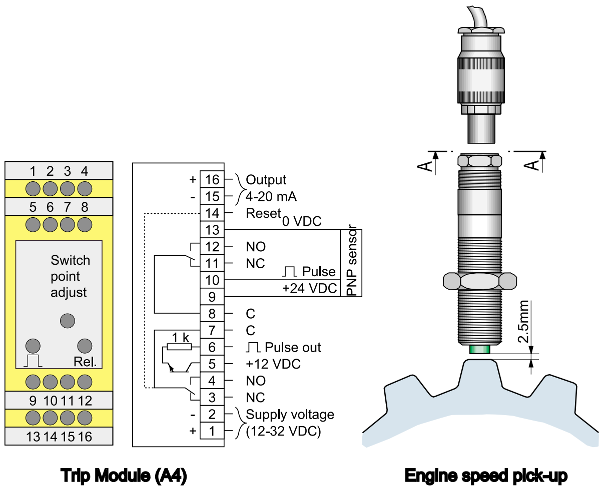


Fig. 23-4

23.3.2 Turbocharger speed measurement

The speed is measured by magnetic sensor (1 sensor for each turbocharger) giving a signal of two pulses for every rotation of the turbocharger. The sensor is connected to a DCU which computes the speed.

Turbocharger speed sensor

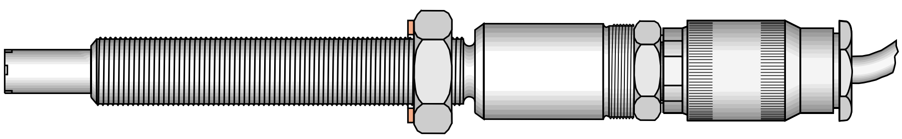


Fig. 23-5

23.4 Engine operating mode regulation

This Section describes how, in the MCU software, the engine status is characterised by five modes; it describes what happens during each of these five modes and what causes the switch from one mode to another.

23.4.1 Engine operating modes

The five operating modes defined by the software and described in the sections below are by order of priority:

- emergency
- shutdown
- run
- start
- stop

When the MCU is powered up, it switches the regulation automatically to stop mode if no emergency or trip order has been given to it, since either of these orders have priority and would switch operating mode. The test/control device for the operating modes checks, at regular intervals, whether a mode change order has been given. If it finds a current order and the order is valid, the device, the mode controller, starts the regulation sequences of the new mode to switch over to this mode.

Engine operating mode control

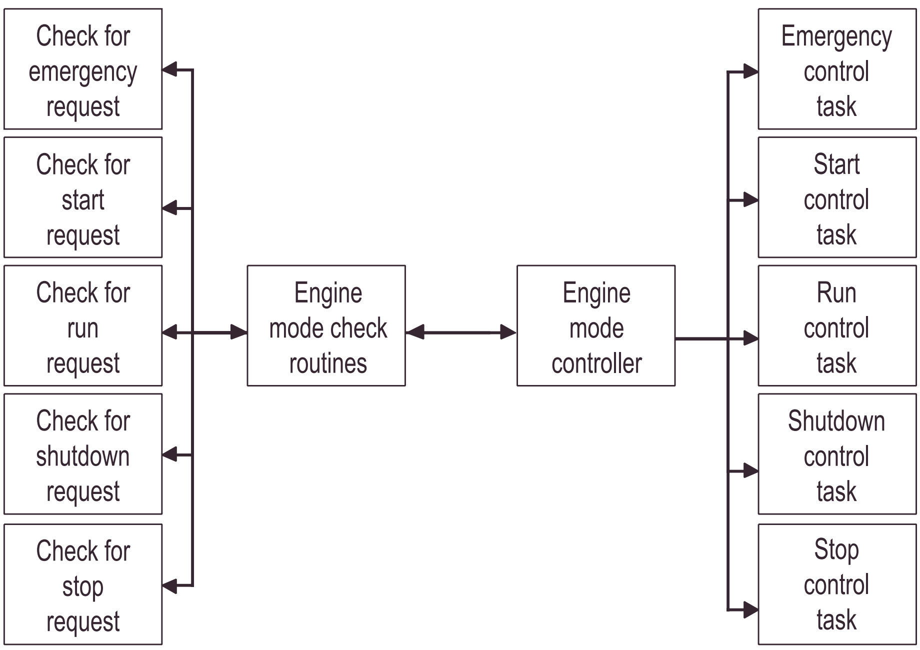


Fig. 23-6

A mode change order is only valid when the new mode to be set up has priority over the current mode. For example, no mode switch occurs if a shutdown order is given when the engine is in emergency mode. To be valid, mode changes must also comply with Fig. 23-7.

Valid mode changes

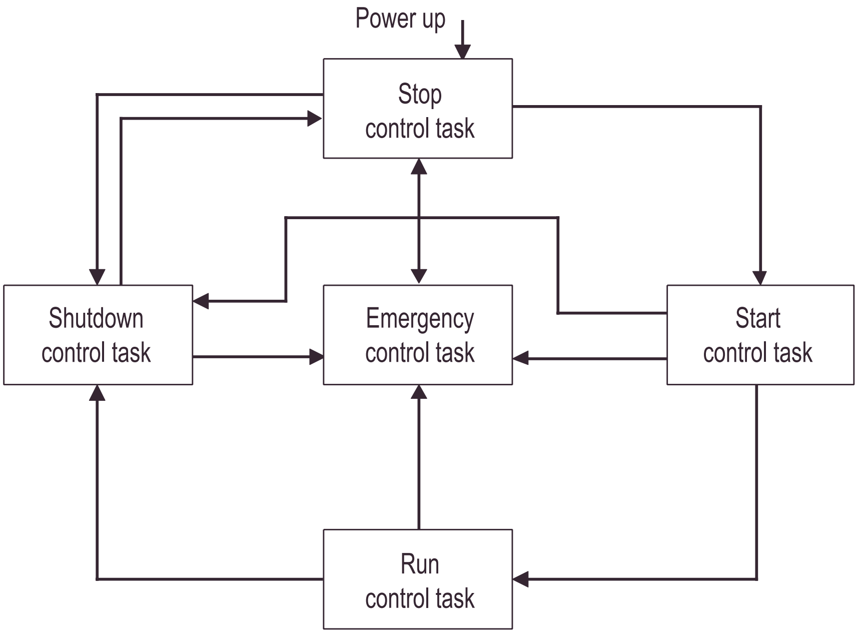


Fig. 23-7

23.4.2 Start mode

To obtain a valid start order, the PLC must activate the “engine start” digital input. If the engine is in “stop mode” and no order preventing starting is current (see Section), the mode controller will begin the start sequence which will lead to the engine starting up. This sequence comprises:

1 **Open throttle valve.**

2 **Start gas supply** pressure regulation.

3 **Activate pneumatic starter** which entails venting of the air manifold, cylinders and exhaust manifold. To vent (bleed) the engine, gas injection and ignition will begin only when the engine has reach a specified number of rpm determined by the PLC (data transmitted via Profibus).

4 **After venting** and when engine speed exceeds 50 rpm, the speed governor, gas injection and ignition systems are activated.

5 **After ignition** and at more than 150 rpm the starter disengages and the supercharge throttle valve is activated.

6 **When speed reaches 250 rpm,** the normal running order is activated. The starting sequence is then completed.

The start mode may be interrupted for the following two reasons:

- If in five seconds after activating the regulation, gas intake pressure does not meet the setpoint value given by the MCU.
- If in 20 seconds, the engine speed has not reached 250 rpm.

These two faults activate the trip sequence and send an alarm to the PLC via Profibus. It is a failed attempt to start and the systems must be zero reset / reset by the operator in charge before any new attempt is made.

23.4.3 Run mode

The normal running mode is activated when the start mode is still current and speed has reached 250 rpm.

The regulation sequence comprises :

1 **Deactivate restriction** of gas flow at start up when speed is 20 rpm less than setpoint speed. The engine then rotates at setpoint (nominal) speed and is ready to be synchronised on a network or run in isolation.

2 **After a time delay,** exhaust temperature testing is activated.

3 **After a time delay,** pressure monitoring (suspended while immobilised) is activated.
This normal running operating mode last until the next normal stop, shutdown or emergency stop order.

23.4.4 Shutdown mode

A stop order may come from several sources. A normal stop made by the operator in charge of the engine means the PLC switches off the "engine stop" digital input. Certain sensors also give a stop order (see Section <$R[C*,23.7.3,~13]23.6.3>.)for the list of these orders). Unless in emergency stop mode, a stop order makes the mode controller switch to trip mode.

The sequence comprises:

1 **Deactivate relay K2 (in the MCU cabinet),** opening the alternator coupling cut-out and interrupting the gas supply via the PLC.

2 **Switch off the gas pressure regulation** (main chamber and precombustion chamber).

3 **When engine speed has fallen below 100 rpm,** gas injection stops and the throttle closes.

4 **When speed falls below 50 rpm,** ignition is disabled.
Because gas injection and ignition operate while the engine is slowing down, the gas in the pipes is burned, thereby minimising the risk that it can build up in the cylinders and exhaust and create a danger when the engine is next started.

If the system is tripped by a sensor order, the engine stays in this mode until zero speed, until the cause of the trip is identified and the operator clears the fault.

23.4.5 Emergency stop mode

An emergency stop may come from one of the emergency stop push buttons, but also from certain sensor and communication faults (see

Section). An emergency stop order switches the engine from any mode to emergency stop mode.

The sequence comprises :

1 **Deactivate relay K2 (in the MCU cabinet),** opening the alternator coupling cut-out and interrupting the gas supply via the PLC.

2 **Close the throttle.**

3 **Switch off the ignition,** gas injection and pressure regulation system (main and PLC).

4 **Deactivate relay K1 (in the MCU cabinet),** which cuts off the power supply to the CCUs and consequently completely blocks ignition and gas injection.
When the speed has fallen to zero rpm, relay K1 is reactivated, but the cause of the emergency stop must be detected before relay K2 can be reactivated. The engine will be able to restart when this cause has been identified and the emergency stop displays cleared.

23.4.6 Stop mode

This mode is necessary for manual stoppage, after which the engine can be restarted without having to reset or zero reset any devices. In the event of an emergency stop or tripping, the stop order is activated when speed falls to zero rpm. The mode controller switches the engine to stop mode when the current mode is no longer “not tripped” or “emergency stop” (after clearing and resetting).

The sequence for switching from trip mode or emergency stop mode to stop mode comprises:

1 **Activate relay K2 (in the MCU cabinet).** Unless blocked elsewhere, the engine remains ready to restart.

23.5 Data capture

Data capture is distributed around the entire WECS 3000 system, i.e. the sensors are connected to SMUs or DCUs distributed at various points of the engine. Only the start and stop switches are connected to the MCU (see Fig. 23-8).

WECS 3000 sensor connection diagram

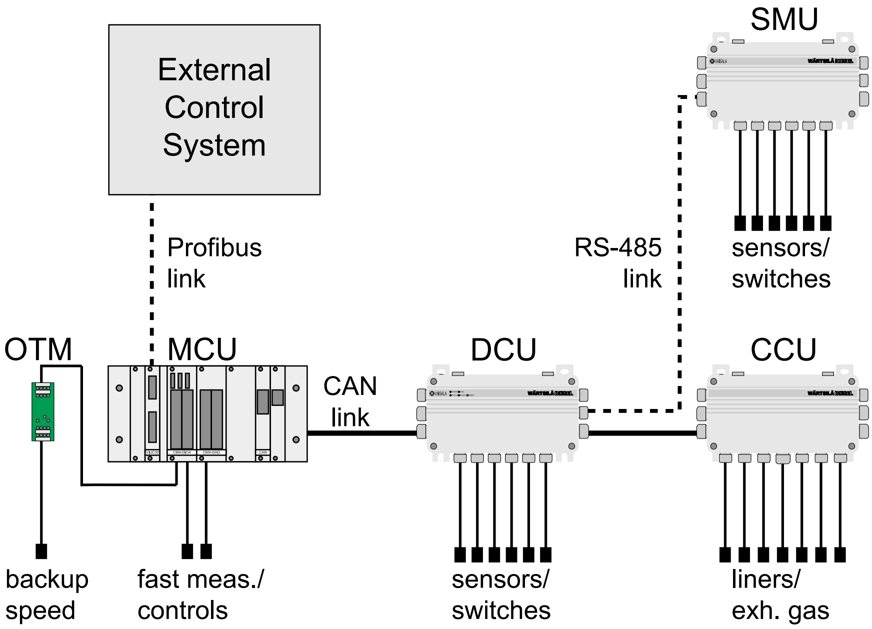


Fig. 23-8

23.5.1 DCU / SMU

DCUs and SMUs have the same sensor connections, but DCUs also have a printed circuit for communication via CAN bus and data processing.

Two types of unit only are required as the measurement channels are of the multi-purpose type; various types of sensor can be connected to them.

- 4 - 20 mA loops,
- Current transducers,
- Pt-100,
- Thermocouples (K),
- Switches (max. 2 channels),
- Frequency

Digital input and measurement channel frequency may vary but is usually 1 Hz.

23.6 Alarms and safety devices

23.6.1 Start-up impediments

Before the PLC gives an order to start, the engine must be ready to start. The list of conditions to be met is given below. The status of all starting impediments (alarms) and “ready to start” indications are sent to the PLC via Profibus.

- CCU status: OK (valid)
- If the MCU has been restored, it must be reset to zero at the operator console. A restarted MCU is made ready to start when the supply current is restored.
- The engine must be in stop mode.
- The emergency stop button on the MCU cabinet must be in the normal position.
- The limit switch indicating that the cranking gear is engaged must not be active.
- The start-up air pressure must exceed the start-up lock-out threshold.
- The prelubrication oil pressure must exceed a setpoint value and activate the turbo oil level controller.
- In the MCU, the “engine stop” digital input must not be operative.

23.6.2 Alarms

The alarms, listed below, are tripped in the MCU and transmitted to the PLC via Profibus. Starting impediments cited in Section are not repeated here.

- Sensor fault. The sensors used in the WECS 3000 system are monitored. If the signal level or value are erroneous (outside limits) an alarm is triggered. The digital signal sensors are wired to transmit a high level (NC) signal to the measurement device. If a cable is cut an alarm will be triggered. Some sensors that are essential for engine performances or safety will give rise to an engine trip order and switch to emergency mode whereas others only indicate an alarm. Failure of a sensor which is designed for measurement only, and therefore has no alarm threshold, will however trigger an alarm. For further information see Sections et .
- Prechamber and main chamber pressure deviation. Actual gas pressure is compared with supercharge air pressure: an alarm is given if it is less than a preset value above the supercharge pressure.
- Lubricating oil: level low
- Lubricating oil at engine inlet: temperature high
- Lubricating oil: pressure low
- Control air: pressure low

- Start-up air: pressure low
- HT water: pressure low
- LT water: pressure low
- HT water from engine: temperature high
- Exhaust gas: temperature high after each cylinder
- Exhaust gas: temperature deviation between cylinders high
- Supercharge air: temperature high
- CCU: internal temperature high
- DCU: internal temperature high
- SMU: internal temperature high
- Engine overload
- Cranking gear engaged
- Emergency stop activated
- False start

The alarms can be cleared by the operator only. They are not cleared automatically when conditions return to normal.

23.6.3 Engine faults

These occur for many reasons. They originate in the MCU following a shutdown order. Stop conditions are sent to the PLC via Profibus. All the stop orders are listed below :

- Normal stop order to PLC. “ Engine stop” digital input is cancelled at MCU.
- In start mode, failed start
- Lubricating oil: pressure low
- Lubricating oil: pressure sensor fault
- HT water: high temperature
- HT water: temperature sensor fault
- Supercharge air: temperature high
- Exhaust gas: temperature high after each cylinder
- Exhaust gas: temperature deviation between cylinders high
- Engine speed: deviation between actual speed and set-point speed
- Alternator bearing: temperature high (setpoint established by PLC, transmitted via Profibus)
- Alternator winding: temperature high (setpoint established by PLC, transmitted via Profibus)
- Engine overload
- Alternator power sensor fault (kW)
- Under frame level lowered

- Pressure low, engine fastening shock absorbers

23.6.4 Emergency stops

These may occur for many reasons. They originate in the MCU via an emergency stop order. The stop conditions are all sent to the PLC via Profibus. All the emergency stop orders are listed below.

- By pressing the emergency stop push button on the engine or remote
- Rotary encoder sensor fault
- Overspeed given by rotary encoder
- Overspeed from speed sensor
- Deviation between speeds given by encoder and sensor
- Degassing fault. Degassing is activated if gas pressure is still detectable after triggering sequence has stopped gas inlet pressure regulation.
- CAN bus fault
- CCU power supply fault

23.7 Gas injection

23.7.1 Gas supply

Ahead of the engine, the gas is fed through a regulator device comprising a filter, pressure regulator valves, safety shut-off valves and degassing valves (see Fig. 23-9). The system is designed to supply the main combustion chambers and pre-combustion chambers (PCC) separately.

Gas regulating device

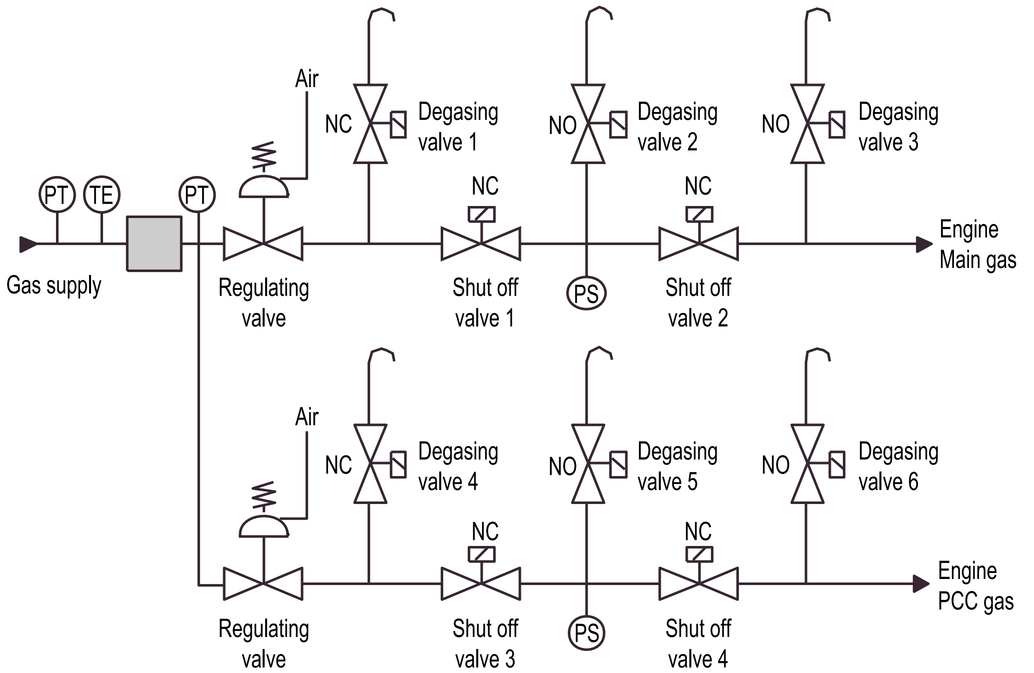


Fig. 23-9

The safety shut-off and degassing solenoid valves of the regulation system are controlled by the PLC. The pressure regulating valves are controlled by the MCU through built-in pressure/current (I/P) converters. The gas pressure referenced in the MCU is dependent on the effective engine load. The actual pressure is measured and compared with the set reference (See Fig. 23-10). An excessive deviation between the two values triggers an alarm which is sent to the PLC via Profibus. If the deviation increases further, the safety valves ahead of the engine immediately shut off incoming gas flow. The two pressure levels (actual and MCU reference), for the PCC and for the main combustion chamber, are transmitted to the PLC via Profibus.

Gas supply pressure regulation

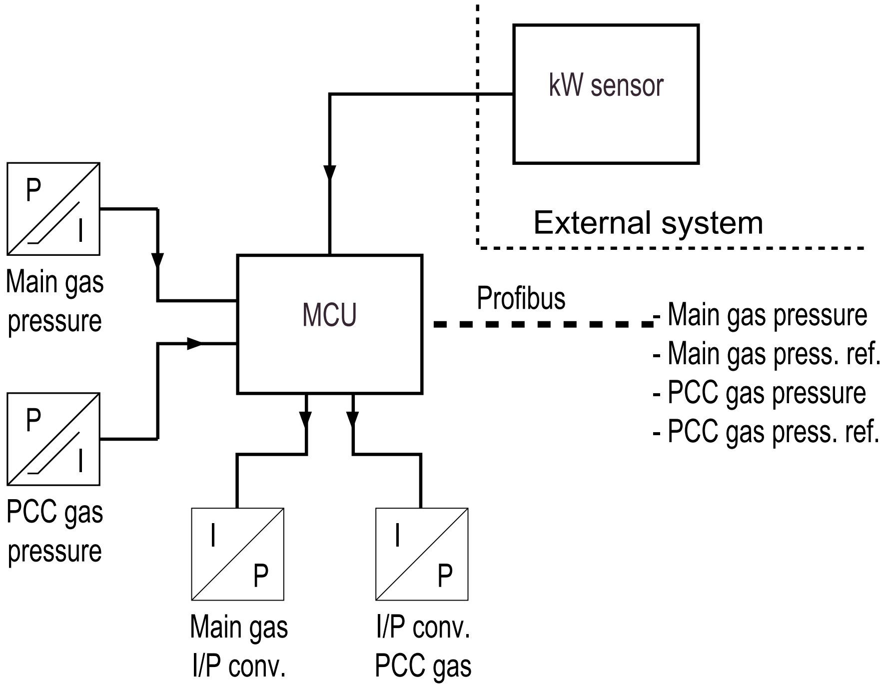


Fig. 23-10

23.7.2 Gas injection into prechamber

The volume of gas entering the prechamber (PCC) is controlled by the solenoid valve connected to the CCU (Fig. 23-11). This volume depends on supply pressure and on valve opening duration. To obtain an optimal fuel mixture, the opening point can be adjusted around TDC.

The valve opening point and duration given by the MCU are transmitted to the CCU via the CAN bus. These data can be individually set from one cylinder to another. They depend on engine load. The gas entering the prechamber must form an easy-to-ignite stoichiometric mixture.

The CCU uses the rotary encoder pulses to calculate the engine's angular position and speed in order to operate the valve in compliance with the reference data. The two reference values are transmitted to the PLC via Profibus.

23.7.3 Gas injection into main chamber

The volume of gas entering the main combustion chamber is controlled by the solenoid valve of the main circuit, connected to the CCU (Fig 23-15). This volume is dependent on the supply pressure and valve opening duration. To obtain an optimal fuel mix, the point of opening can be adjusted around TDC.

The valve opening point and duration given by the MCU are transmitted to the CCU via the CAN bus. These data can be individually set from one cylinder to another. The opening point depends on engine speed and load. The opening duration is adjusted by the PID controller so that speed and load always comply with the reference values.

The CCU uses the rotary encoder pulses to calculate the engine's angular position and speed in order to operate the valve in compliance with the reference data. The two reference values are transmitted to the PLC via Profibus.

Injection - main chamber and pre-chamber

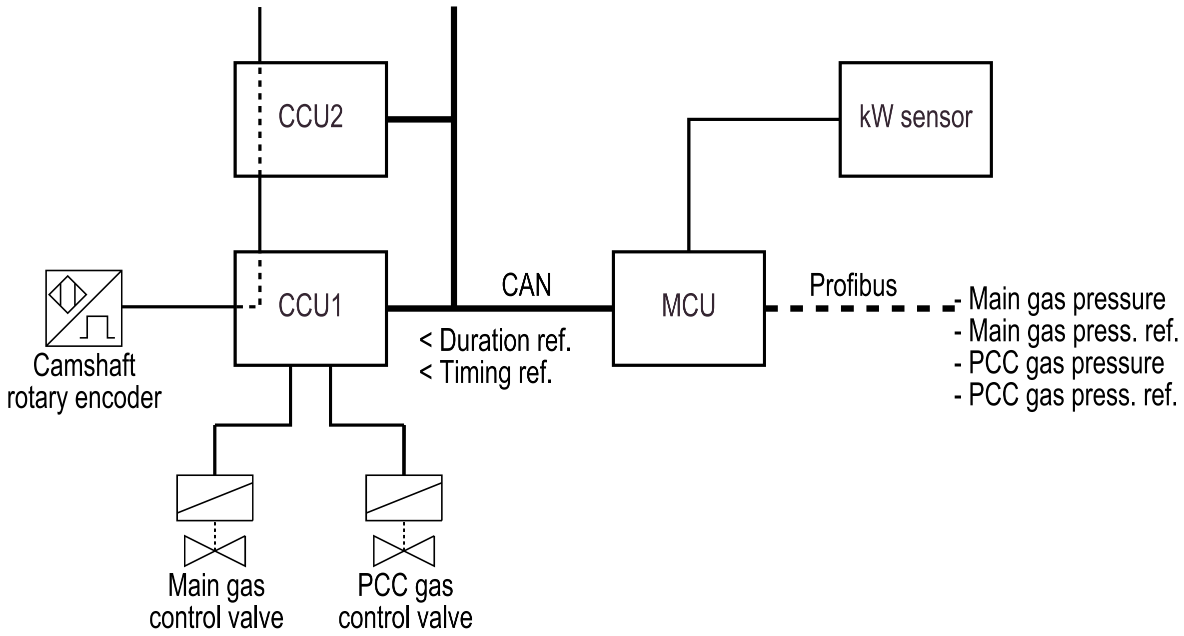


Fig. 23-11

23.8 Supercharge air regulation

Compressed air from the turbocharger is fed through the cooler and through the pressure regulating valve before reaching the engine block air manifold. The cooler keeps the temperature relatively constant and at an optimal level. The regulator valve adjusts the air flow in the manifold to optimise the air/fuel ratio over the entire load range. The regulating position corresponds to a set value on a reference angle table depending on engine load and speed.

For the same purpose of optimising the fuel mixture, the air flow is also controlled by a spent gas by-pass valve which feeds some of the exhaust gas around the compressor turbine. The manifold air pressure is measured constantly to provide this regulation feature. The by-pass valve position is controlled by the PID controller output value. the regulator setpoint is found from a table of manifold pressures versus engine loads; the actual rate is the servo-information fed back to the controller. In the event of pressure sensor failure, engine power is restricted to a preset level and the by-pass vane closes immediately.

Supercharge air regulation

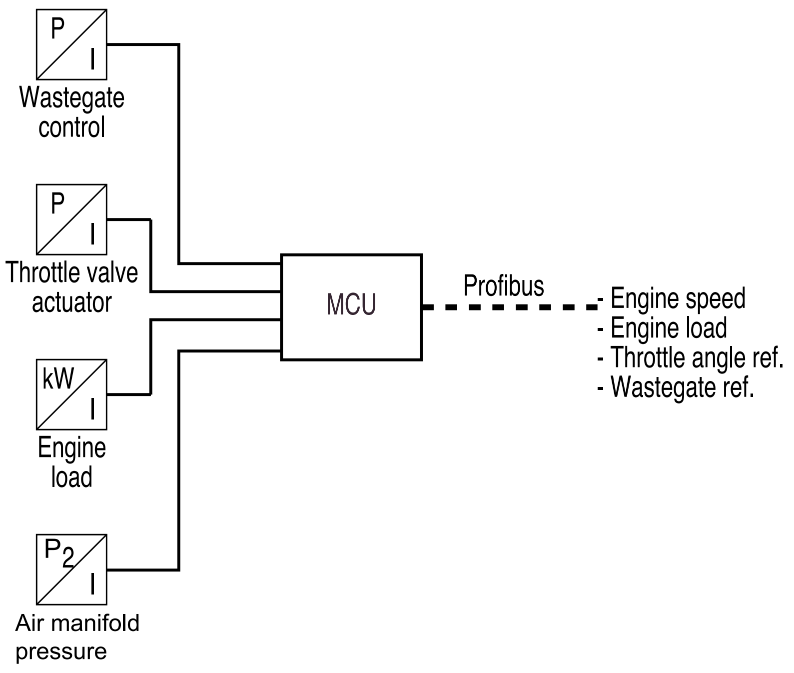


Fig. 23-12

23.9 Ignition system

The ignition system for each cylinder comprises an ignition module, an ignition coil, an extension and a spark plug. The ignition control is calculated and implemented by the CCU (Fig. 23-13.). The ignition module is described in Section . The spark plug extension is Teflon insulated and has a 5kW resistor to minimise interference from the sparks.

Ignition system diagram

1. Ignition coil
2. Spark plug extension
3. Spark plug
4. CCU
5. Ignition module

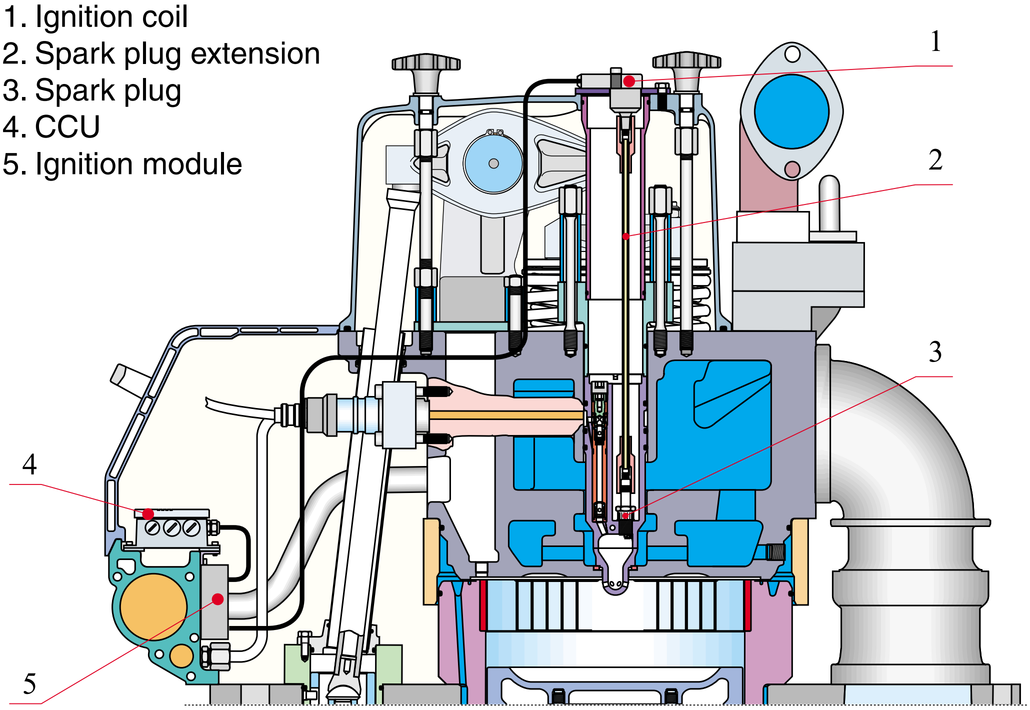


Fig. 23-13

23.9.1 Ignition control

The reference values for timing and duration of ignition are determined by the MCU for each cylinder. Ignition timing and duration vary with engine load

Ignition timing is given in degrees with precision of 1/10; ignition duration is in micro-seconds. These two values are transmitted to each CCU via the CAN bus. The timing value is the point (in degrees before TDC ignition) when the spark flashes. The ignition output control signal from CCU to the ignition module is activated (low) during the dwell time period and the start point is derived from the signal from the rotary encoder on the camshaft.

Ignition system

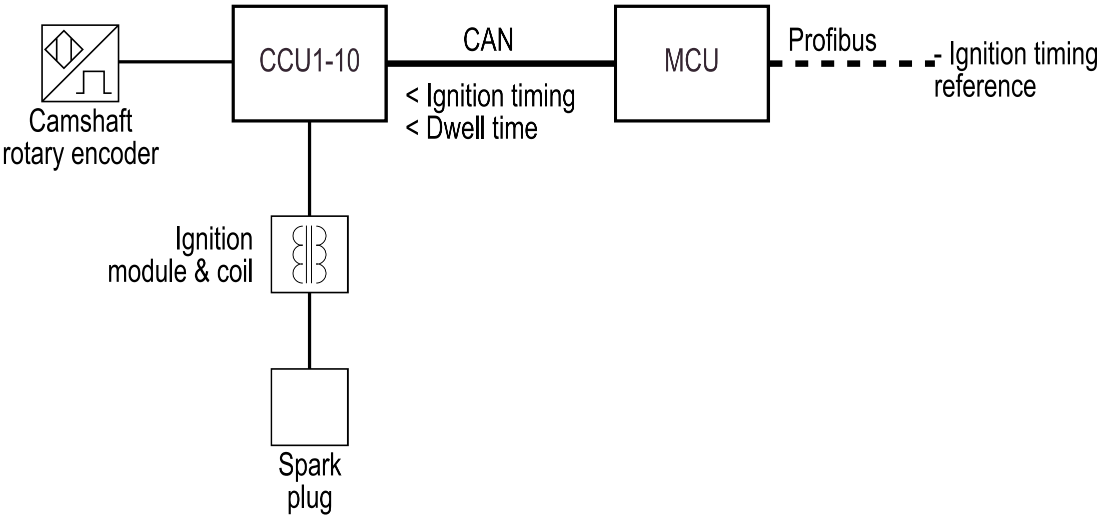


Fig. 23-14

23.9.2 High voltage circuit

Ignition is produced by inductive discharge and the control circuit operates by “ramp rise and sparking”. This means that the primary current is applied at a pre-calculated point before the spark jumps, so that it can rise on the ramp and reach the desired sparking level. That minimises energy losses in the control devices as there is no need to limit primary current.

The primary current is applied when “Ignition Control” become active (low) and will be cut when the signal disappears. If the duration exceeds 900 µs, the primary current is cut internally to protect the coil and its control device from overcurrents.

During the load duration (or ignition time), energy is stored in the coil in accordance with the formula W = LI2. When the primary current is cut, this energy is restored by the secondary and transferred to the high voltage output by the extension to the spark plug tip where it produces the spark.

Ignition diagram

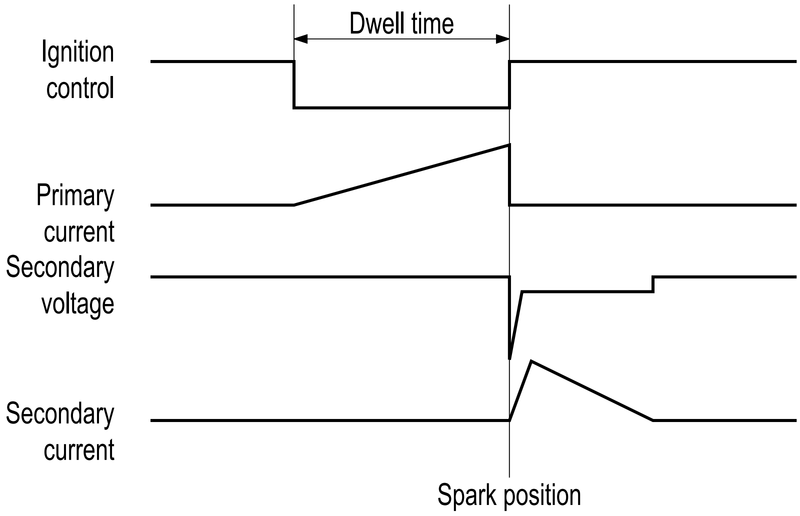


Fig. 23-15

The physical interface of the high voltage output comprises the coil control circuit, the coil, the high voltage extension and the spark plug.

Ignition module and high voltage control

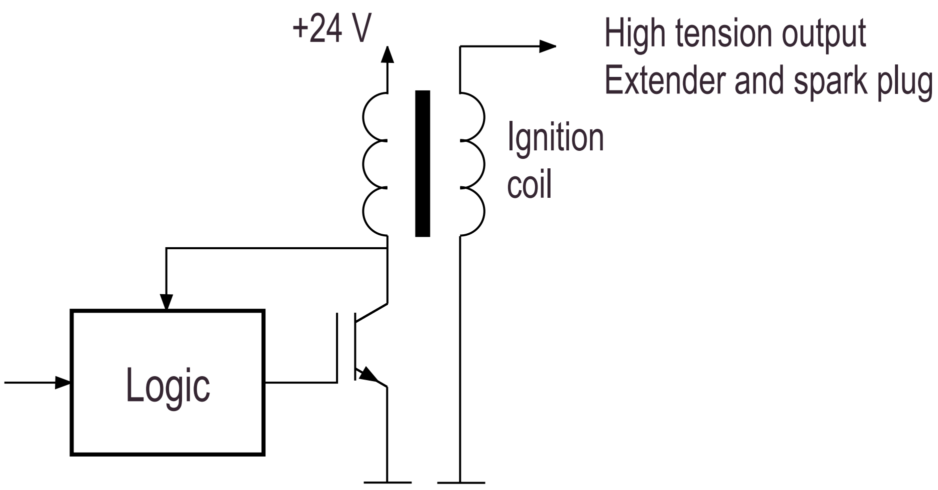


Fig. 23-16

23.10 Engine speed and load control

The following sections describe engine speed and power regulation as well as the synchronisation sequences.

23.10.1 General information

The MCU software provides speed regulation for isochronous operation (constant speed) of the installation or regulation by statism (see ; for speed measurement see). Load regulation (kW control) is also available. The following is an overview of the regulating and monitoring devices that control engine speed and power. All the data are transmitted to the PLC via Profibus. The PLC transmits installation specific data to the MCU such as power generated by the engine, choice of speed / power regulation, etc.

Engine speed and power regulation

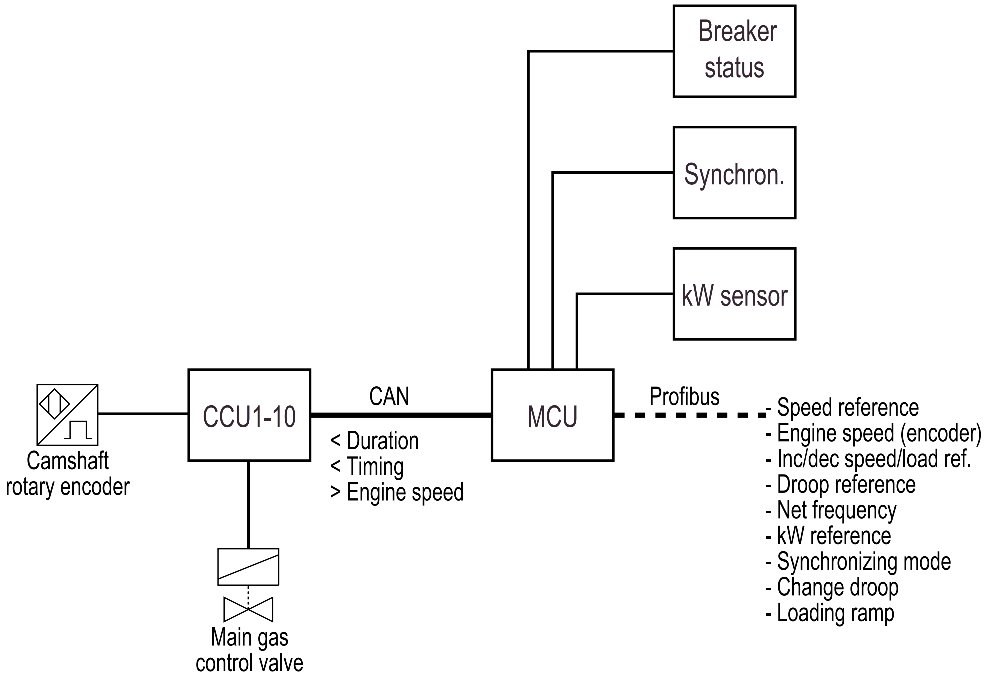


Fig. 23-17

23.10.2 Speed regulation

The speed regulation algorithm is calculated by a PID controller. The actual speed is compared with a setpoint speed (reference) and the error (deviation between the two) is transmitted to the PID controller which alters the opening duration of the main combustion chamber solenoid valves in order to match the actual speed and setpoint speed at all power levels. The P and I parameter values are plotted against load curves to obtain maximum stability whatever the power level.

23.10.3 Synchronisation sequence

When the engine reaches nominal speed, the PLC, via Profibus, can implement a synchronisation sequence. The order given allows the two “faster” “slower” digital inputs on the MCU to operate. The synchroniser will use them to change the speed reference so that alternator frequency is compatible with mains frequency. An instantaneous increase of 5 rpm of engine speed will prevent a power return when the circuit breaker is closed. If frequencies are matched, when the circuit breaker is closed, a base load reference is established if statism regulation or kW regulation has been selected. This reference is then adjusted by the PLC. This does not apply if isochronous mode has been selected, in which the load level is established depending on demand from customers connected to the separate network.

23.10.4 Power regulation

Load can be regulated by statism or by kW. The regulation mode is chosen in the PLC and transmitted to the MCU via Profibus. kW regulation is the more advantageous for low speed operation because of its intrinsic immunity from interference caused by mains frequency variation. This function becomes active when the circuit breaker is closed (digital input to MCU). In this mode of regulation, the power reference and a load increase gradient are transmitted from the PLC via Profibus to the MCU. The MCU measures the power (kW) delivered by the alternator and compares it with the reference power. The error (deviation between the two values) is transmitted to an internal PID controller which modifies the opening time of the main combustion chamber solenoid valves so as to match alternator power and reference power.

23.10.5 Exhaust gas temperature regulation

Identical opening times for all the main combustion chamber solenoid valves will not lead to identical exhaust gas temperatures from all cylinders because there are differences between the constituent parts from one cylinder to another. These small deviations are compensated by exhaust gas temperature regulation. The MCU compares exhaust gas temperature from each cylinder with their mean temperature and adjusts valve opening duration so as to reduce deviations. There are limits to these adjustments so that any faults in the components do not cause over rich or over lean fuel mixtures. At more than 50% load, this compensation is no longer operative and changes in opening duration should be determined by fixed values.

23.11 List of abbreviations, expressions and acronyms in this section

List of abbreviations, expressions and acronyms		
Abbreviation	**English**	**French**
CAN bus	CAN bus	Bus CAN (bus = liaison)
CCU	Cylinder Control Unit	Unité de contrôle / commande des cylindres
D	Defect - Default	Défaut, panne
DCU	Distributed Control Unit	Unité(s) de contrôle réparties en divers endroits du moteur
GND	Ground	Masse, terre
HT	High Temperature	Haute température (eau)
I	Current intensity	Symbole intensité, désignant le courant
I/O	Input/Output	Entrée/sortie
I/P	Intensity/Pressure	Intensité/Pression
I/P converter	I/P converter	Convertisseur I/P
kW	kW sensor	Capteur de kW
LDU	Local Display Unit	Unité d'affichage local
LT	Low Temperature	Basse température (eau)
MCU	Main Control Unit	Unité principale de contrôle/commande
NC	Normally Closed (contact)	Normalement fermé au repos
NO	Normally Open (contact)	Normalement ouvert au repos
O	Old	Précédent
OTM	Overspeed Trip Module	Module de déclenchement par survitesse
PCB	Printed Circuit Board	Carte de circuit imprimé
PCC	Pre-Combustion Chamber	Chambre de précombustion
PID Controller	Proportional, integral differential	Proportionnel, integral différentiel (régulateur)
PLC	Programmable Logic Controller	Automate programmable
Profibus	Profibus	Profibus (liaison)
RS232C	Link (bus)	Liaison RS232C
RS485	RS485 serial link (bus)	Liaison (bus) série RS485
S	Shutdown	Arrêt (automatique)
SMU	Sensor Multiplexer Unit	Unité Acquisition de Mesures
Status	Status	Etat
Terminals	Terminals	Bornes, connexions
U	Unit	Unité
WECS	Wärtsilä Engine Control System	Système Wärtsilä de contrôle/commande du moteur

23.12 WECS 3000 system status

All the components are connected: actuators, sensors, test/control cabinet information and the Profibus communication cable. The system is not energised. The PLC is then started up.

23.12.1 WECS 3000 system testing without 24 Vdc supply

Caution: **It is essential to de-energise the WECS 3000 system whenever work is done on the wiring and associated electronics system.**

1 **Check the different units are clean:** small shielding wire, piece of cable, etc.

2 **Check the wiring of the electronic units** (DCU, CCU, KDU, MCU).

Critical points:

- all electrical power supplies (12 Vdc - 24 Vdc)
- CAN bus
- angular encoder information to KDU and CCU
- earthing

3 **Check the engine ground connection.**

4 **Check the identity selectors** and the number of cylinders on the CCUs and KDUs (see Fig. 23-18)

SW3 : Sélecteur d'identité et de test des électrovannes
Identity selector and solenoid valve test
SW4 & SW5 : Sélecteur du nombre de cylindres
Number of cylinders sélector

Ex : SW4 sur 1 et SW5 sur 2
= moteur 12 V
SW4 on 1 and SW5 on 2
= 12 V engine

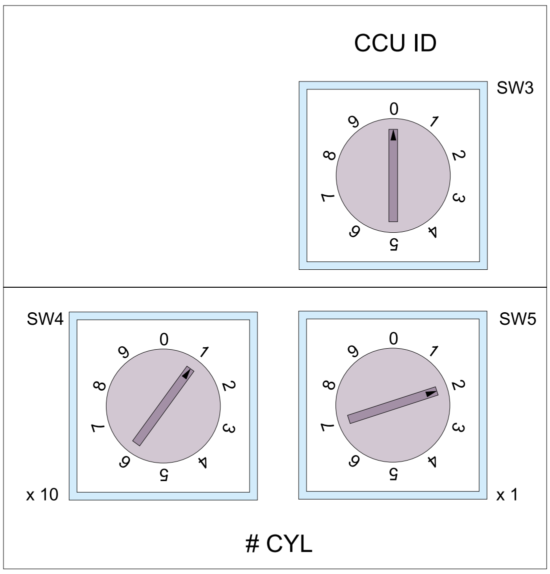


Fig. 23-18

23.12.2 EPROM insertion in MCU

This job is currently done by Wärtsilä France Technology Dept.

23.12.3 Testing after restoring 24 Vdc supply

1 **Open all the modules** and energise.

2 **Read the LED status** of the electronic modules.

23.12.3.1 MCU

The red LED on the VIUC board must be off.

If it is on, press the black button A and then the red button R:

- if it remains on: fault condition
- if it is of f: OK

23.12.3.2 CCU

- If green LED is flashing: :

No 24 Vdc to ignition driver and solenoid valves (relay K1 open, WECS 3000 system is in shutdown or emergency stop mode).

- If green LED is steady:

24 Vdc to ignition driver and solenoid valves: the system is ready to start at CCU level.

Other status : fault

- Orange LED:

CAN bus display. The LED should flash when communication is OK.

Other status = fault

23.12.3.3 KDU

- Green LED:

Must be on and steady

- Orange LED:

Must be off.

23.12.4 Loading DCU set-up

This job is currently done by Wärtsilä France Technology Dept.

23.12.5 DCU LED status

- Power LED

The green LED is located in the cover. it is on when the DCU supply is correct.

- LED status no. 1

The green LED is located in the cover. It should flash when the DCU is running correctly.

- CAN LED

The orange LED is located in the cover. It should flash rapidly when communication is OK.

- LED status no. 2

The green LED is located at the bottom of the DCU (terminal block board). It should flash at different speeds: a once per second signal, a faster signal.

23.12.6 Measurement verification

Check the following information:

- All cylinder temperatures.

If the value is close to ambient temperature, the CCUs are measuring, if not there is a fault.

- Oil temperature

If the value is close to ambient temperature, DCU 1 is measuring, if not there is a fault.

- LT water temperature

If the value is close to ambient temperature, DCU 2 is measuring, if not there is a fault.

- Supercharge air pressure

If the value is close to 1 bar, the MCU is measuring, if not there is a fault.

23.12.7 Angular encoder setting

1 **Crank the engine** to bring cylinder 1A to TDC on the ignition stroke.

2 **Open CCU 1**

3 **Cut the power supply to CCU 1** (remove the relevant fuse in the MCU).

4 **Set the three selectors** to the zero mark (see Section 23.12.1)

5 **Restore 24 Vdc supply** to the module.

6 **No LED flashes.**

7 **Loosen the two CHC screws** fixing the angular encoder to the frame.

8 **Turn the encoder** until the orange LED comes on. The green LED should light up when the encoder is rotated.

9 **Tighten the encoder again** in the position found. The orange LED should remain on after tightening.

10 **Cut the power supply to CCU1** (remove the relevant fuse in the MCU).

11 **Put the selectors** back to their initial position.

12 **Restore the 24 Vdc supply.**

23.12.8 Gas solenoid valve testing

1 **Cut the power supply** to the CCU 1 module.

2 **Set the identity selector** SW 3 to zero.

3 **Restore the 24 Vdc supply** to the CCU 1 module.

4 **Set the identity selector SW 3 to 1:**cylinder A2 main chamber solenoid valve starts.

5 **Set the identity selector SW 3 to 2:** cylinder A2 pre-chamber solenoid valve starts.

6 **Set the identity selector SW 3 to 4:** cylinder A1 main chamber solenoid valve starts.

7 **Set the identity selector SW 3 to 5:** cylinder A1 pre-chamber solenoid valve starts.

8 **Set the identity selector** SW 3 to zero.

9 **Cut the 24 Vdc supply** to the unit.

10 **Reset the selector** to the module identity.

11 **Restore the 24 Vdc supply.**

Note: **Repeat these manipulations for all the gas solenoid valves (see table below)**

	CCU 1	CCU 2	CCU 3	CCU 4	CCU 5	CCU6
Position 1	SV Main A2	SV Main A4	SV Main A6	SV Main B1	SV Main B3	SV Main B5
Position 2	SV PCC A2	SV PCC A4	SV PCC A6	SV PCC B1	SV PCC B3	SV PCC B5
Position 4	SV Main A1	SV Main A3	SV Main A5	SV Main B2	SV Main B4	SV Main B6
Position 5	SV PCC A1	SV PCC A3	SV PCC A5	SV PCC B2	SV PCC B4	SV PCC B6

18V220	CCU 1	CCU 2	CCU 3	CCU 4	CCU 5	CCU6	CCU7	CCU8	CCU9	CCU10
Position 1	EV Main A2	EV Main A4	EV Main A6	EV Main A8	/	EV Main B1	EV Main B4	EV Main B6	EV Main B8	/
Position 2	EV PCC A2	EV PCC A4	EV PCC A6	EV PCC A8	/	EV PCC B1	EV PCC B4	EV PCC B6	EV PCC B8	
Position 4	EV Main A1	EV Main A3	EV Main A5	EV Main A7	EV Main A9	EV Main B2	EV Main B3	EV Main B5	EV Main B7	EV Main B9
Position 5	EV PCC A1	EV PCC A3	EV PCC A5	EV PCC A7	EV PCC A9	EV PCC B2	EV PCC B3	EV PCC B5	EV PCC B7	EV PCC B9

23.12.9 Ignition test

Caution : **In order to realize this test, remove the coil, the spark plug and its extension and reassemble them externally of the cylinder head. To provide the ignition spark, put the spark plug body against the engine earth.**

1 **Cut the power supply** to the CCU1 module

2 **Set the identity selector** SW 3 to zero

3 **Restore the 24 Vdc supply** to the CCU1 module

4 **Set the identity selector** SW 3 to 3 : ignition spark will be generated on A2 cylinder

5 **Set the identity selector** SW 3 to 6 : ignition spark will be generated on A1 cylinder

6 **Set the identity selector** SW 3 to zero

7 **Cut the 24 Vdc power supply** to the unit

8 **Reset the selector** to the module identity

9 **Restore the 24 Vdc supply.**

Note: **Repeat these manipulations for all cylinders (see table below)**

	CCU 1	CCU 2	CCU 3	CCU 4	CCU 5	CCU6
Position 3	Ignition A2	Ignition A4	Ignition A6	Ignition B1	Ignition B3	Ignition B5
Position 6	Ignition A1	Ignition A3	Ignition A5	Ignition B2	Ignition B4	Ignition B6

18V220	CCU 1	CCU 2	CCU 3	CCU 4	CCU 5	CCU 6	CCU 7	CCU 8	CCU 9	CCU 10
Position 3	Ignition A2	Ignition A4	Ignition A6	Ignition A8	/	Ignition B1	Ignition B4	Ignition B6	Ignition B8	/
Position 6	Ignition A1	Ignition A3	Ignition A5	Ignition A7	Ignition A9	Ignition B2	Ignition B3	Ignition B5	Ignition B7	Ignition B9

23.13 Sensors location

23.13.1 Introduction

This chapter describes the normally sensors location on a standard engine. In case that the Fig. 23-19 and Fig. 23-20 here after shows a wrong location (in comparison with location on the engine), please contact Wärtsilä France or the local Network Dealer.

23.13.2 Location and settings

23.13.2.1 General description

See the Fig. 23-19 and Fig. 23-20 here after which shows location of the differents sensors.

Sensors location on the engine A side

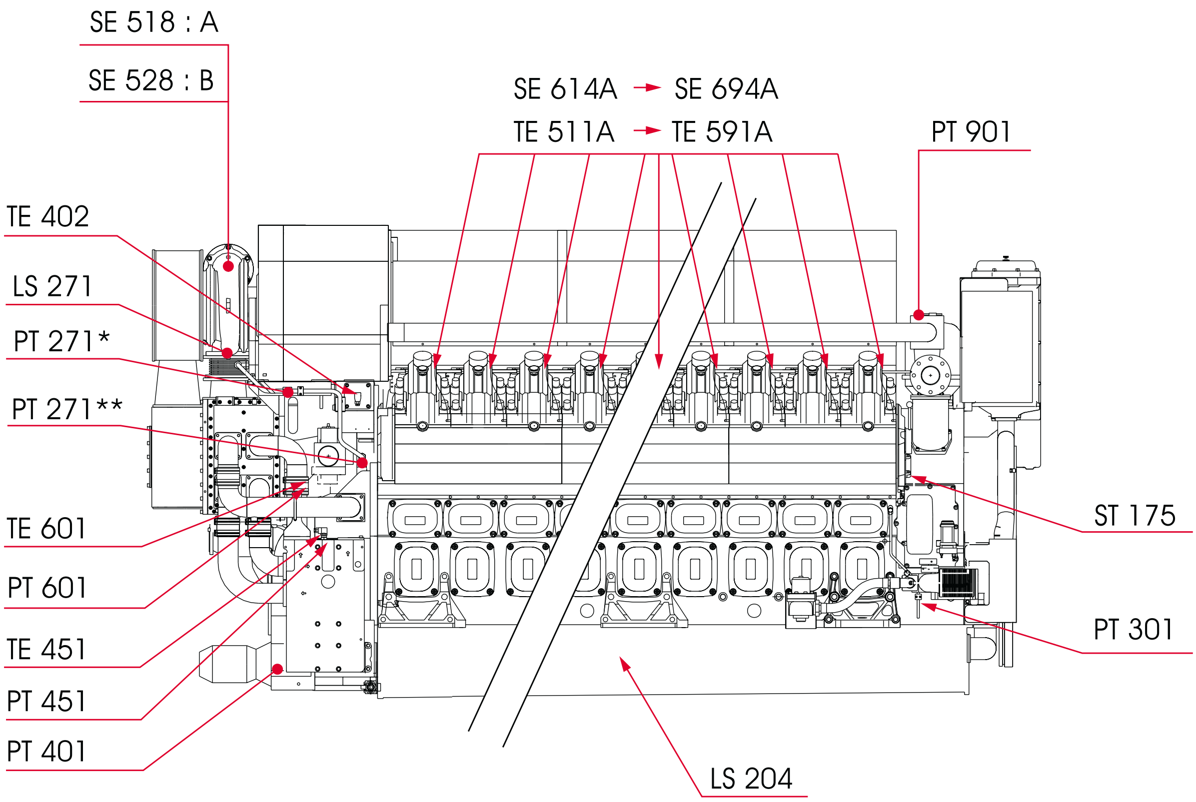


Fig. 23-19

Sensors location on the engine B side

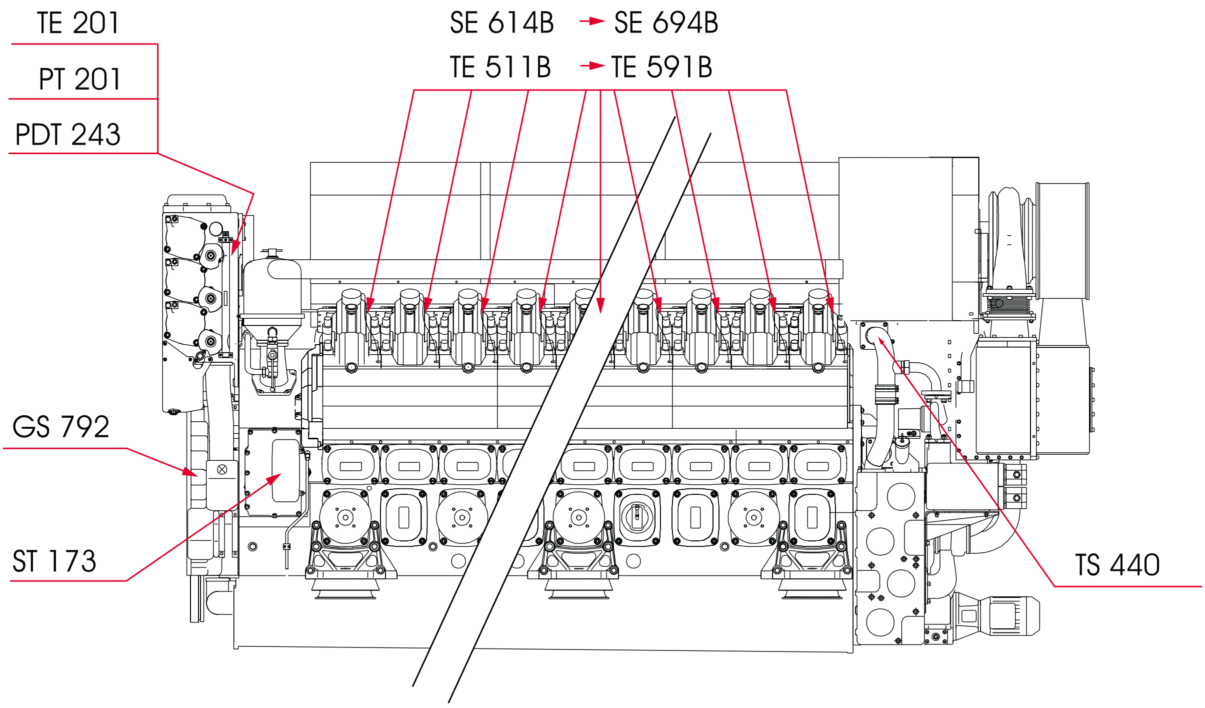


Fig. 23-20

23.13.3 Sensors functions

CODE	DESCRIPTION	Start blocked	Alarm	Unloading	Shutdown	Emergency stop	Derating
LS 204	Lub-oil level in sump		X				
ST 175	Crankshaft position (encoder)				X	XXX	
GS 792	Turning gear engaged	X					
ST 173	Engine speed sensor		XX			X	
SE 518	Single turbo speed or dual turbo A side						
SE 528	Dual turbo speed B side (option)						
TS 440	Thermostat	X					
TE 511A - TE 591A	Exhaust gas temperature cylinders A1 - A9		XX		XXXX		X
TE 511B - TE 591B	Exhaust gas temperature cylinders B1 - B9		XX		XXXX		X
TE 201	Oil temperature before engine		XX	X			
TE 402	HT water temperature after engine		XX	X	XX		
TE 451	LT water temperature after engine		XX				
TE 601	Charge air temperature CAC outlet		XX				X
PT 601	Charge air pressure engine inlet		X				X
PDT 243	Oil pressure difference between filters		X				
SE 614A - SE 694A	Knocking sensors cylinders A1 - A9		X			X	X
SE 614B - SE 694B	Knocking sensors cylinders B1 - B9		X			X	X
PT 201	Oil pressure before engine	X	XX		XX		
PT 271	Oil pressure before turbo	X	X		XX		
PT 301	Starting air pressure (16-18V)		X				
PT 301	Starting air pressure (12V)						
PT 401	HT water pressure before engine		XX	X			
PT 451	LT water pressure before engine		XX	X			
PT 901	Main gas line pressure		XX		X	XX	
PT 700	Crankcase pressure						

23.13.4 Water cooling circuit

The engine water circuit is divided in two internal separate circuits:

- Low temperature water circuit (LT).
- High temperature water circuit (HT).

For more information, cf. Chap. 19 Cooling water circuit page 269.

Into this chapter we don't take into account the two separate circuits.

23.13.4.1 Sensors location on water circuit

Water circuit sensors 16/18V

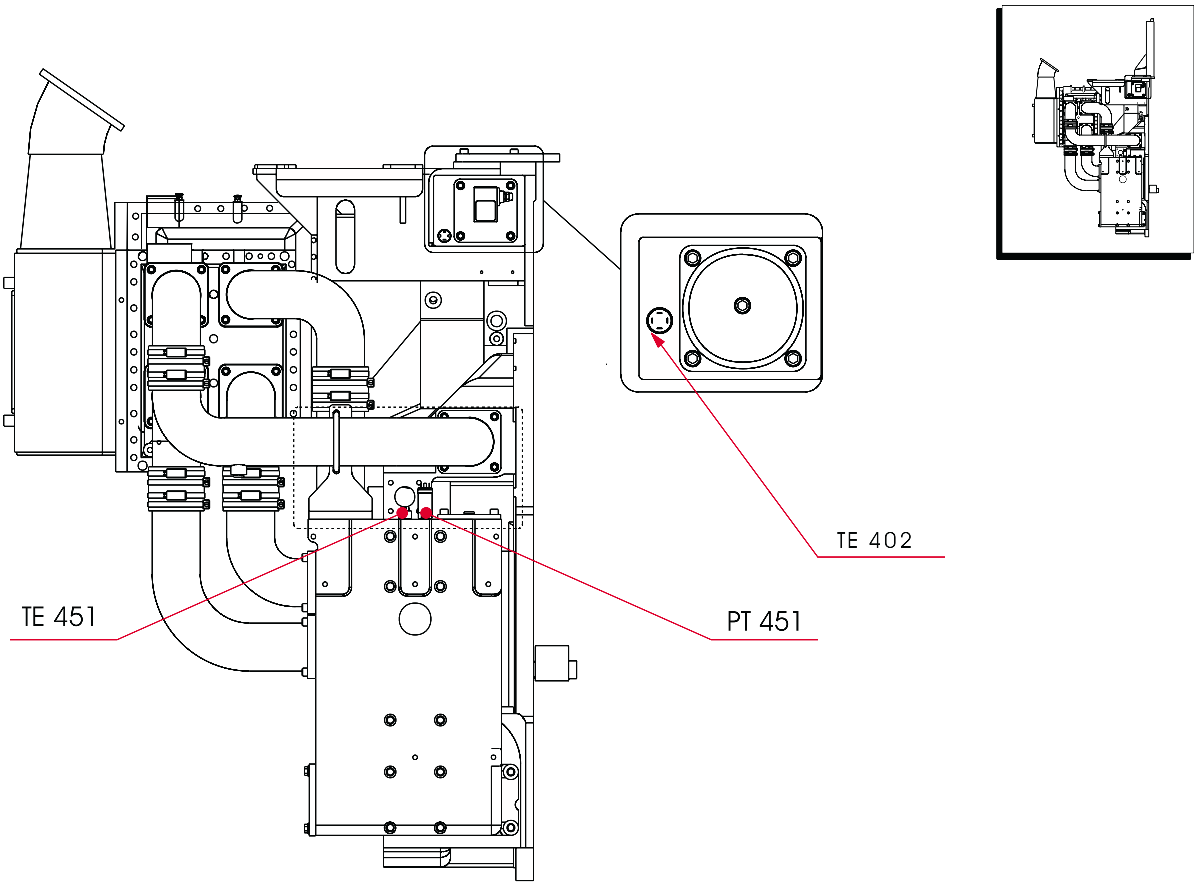


Fig. 23-21

Water circuit sensors 12V

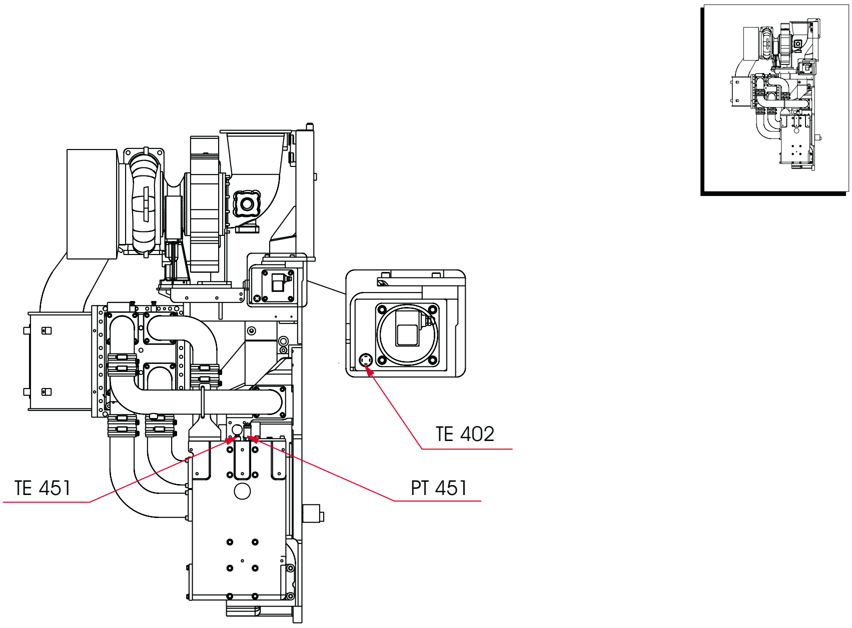


Fig. 23-22

Preheating water circuit sensors

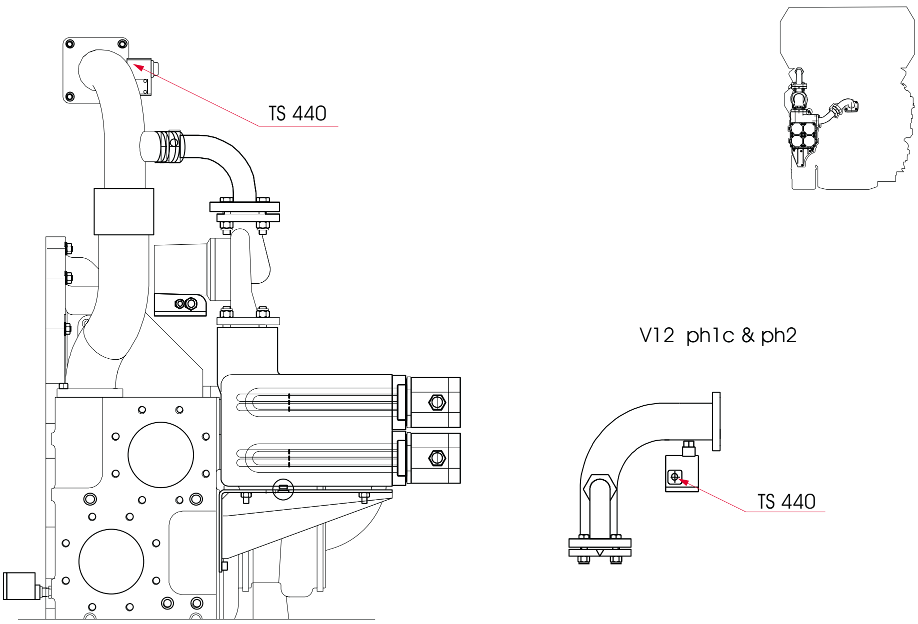


Fig. 23-23

Water circuit pressure sensor

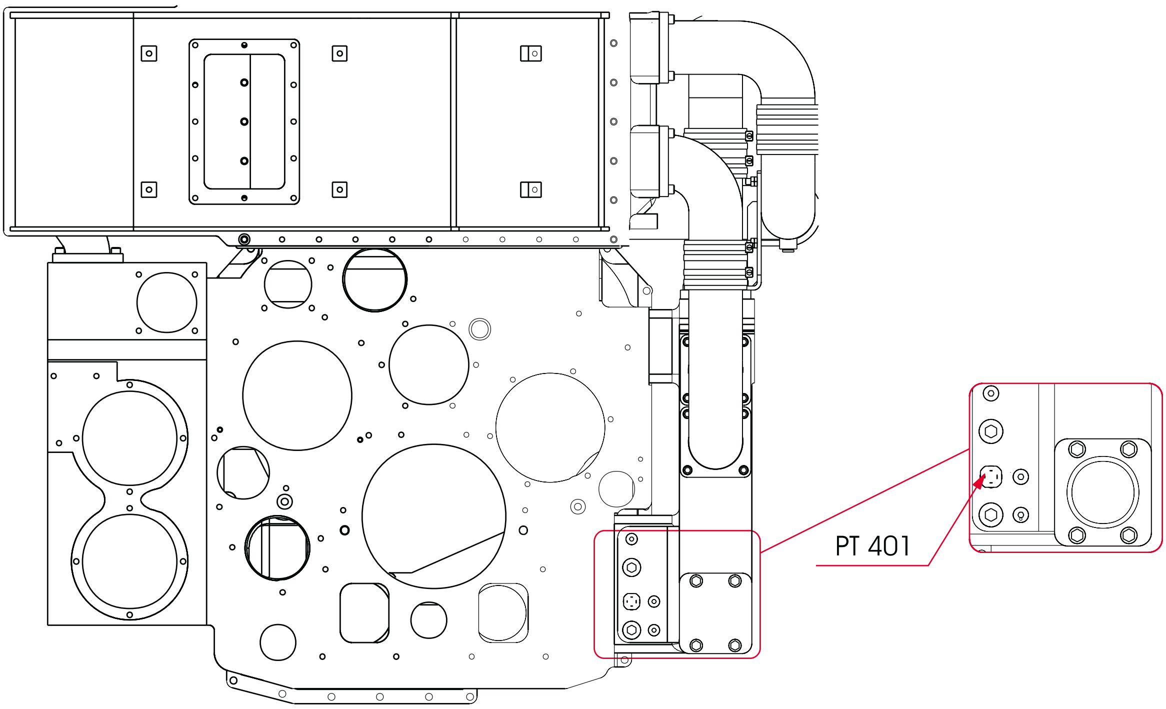


Fig. 23-24

23.13.4.2 Settlements

The HT and BT sensors datas are:

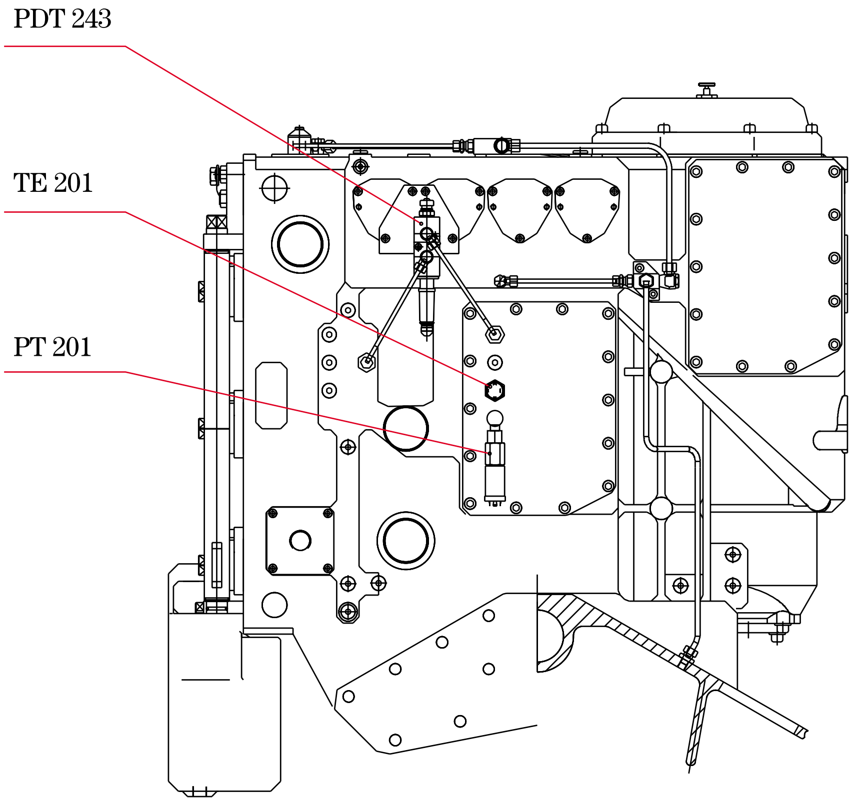
Engine parameters recorded on the WECS 3000

Code	Function	Measuring range	Type of condition	Inhibited at starting	Sensor type
TE 402	HT water temp. After engine	0° - 160°C	High	X	PT 100
TE 451	BT water temp after engine	0° - 160°C	High	X	PT 100
PT 451	BT water pressure before engine	0 - 6000 mB	High	X	Current
PT 401	HT water pressure after engine	0 - 6000 mB	High	X	Current

Safety devices

Code	Function	Setting point	Start blocked	Sensors type
TS 440	Preheating thermostat	Low 45°C High 54°C	X	Switch

23.13.4.3 Lube oil circuit sensors



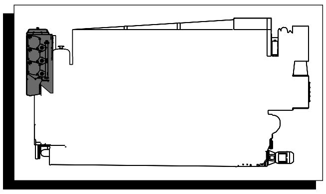
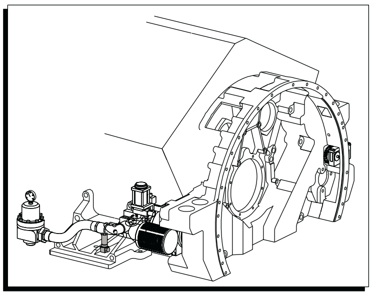


Fig. 23-25

Code	Function	Type of condition	Sensor type
T 201	Oil temperature before engine	High	PT 100
PT 201	Oil pressure before engine	Low	Current
PDT 243	Oil pressure difference between filters	Low	Current

23.13.4.4 Air starting circuit sensor 16/18V



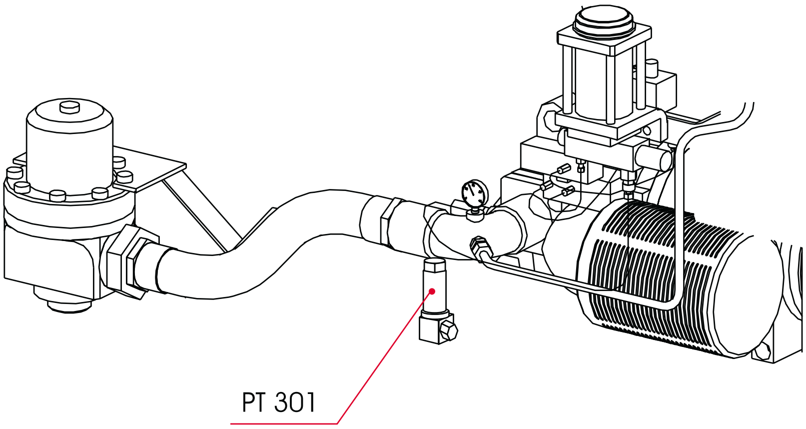


Fig. 23-26

Code	Function	Type of condition	Setting point	Sensor type
PT 301	Air starting pressure	Low	17 Bar	Current

23.13.4.5 Exhaust gas temperature sensor

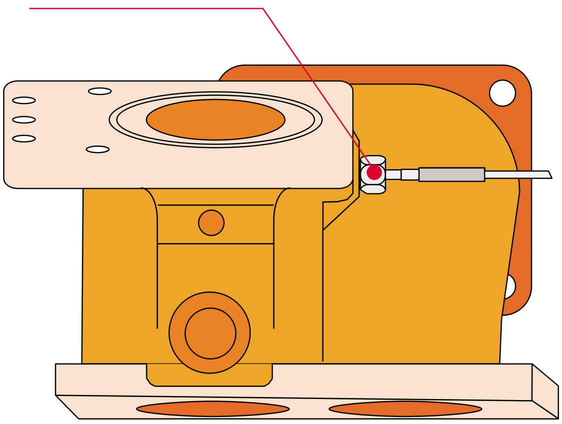


Fig. 23-27

Code	Function	Sensor type
TE 511A - TE 591B	Exhaust gas temperature (1)	Thermo K

(1) Exhaust gas temperature fault

- Activation delay : 15 seconds
- High setting point : 550°C
- Deviation : 170°C

23.13.4.6 Engine speed sensor

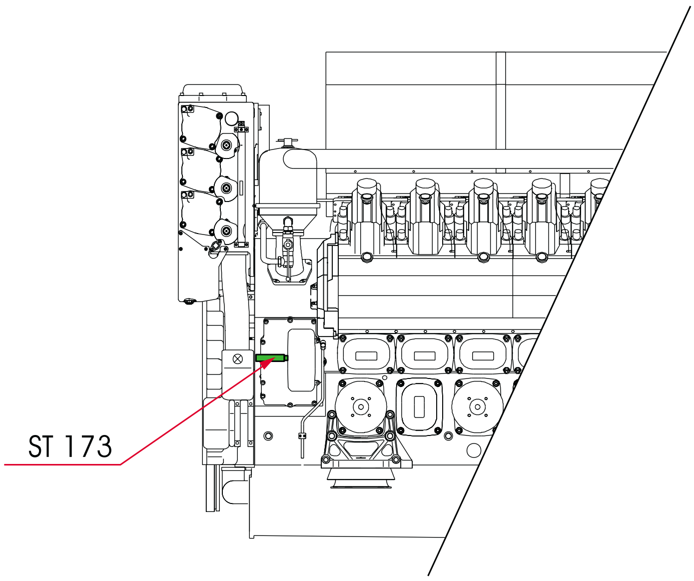


Fig. 23-28

Safety device in case of overspeed alarm.

Code	Function	Setting point	Sensor type
ST 173	Overspeed	1725 t/mn (1) 1380 t/mn (2)	Current

(1) 1500 rpm engine

(2) 1200 rpm engine

Setting of the sensor / flywheel teeth distance : 2,5 mm

Contact on tooth : 2,5 round

23.13.4.7 Gas circuit sensor

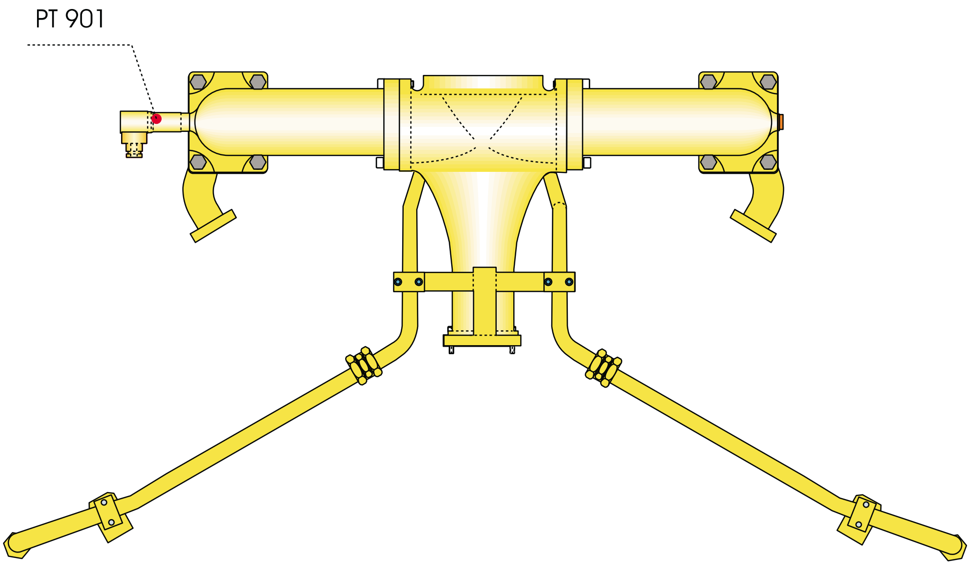


Fig. 23-29

Engine parameters recorded on supervision software

Activation delay : 4 secondes

Code	Function	Type of condition	Sensor type
PT 901	Engine gas circuit pressure	High	Current

23.13.4.8 Charge air circuit sensor

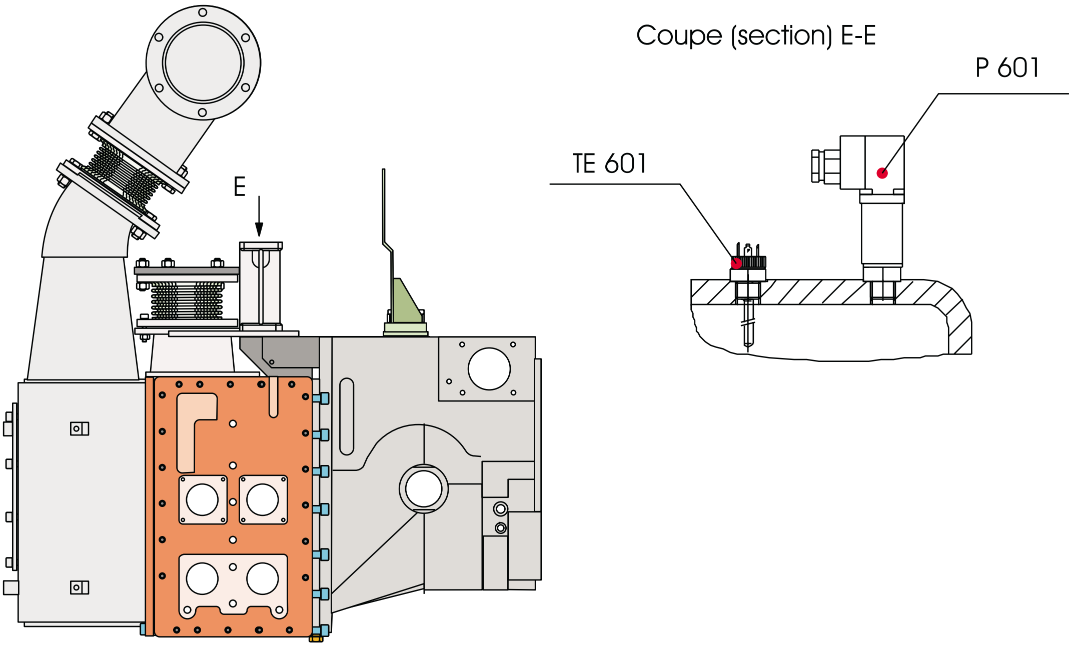


Fig. 23-30

Engine parameters recorded on supervision software

Activation delay : 4 secondes

Code	Function	Type of condition	Sensor type
TE 601	Charge air temperature after cooler	High	PT 100
P 601	Charge air pressure after cooler	High	Current

23.13.4.9 Settlements

Engine parameters recorded on WECS 3000

Activation delay : 4 secondes

Safety device on lube oil circuit

Code	Function	Setting point	Start bloc-ked	Emergency stop	Alarm	Sensor type
LS 271	Turbo oil level	NO (*)	X (**)	X		Level switch
L 204	Oil level in sump (1)	NC (***)	X		X	Level switch

(1) Fault recorded one minute before alarm indication

(*) Normally open when no lube oil (closed when lube oil)

(**) Switch open when no lube oil (low level)

(***) Normally closed when lube oil level is correct

23.13.4.10 Miscellanous

Code	Function	Setting point	Start blocked	Emergency stop	Alarm	Sensor type
PT 700	Engine crankcase pressure	30 mbar		X		Current
GS 792	Turning gear	NC	X		X	Contact switch

23.14 Maintenance and troubleshooting

23.14.1 Technical characteristics

The engine is equipped with four different types of sensors, which characteristics are :

- Thermocouple K type
  - alloy combination : Nickel-Chromium (Ni-Cr)
  - maximum temperature range : 0 to 600°C
  - limits of error : 2°C or 0,75%
- PT 100 Ohms at 0°C
  - maximum temperature range : -50°C to +250°C
  - Limit of error : 0,8%
- 4-20 mA sensor (current)
  - maximum pressure range : depending on the type of circuit 0-6 b, 0-10 b, 0-16 b
  - supply voltage : 24Vdc
- Contact switches and safety devices : switch type

Important : **In case of sensor replacement, take the same type and measuring scale of sensor.**

23.14.2 Calibration

23.14.2.1 Temperature

The different temperature sensors have to be checked according to the Maintenance Schedule (chap 04, O&M Manual), at least once a year.

Thermocouple and PT 100 sensors

a) Sensor

1 **Put the sensor in a temperature-controlled bath** and measure the voltage or the resistance at, at least, three different values of the sensor temperature range.

2 **Compare the values** with the one given by the reference tables.

3 **If the difference is lower than 5%,** you may consider that the sensor is OK.

4 **If not,** replace the sensor

b) Switch type temperature safety device

Use a temperature-controlled bath to check and adjust the calibration of the sensor according to the data given in the previous sections. The difference after checking must be lower than 2%, if not, recalibrate the sensor or replace it.

23.14.2.2 Line

1 **Put the sensor in a temperature-controlled bath** and check the values given by the CMR unit.

2 **If the difference is lower than 5%,** you may consider that the measurement system is OK.

3 **In the other cases,** test each component of the measurement system (continuity of wires, noise, CMR calibration,...).

23.14.2.3 Pressure

- Switch type pressure safety device

Use the dedicated pressure calibrating tool to check and adjust the pressure sensors. The difference after checking must be lower than 2%, if not, recalibrate the sensor or replace it.

- 4-20 mA sensor

Check and adjust the calibration as described in the following example.

Example : P 202 sensor = lub oil pressure

Range : 0 - 10 bar 0 bar <=> 4 mA

Current : 4 - 20 mA 10 bar <=> 20 mA

X bar = (4+1,6 X)mA

or

X mA = (0,625 x -2,5)b

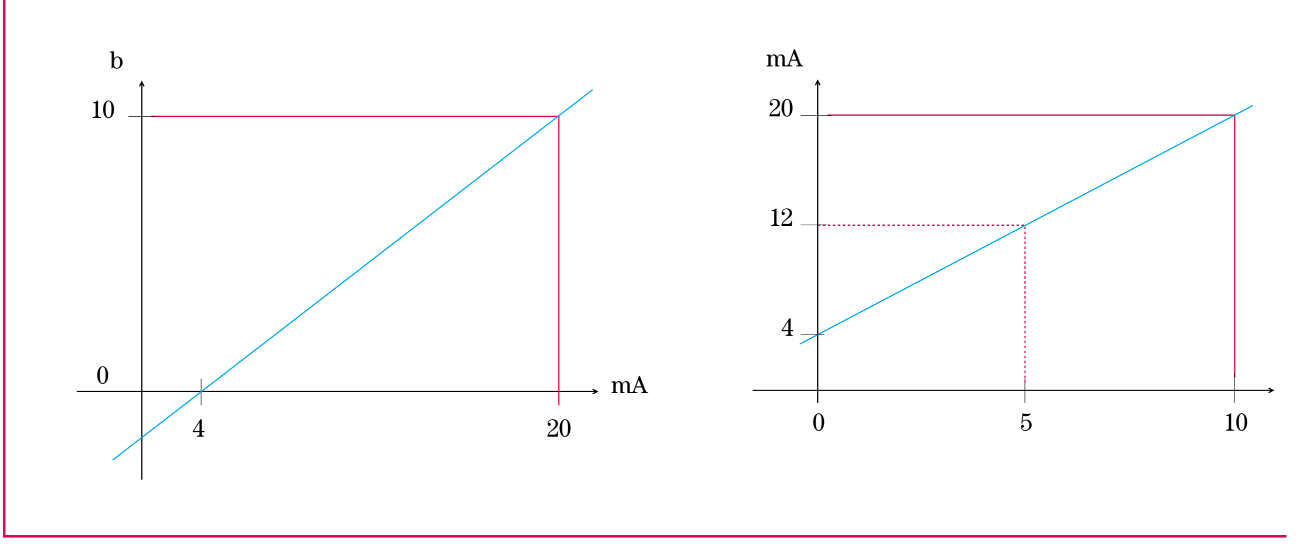


Fig. [C#]-[F#]

5 bar due to pressure calibrating tool give 12 mA on the sensor

If the difference is higher than 1 mA, the sensor has to be changed.

23.14.2.4 Troubleshooting

Safety device

In case of tripping when the data recorded on the CMR unit is correct, check all components and line continuity on the safety device and measurement device systems.

Measurement device

The CMR and IVO units are programmed to detect line continuity or a sensor failure.

Important : **In case of sensor failure, please follow the information given in the previous sections**

Note : **Fore more information, please refer to the CMR and IVO sections given chapter 23 of the manual.**

PT 100 Reference table

Temp °C	Ohms	Temp. °C	Ohms
0	100,00	60	123,24
5	101,95	65	125,16
10	103,90	70	127,07
15	105,85	75	128,98
20	107,79	80	130,89
25	109,73	85	132,80
30	111,67	9*0	134,70
35	113,61	95	136,60
40	115,54	100	138,50
45	117,47	105	140,39
50	119,40	110	142,29
55	121,32	115	144,17

Thermocouple reference table

Temp °C	Millivolts	Temp. °C	Millivolts
0	0,000	350	14,293
10	0,397	360	14,713
20	0,796	370	15,133
30	1,203	380	15,554
40	1,612	390	15,975
50	2,023	400	16,397
60	2,436	410	16,820
70	2,851	420	17,243
80	3,267	430	17,667
90	3,682	440	18,091
100	4,096	450	18,516
110	4,509	460	18,941
120	4,920	470	19,366
130	5,328	480	19,792
140	5,735	490	20,218
150	6,138	500	20,644
160	6,540	510	21,071
170	6,941	520	21,497
180	7,340	530	21,924
190	7,739	540	22,350
200	8,138	550	22,776
210	8,539	560	23,203
220	8,940	570	23,629
230	9,343	580	24,055
240	9,747	590	24,480
250	10,153	600	24,905
260	10,561	610	25,330
270	10,971	620	25,755
280	11,382	630	26,179
290	11,795	640	26,602
300	12,209	650	27,025
310	12,624	660	27,447
320	13,040	670	27,869
330	13,457	680	28,289
340	13,874	690	28,710