00. Contents, Instructions, Terminology

00.1 Contents of the Manual

1. This manual contains data and instructions for operation and maintenance of engine as well as instruction for handling, personal protection and first aid when fuel-, lubricating oils and cooling water additives are handled during normal operation and maintenance work.
Basic general knowledge has not been entered. Consequently, it is assumed that the engine operation and maintenance staff is well informed of the care of diesel engines.
2. Wärtsilä reserves for itself the right to minor alterations and improvements owing to engine development without being obliged to enter the corresponding changes in this Manual.
3. The diesel engines will be equipped as agreed upon in the sales documents. No claim can be made on the basis of this Manual as here are described also components not included in every delivery.
The system diagram plans (fuel, oil, cooling etc.) are just indicative and thus do not cover all installations. See installation specific system drawings for more details.
4. Exact engine build-up in all details is defined by the specification number on the name plate located on the engine. **In all correspondence or when ordering spare parts, be careful to state engine type, specification number and engine number.**
5. This Manual is supplemented by the Spare Parts Catalogue including sectional drawings or exterior views of all components (partial assemblies).

00.2 General rules

1 Read the corresponding item carefully in this Manual before any steps are taken.

2 Keep an engine log book for every engine.

3 Observe the utmost cleanliness and order at all maintenance work.

4 Before dismantling, check that all systems concerned are drained or the pressure released. After dismantling, immediately cover holes for lubricating oil, fuel oil and air with tape, plugs, clean cloth or the like.

5 When exchanging a worn-out or damaged part provided with an identification mark stating cylinder or bearing number, mark the new part with the same number on the same spot. Every exchange should be entered in the engine log and the reason should be clearly stated.

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

00.3 Terminology

The most important terms used in this manual are defined as follows:
Operating side. The longitudinal side of the engine where the operating devices are located (start and stop, instrument panel, speed governor).
Rear side. The longitudinal side of the engine opposite the operating side.
Driving end. The end of the engine where the flywheel is located.
Free end. The end opposite the driving end.
Designation of cylinders. According to ISO 1204 and DIN 6265 the designation of cylinders begins at the driving end. In a V-engine the cylinders in the left bank, seen from the driving end, are termed A1, A2 etc. and in the right bank B1, B2 etc., see below:

Terminology

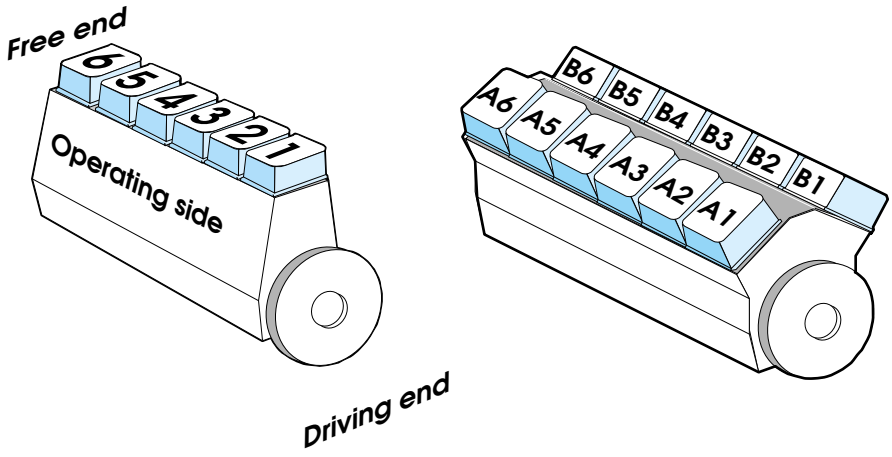


Fig 00-1 WV00519331

Designation of bearings.

- Main bearings. The flywheel bearing is No. 0, the first standard main bearing is No. 1, the second No. 2 etc.
- The thrust bearing rails are located at the flywheel bearing. The outer rails close to the flywheel are marked with 00 and the inner rails with 0.
- The camshaft bearings are designated as the main bearings, the thrust bearing bushes being designated 00 (outer) and 0.
- Camshaft gear bearings. The bearings located on the flywheel side are designated 00 and the inner bearings 0.

- Upper and lower bearings shells. In bearings where both the shells are identical, the upper one is marked with “UP”.

Designation of bearings

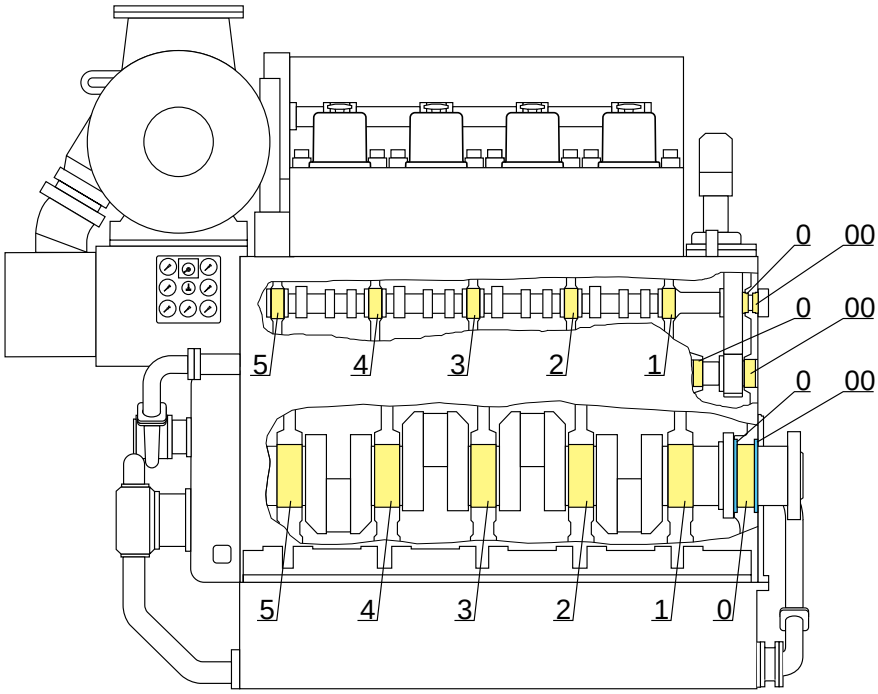


Fig 00-2 3200528935

Operating side and rear side. Details located at the operating side may be marked with “M” (Manoeuvering) and correspondingly “B” for the back of the engine (B-bank on a V-engine).
Clockwise rotating engine. When looking at the engine from the driving end the shaft rotates clockwise.
Counter-clockwise rotating engine. When looking at the engine from the driving end the shaft rotates counter-clockwise.
Bottom dead centre, abbreviated **BDC**, is the bottom turning point of the piston in the cylinder.
Top dead centre, abbreviated **TDC**, is the top turning point of the piston in the cylinder. TDC for every cylinder is marked on the graduation of the flywheel. During a complete working cycle, comprising in a four-stroke engine two crankshaft rotations, the piston reaches TDC twice:
a) For the first time when the exhaust stroke of the previous working cycle ends and the suction stroke of the following one begins. Exhaust valves as well as inlet valves are then somewhat open and scavenging takes place. If the crankshaft is turned to and fro near this TDC, both exhaust and inlet valves will move, a fact that indicates that the crankshaft is near the position which can be named **TDC at scavenging.**
b) The second time is after the compression stroke and before the working stroke. Slightly before this TDC the fuel injection takes place (on an engine in operation) and this TDC can therefore be defined **TDC**

at firing. Characteristic is that all valves are closed and do not move if the crankshaft is turned. When watching the camshaft and the injection pump it is possible to note that the pump tappet roller is on the lifting side of the fuel cam.

Marking of the flywheel. The flywheel is divided in 360°, starting from **TDC at firing** for cylinder 1. TDC at firing for every cylinder is marked on the flywheel. There is a common marking for the cylinders in engines with even cylinder numbers, one cylinder is at TDC at firing and the other is at TDC at scavenging. There are separate scales for A- and B-bank in a V-engine. See also the firing order in chapter 01. Firing interval, in crank angles, can be determined by dividing 720° with the number of cylinder.

Example of reading the flywheel

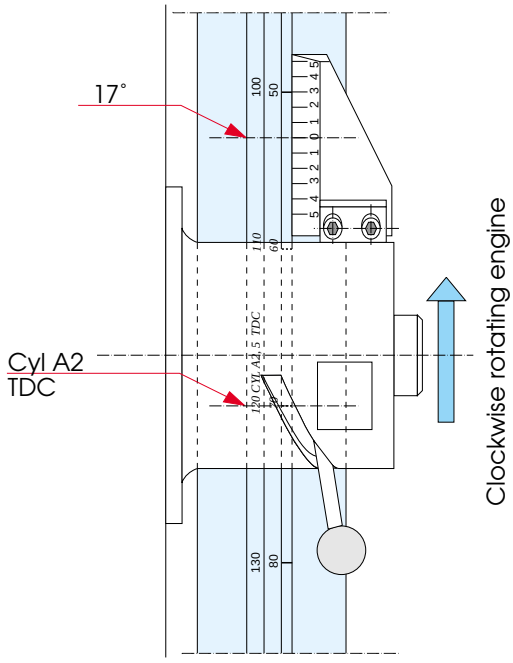


Fig 00-3 3200538935

Example: *On a VASA 12V32 engine, the fuel timing is read to 17° for cylinder A2 when the flywheel is in the position shown in the above figure.*

00A. Risk Reduction

00A.1 General

Read the engine manual including this appendix before installing, operating or servicing the engine and/or related equipment.

Failure to follow the instructions can cause personal injury, loss of life and/or property damage.

Proper personal safety equipment, e.g. gloves, hard hat, safety glasses and ear protection must be used in all circumstances. Missing, imperfect or defective safety equipment might cause serious personal injury or loss of life.

This appendix contains listed general identified hazards, hazardous situations or events, which are to be noticed during normal operation and maintenance work.

Identified hazard,hazardous situation or event	Chapter of engine manual																
	3	4	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Dropping parts during maintenance work		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Turning device engaged during maintenance work [1)]	x	x		x	x	x	x	x		x							
Crankcase safety expl. valves will open if crankcase explosion	x			x													x
Noise level	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Running engine without covers	x	x		x	x	x	x	x		x					x	x	
In case of major failure, risk of ejected parts	x	x		x	x	x	x	x								x	
Contact with electricity during maintenance work if power not disconnected		x			x						x	x			x	x	x
Electrical hazard if grounding of electrical equipment is incorrect	x	x			x						x	x					
Ejection of components / high pressure gas due to high firing pressures	x	x				x	x	x		x					x		
Risk of ejected parts due to break down of turbocharger	x								x								
Overspeed or explosion due to air-gas mixture in the charge air [2)]	x	x							x								
Ejection of fuel injector if not fastened and turning device engaged		x				x				x							
Fire or explosion due to leakage on fuel / gas line or lube oil system	x	x								x	x	x		x			
Inhalation of exhaust gases due to leakage [3)]	x								x					x			
Inhalation of exhaust gas dust		x	x	x	x	x			x					x			

Continues

Identified hazard,hazardous situation or event	Chapter of engine manual																
	3	4	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Explosion or fire if flammable gas/vapour is leaking into the insulation box. [4]	x													x			
Touching of moving parts	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x

[1] Warning light when turning device engaged.
[2] Suction air to be taken from gas free space.
[3] Require proper ventilation of engine room/plant.
[4] Require proper ventilation and/or gas detector in the engine.

00A.1.1 General identified hazards, hazardous situations or events

00A.1.1.1 Hazards that may be due to moving parts

- Running engine without covers, coming in contact with moving parts,
- Touching pump parts during unintentional start of el. driven pump motor,
- Charger starts to rotate due to draft if not locked during maintenance,
- Somebody sticks his hand into the compressor housing when the silencer is removed and engine running,
- Unexpected movement of valve or fuel rack(s) due to broken wire or soft / hardware failure in the control system,
- Unexpected movement of components,
- Turning device engaged during maintenance work,
- Turning device not engaged e.g. Turning device removed for overhaul, during maintenance work could cause rotating crankshaft,
- Mechanical breakage (of e.g. speed sensor) due to erratic actuator assembly to engine or electrical connections.

00A.1.1.2 Hazards that may be due to incorrect operating conditions

- Overspeed or explosion due to air-gas mixture in the charge air,
- Overspeeding due to air-oil mist mixture in the charge air,
- Malfunction of crankcase ventilation,
- Oil mist detector will trip if water is present in lubricating oil,
- Crankcase explosion if oil mist is mixed with “fresh” air during inspection after an oil mist shut down,
- Crankcase safety explosion valves will open if there is a crankcase explosion.

00A.1.1.3 Hazards that may be due to different leakages, breakdown or improper assembly of component

- Fuel or gas pipe will burst and spray fuel / gas,
- Leakage of:

— fuel in joints on low and/or high pressure side,
— lube oil,
— high pressure water on DWI engines,
— HT water,
— charge air,
— exhaust gas,
— pressurised air from air container, main manifold or pipes,
— high pressure gas and sealing oil on GD engines,

- Fire or explosion due to leakage on fuel line,
- Fire due to oil or fuel / gas leakage,
- Explosion or fire if flammable gas/vapour is leaking into the insulation box,
- Inhalation of exhaust gases or fuel gases due to leakage,
- Failure of pneumatic stop,
- Ejected components due to:

— breakdown of hydraulic tool,
— breakdown of hydraulic bolt,
— breakdown of turbocharger,
— high firing pressures,
— major failure,

- Ejection of:

— pressurised liquids and gases from the block and pipings,
— high pressure fluid due to breakdown of hydraulic tool,
— gas due to high firing pressures,
— pressurised gases from high pressure gas system,
— high pressure fluid due to breakdown of HP sealing oil pipe,
— high pressure air during maintenance of oil mist detector main air supply piping,
— cooling water or fuel/lube oil if sensor is loosened while the circuit is pressurised,
— springs during maintenance work,

- Oil spray if running without covers,
- Ejection of fuel injector if not fastened and turning device engaged.

00A.1.1.4 Hazards that may be due to electricity or incorrect connections of electricity

- Fire or sparks due to damage or short circuit in electrical equipment,
- Contact with electricity during maintenance work if power not disconnected,
- Electrical hazard if grounding of electrical equipment is incorrect,
- Electrical shock if electrical equipment has a lead isolation break or connector damage or is dismantled with power connected,
- Overheating of control system component due to erratic electrical connections,
- Incorrectly wired or disconnected emergency stop switch,
- Overload of control system components due to damaged control circuitry or incorrect voltage,
- Engine not controllable if failure in the shutdown circuitry,
- Unexpected start up or overrun,
- Crankcase explosion if:

— engine not safeguarded at high oil mist levels, due to energy supply failure,
— engine not (fully) safeguarded at high oil mist levels, due to failure in oil mist detector circuitry,
— engine not (fully) safeguarded at high oil mist levels, due to erratic electrical connector or leakage in pipe connection.

00A.1.1.5 Other hazards and hazardous situations where it's especially important to use personal safety equipment

- Slip, trip and fall,
- Water additives and treatment products (see appendix 02A, section 02A.4),
- Touching the insulation box, turbo-charger, pipes exhaust manifold or (other) unprotected parts without protection during engine operation,
- Dropping parts during maintenance work,
- Starting maintenance work too early i.e. causing risk when handling hot components,
- Neglecting use of cranes and/or lifting tools,
- Not using proper tools during e.g. maintenance work,
- Contact with fuel oil or oily parts during maintenance work (see appendix 02A),
- Noise level,
- Touching or removing Turbocharger insulation,
- Preloaded fixation springs during check / replacement of sensor.

00B. Welding Precautions

00B.1 Precautions General

Main principles:

- Prevent uncontrolled current loops
- Prevent radiation
- Prevent sparkles flying around
- If convenient, disconnect all global signals like power supply, data communication etc.

00B.1.1 Preventing uncontrolled current loops

Welding current path must always be checked, there should be a straight route from the welding point back to the return connection of the welding apparatus.
The biggest current is always going where it meets the lowest resistance, in certain cases the return current can therefore go via grounding wires and electronics in the control system.
To avoid this, the distance between the welding point and the return connection clamp of the welding apparatus should always be shortest possible and without electronic components in the returning loop path.
Attention must be paid to the connectivity of the return connection clamp, a bad contact might also cause sparkles and radiation.

00B.1.2 Preventing Radiation

The welding current and the arc is emitting a wide spectrum of electromagnetic radiation. This might cause damages on sensitive electronic equipment.
To avoid these damages all cabinets and terminal boxes must be kept closed during the welding. Sensitive equipment can also be protected by means of shielding with a conductive metal plate.
Also avoid having the cables of the welding apparatus going in parallel with wires and cables in the control system. The high welding current is easily inducting secondary currents in other conductive materials.

00B.1.3 Preventing damage due to sparkles

Sparkles are commonly flying around from the welding arc. Few materials withstand the heat from these sparkles. Therefore all cabinets and terminal boxes should be kept closed during the welding. Sensors, actuators, cables and other equipment out on the engine must be protected by means of proper protection.

Sparkles can also be a problem after they have cooled down, i.e. causing short circuits, sealing problems etc.

00B.2 Precaution checklists

00B.2.1 Checklists General

The checklists (preferable glued to a plastic plate) in this chapter should be put into the engines cabinet for respective system type. The checklist must be easily visible and accessible when opening the cabinet.

00B.2.2 Basic ECU (Despemes/Spemos) checklist

The following precautions must be paid attention to before welding in the vicinity of a basic ECU system:

- Close the cover of the cabinet
- Deactive the system by disconnecting all external connectors (X1...X4).
- If convenient, protect cables, sensors and other equipment from sparkles with a proper metal sheet.

00B.2.3 WECS 2000 checklist

The following precautions must be paid attention to before welding in the vicinity of a WECS 2000 control system:

- Close the covers of the cabinet and all the distributed units.
- Deactivate the system by disconnecting all external connectors (X1...X6).
- If convenient, protect cables, sensors and other equipment from sparkles with a proper metal sheet.

00B.2.4 WECS 3000 checklist

The following precautions must be paid attention to before welding in the vicinity of a WECS 3000 control system:

- Deactive the system by disconnecting all external connectors (X1...X5).
- Do not connect the welding apparatus return line to the aluminium profile containing CCU's, KDU's and ignition modules. The profile is used as a common ground for these modules.
- Open all terminal fuses (F1...F20) in the cabinet.
- Close the covers of the cabinet and all the distributed units.
- If convenient, protect cables, sensors and other equipment from sparkles with proper metal sheet.

00B.2.5 WECS 7000/8000 checklist

The following precautions must be paid attention to before welding in the vicinity of a WECS 7000 or 8000 control system:

- Deactive the system by disconnecting all external connectors (X1...X6).
- If the welding point is close to (approximately within a radius of 2 m) an electronic module (SSM-701, SSM-558, CCD/PDM, Cense etc.) disconnect all connectors of the unit
- Close the covers of the cabinet
- Disconnect the interconnections between the harnesses and the cabinet.
- If convenient, protect harnesses, cables, sensors and other equipment from sparkles with a proper metal sheet.

01. Main Data, Operating Data and General Design

01.1 Main data for Vasa 32DF

Cylinder bore ..... 320 mm
Stroke ..... 350 mm
Piston displacement per cylinder ..... 28.15 l

Firing order		
Engine type	Clockwise rotation	Counter-clockwise rotation
12V32	A1-B1-A5-B5-A3-B3-A6-B6-A2-B2-A4-B4	A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5-B1
16V32	A1-B1-A3-B3-A7-B7-A4-B4-A8-B8-A6-B6-A2-B2-A5-B5	A1-B5-A5-B2-A2-B6-A6-B8-A8-B4-A4-B7-A7-B3-A3-B1
18V32	A1-B1-A7-B7-A4-B4-A2-B2-A8-B8-A6-B6-A3-B3-A9-B9-A5-B5	A1-B5-A5-B9-A9-B3-A3-B6-A6-B8-A8-B2-A2-B4-A4-B7-A7-B1

Normally the engine rotates clockwise.

Lubricating oil volume in the engine			
Engine type	12V32	16V32	18V32
App. oil volume in litres Normal sump Deep sump	 1875 2825	 2405 3620	 2670 4020
Oil volume between max. and min. marks c. litres/mm	4.6	6.1	6.9

App. cooling water volume in the engine in litres			
Engine only	740	950	1060
Engine and inverse cooling system	950	1220	1360

01.2 Recommended operating data

Apply to normal operation at nominal speed.

	Normal values	Alarm (stop) limits
Load	100 %	30 - 100 %
Temperatures, (°C)		
Lube oil before engine	62 - 70	80
Lube oil after engine	10 - 13 higher	
HT water after engine	91 - 100	100 (105)
HT water before engine	5 - 8 lower	
HT water rise over turbocharger	8 - 12 (15)	
LT water before engine	28 - 38	
Charge air in air receiver	40 - 60	70 (80)
Exhaust gas after cylinder	See test records	550 (580)
Preheating of HT and LT water	70	
Gauge pressures (bar)		
Lube oil before engine at a speed of 600 RPM (10.0 r/s)	3.5	3.5 (2.5)
720 RPM (12.0 r/s) - 750 (12.5 r/s)	4.5 - 5.5	3.5 (2.5)
HT/LT water before HT/LT pump (=static)	0.7 - 1.5	
HT water before engine	2.2 - 4.8 (x)	2.0
LT water before charge air cooler	2.2 - 4.4 (x)	2.0
Gas before engine	3	
Fuel oil before engine	6 - 8	4 (HFO) 2 (MDO)
Starting air	max. 10.3	
Charge air	See test records	
Other pressures (bar)		
Opening pressure of safety valve on lube oil pump	6 - 8	
Visual indicator and electronic transducer for high pressure drop over lube oil filter and fuel filter	1.2 - 1.8	

(x) Depending on speed and installation.

01.3 Reference conditions

Reference conditions according to:

Air pressure . . . . . 100 kPa (1.0 bar)
Ambient temperature . . . . . 303 K (30°C)
Relative air humidity. . . . . 30 %
Cooling water temperature of charge air cooler . . . . . 308 K (35°C)

In case the engine power can be utilized under more difficult conditions than those mentioned above, it will be stated in the sales documents. Otherwise, the engine manufacturer can give advice about the correct output reduction. As a guideline additional reduction may be calculated as follows:

Reduction factor = (a + b + c) %

a = 0.5 % for every °C the ambient temperature exceeds the stated value in the sales documents.
b = 1 % for every 100 m level difference above stated value in the sales documents.
c = 1 % for every °C the cooling water of the charge air cooler exceeds the stated value in the sales documents.

01.4 General engine design

The engine is a turbocharged intercooled 4-stroke gas engine with direct pilot fuel injection.
The engine block is cast in one piece. The main bearings are hanging. The main bearing cap is supported by two hydraulically tensioned main bearing screws and two horizontal side screws.

The charge air receiver is cast into the engine block as well as the cooling water header. The crankcase covers, made of light metal, seal against the engine block by means of rubber sealings.

The lubricating oil sump is welded.
The cylinder liners are designed with high collars and drilled cooling holes. The cooling effect is optimized to give the correct temperature of the inner surface.

The liner is provided with an anti-polishing ring in the upper part of the bore to eliminate the risk of bore polishing.
The main bearings are fully interchangeable trimetal or bimetal bearings which can be removed by lowering the main bearing cap. A hydraulic jack is provided for every main bearing to lower and lift the main bearing cap.
The crankshaft is forged in one piece and is balanced by counter-weights as required.

The connecting rods are drop forged. The big end is split and the small end bearing is stepped to achieve large bearing surfaces. The big end bearings are fully interchangeable trimetal or bimetal bearings.
The pistons are of composite type fitted with a Wärtsilä NSD patented skirt lubricating system. The top ring grooves are hardened. Cooling oil enters the cooling space through the connecting rod. The cooling spaces are designed to give an optimal shaker effect.
The piston ring set consists of three chrome-plated compression rings and one chrome-plated, spring-loaded oil scraper rings.
The cylinder head, made of special cast iron, is fixed by four hydraulically tensioned screws. The head is of the double deck design and cooling water is forced from the periphery towards the centre giving efficient cooling in important areas.
The inlet valves are stellited and the stems are chromium-plated. The valve seat rings are made of a special cast iron alloy and are changeable.
The exhaust valves, also with stellited seats and chromium-plated stems, seal against the directly cooled valve seat rings.
The seat rings, made of a corrosion and pitting resistant material, are changeable.
The camshafts are made up from one-cylinder pieces with integrated cams. The bearing journals are separate pieces and thus it is possible to remove a camshaft piece sideways.
The injection pumps have integrated roller followers and can normally be changed without any adjustment. The pumps and piping are located in a closed space which is heat insulated for heavy fuel running.
The turbochargers are normally located at the free end of the engine but, at request, can also be located at the driving end.

On a V-engine there are two chargers, one for each bank.

The charge air coolers are made as removable inserts, on the V-engines two identical ones.
The lubricating oil system includes a gear pump, oil filter, cooler with thermostat valve (not in V-engine), centrifugal bypass filter and an electrically driven prelubricating pump. The oil sump is dimensioned for the entire oil volume needed, and all cylinder numbers can be run in wet sump configuration. Dry sump running is also possible.
The starting system. The air supply into the cylinders is controlled by the starting air distributor run by the camshaft. The four-cylinder engine can alt. be provided with an air driven starting motor.

02. Fuel, Lubricating Oil, Cooling Water

02.1 Fuel

02.1.1 General

The engine is designed to operate on natural gas as a main fuel and light fuel oil as a pilot fuel. The maximum limits of natural gas and light fuel oil for a certain engine are stated in the sales contract.

02.1.2 Gas quality

The Wärtsilä 32DF engine is designed for running on natural gas qualities according to the following specification:

Gas quality	
Lower Heating Value LHV	> 30 MJ/nm^3
Methane Number	> 80
Methane content CH4	> 75 vol. %
Hydrogen sulphide H2S	< 0.01 vol. %
Particles or solids size	< 5 µm

Lower Heating Value corresponds to the energy content of the gas. If the LHV is lower than specified, the engine will have to be derated.

Methane Number is a scale for evaluation of the knock resistance of the fuel. A higher number means better knock resistance. If the components of the fuel gas is known, the methane number can be calculated. Heavier hydrocarbons as ethane, propane and butane tend to lower the methane number and special care should be taken if the gas contains even small portions of these elements.

Carbon monoxide and nitrogen tend to increase the methane number. If the methane number does not match with the requirements, the engine should be derated according to Fig 02-1.

Derating curve for methane number

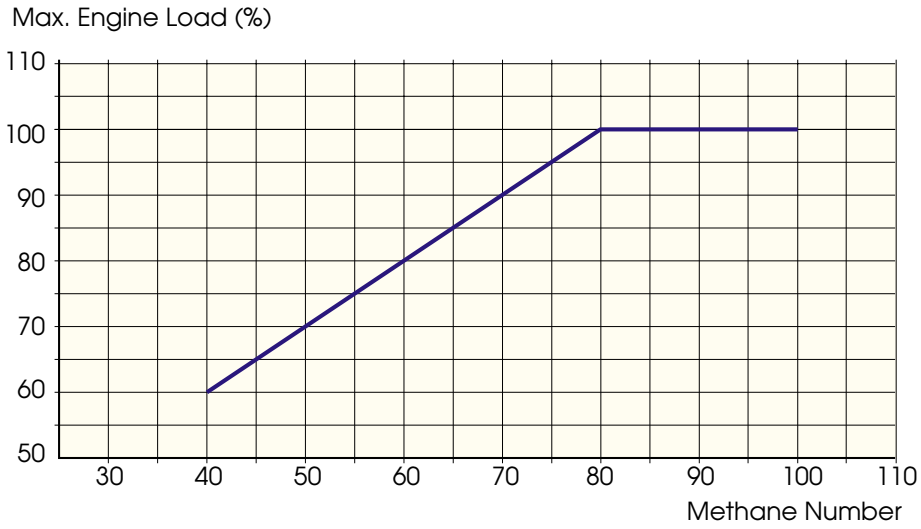


Fig 02-1 3202589552

Hydrogen sulphide H_2S may cause corrosion on the gas handling equipments.

Particles can be the reason for improper sealing and function of the gas handling equipments. The gas regulating unit should contain a suitable filter.

NOTE! During dismantling and assembly of the gas components, special care should be taken in order to avoid foreign particles from entering the gas system.

02.1.3 Pilot fuel quality

The Wärtsilä 32DF engine is designed to operate on light fuel oil as a pilot fuel according to the following specification.

Pilot fuel characteristics, maximum limits		
Kinematic viscosity	cSt at 40 °C	11.0
Kinematic viscosity, min.	cSt at engine inlet	1.8
Density	kg/m^3 at 15 °C	900
Flash point, min.	°C	60
Pour point	°C	6
Sulphur	mass-%	2.0
Carbon residue	mass-%	0.30
Ash	mass-%	0.01
Sediment	mass-%	0.07
Water, before engine	vol-%	0.3

The limits above correspond to the demands:

- ISO 8217:1996 (E), ISO-F-DMX, DMA and DMB
- BS MA 100:1996, DMX, DMA and DMB
- CIMAC 1990, DX, DA and DB

The fuel characteristics' limits for a specific engine may differ from the numbers above. The valid values are stated in the sales contract. If the values in the sales contract are exceeded during the warranty period, the engine warranty is not valid anymore.

02.2 Lubricating oil

02.2.1 System oil characteristics

Viscosity. Viscosity class SAE 40.
Alkalinity. Lubricants with a BN of 4 - 6 mg KOH/g must be used.
Sulphated ash level. The content of sulphated ash in gas engine lubricants is a very important property. Too high ash content can cause preignition, knocking and spark plug fouling, while too low ash content can lead to increased inlet valve wear. Low ash lubricants with sulphated ash levels of 0.3 - 0.6 w-% must be used.
Additives. The oils should contain additives that give good oxidation and nitration stability, corrosion protection, load carrying capacity, neutralisation of acidic combustion products, and should prevent deposit formation on internal engine parts.

Foaming characteristics. Fresh lubricating oil should meet the following limits for foaming tendency and stability (according to the ASTM D 892-92 test method):

- Sequence I: 100/0 ml
- Sequence II: 100/0 ml
- Sequence III: 100/0 ml

In this test a certain amount of air is blown through the lubricating oil sample. The first number in the results is the foam volume after a blowing period of 5 minutes and should be less than or equal to 100 ml. The second number is the foam volume after a settling period of 10 minutes and should always be 0 ml.

Sequences I and III are performed at a temperature of 24°C and sequence II at a temperature of 93.5°C.

02.2.2 Lubricating oil qualities

Lubricating oil is an integrated engine component and thus the quality of it is upmost important. Preliminary approved lubricating oils for Wärtsilä 32DF engine type to be used in natural gas operation are shown in the table below.

Preliminary approved system oils for Wärtsilä 32DF engines				
Manufacturer	**Brand name**	**Viscosity**	**Base Number (mg KOH/g)**	**Sulphated ash(w-%)**
Castrol	NG 304	SAE 40	5.1	0.40
Mobil	Pegasus 480	SAE 40	5.3	0.48
Shell	Mysella LA 40	SAE 40	5.2	0.45

Attention! **Before using a lubricating oil not listed in the table, the engine manufacturer must be contacted. Lubricating oils that are not approved have to be tested according to the approval procedure of the engine manufacturer.**

Note! **Never blend different oil brands unless approved by the oil supplier and during the warranty period, by the engine manufacturer.**

02.2.3 Maintenance and control of the lubricating oil

a) **Centrifuging of the system oil** is recommended in order to separate water and insolubles from the oil. Water must not be added when centrifuging ("washing"). The oil should be pre-heated to 80 - 95°C. Many oil manufacturers recommend a separation temperature of 85 - 95°C for an effective separation. Please check with the supplier of your lubricating oil what the optimal temperature is. Use the highest recommended temperature. For efficient centrifuging, use only about 20 % of the rated flow capacity of the separator. For optimum conditions the centrifuge should be capable of passing the entire oil quantity in circulation 4 - 5 times every 24 hour at 20 % of rated flow. Gravity disc should be chosen acc. to oil density at separation temperature.

Caution! **Defects on automatic, "self-cleaning" separators can quickly increase the water content of the oil under certain circumstances! (The water control valve fails.)**

b) **During the first year of operation** it is advisable to take samples of the lubricating oil at 250 operating hours intervals. The sample should be sent to the oil supplier for analysis. On the basis of the results it is possible to determine suitable intervals between oil changes. Frequent oil analysis at 500 operating hours intervals is also recommended after the first year of operation to ensure safe engine operation.

To be representative of the oil in circulation, the sample should be taken with the engine in operation at the sampling cock located immediately after the oil filter on the engine, in a clean container holding 0.75 - 1 litre. Take samples before, not after adding new oil to compensate for consumption. Before filling the container, rinse it with the 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 furnished with the sample: Installation, engine number, oil brand, engine operating hours, number of hours the oil has been in use, where in the system sample was drawn, type of fuel, any special remarks. Oil samples with no information except installation and engine number are close to valueless.

When estimating the condition of the used oil, the following properties should be observed. Compare with guidance values (type analysis) for new oil of the brand used.

Viscosity. Should not rise by more than 25 % above the guidance value at 100°C and not by more than 50% above the quidance value at 40°C. Minimum permissible viscosity is 110 cSt at 40°C and 11 cSt at 100°C.

Flash point. Should not fall by more than 50°C below the guidance value. Min. permissible flash point (open cup) 170°C. At 150°C there is a risk of crankcase explosion.

Water content. Should not exceed 0.3 vol-%. At 0.5 vol-% measures must be taken; either centrifuging or oil change.

BN (Base Number). The minimum allowable BN value of a used oil is 50 % of the nominal value of a new oil.
TAN (Total Acid Number). Should not increase by more than 2.5 mg KOH/g compared to nominal value of a new oil.
Insolubles. The quantity allowed depends on various factors. The oil supplier's recommendations should be followed. However, an n-Pentan insoluble value above 0.5 w-% calls for attention. A value higher than 1.0 w-% cannot be accepted for longer periods.
Nitration and oxidation. It is also advisable to follow nitration and oxidation levels of gas engine lubricants. Nitration and oxidation values analysed to be above 20 Abs/cm can be considered to be abnormally high.
In general it can be said that the changes in the analysis give a better basis of estimation than the absolute value. Fast and great changes may indicate abnormal operation of the engine or of a system.

c) **Compensate for oil consumption** by adding max. 10 % new oil at a time. Adding larger quantities can disturb the balance of the used oil causing, for example, precipitation of insolubles. Measure and record the quantity added. Attention to the lubricating oil consumption may give valuable information about the engine condition. A continuous increase may indicate that piston rings, pistons and cylinder liners are getting worn, and a sudden increase motivates pulling the pistons, if no other reason is found.

d) **Guidance values for oil change intervals** are influenced by system size (oil volume), operating conditions, centrifuging efficiency and total oil consumption. Efficient centrifuging and large systems (dry sump operation) generally allow for long intervals between changes.

When changing oil the following procedure is recommended:

1 **Empty oil system** while oil is still hot. Be sure that oil filters and coolers are also emptied.

2 **Clean oil spaces,** including filters and camshaft compartment. Insert new filter cartridges.

3 **Fill a small quantity of new oil** in the oil sump and circulate with the pre-lubricating pump. Drain!

4 **Fill required quantity of oil** in the system, see chapter 01, section 01.1.

Oil samples taken at regular intervals analyzed by the oil supplier, and the analysis results plotted as a function of operating hours is an efficient way of predicting oil change intervals.

Send or ask the oil supplier to send copies of oil analyses to the engine manufacturer who will then assist in the evaluation.

02.2.4 Lubricating oils for engine turning device

It is recommended to use EP-gear oils, viscosity 400-500 cSt/40°C=ISO VG 460 as lubricating oils for the turning device. Examples of lubricating oils for the engine turning device approved by the turning device manufacturer:

Manufacturer	Brand name	Viscosity (cSt)		Viscosity Index (VI)
		40°C	100°C	
BP	Energol GR-XP 460	425	27	88
Castrol	Alpha 460	460	30.5	95
Elf	Epona Z 460	470	30.3	93
Esso	Spartan EP 460	460	44.9	152
Mobil	Mobilgear 634	437	27.8	96
Shell	Omala Oil 460	460	30.8	97
Texaco	Meropa 460	460	31.6	100

02.3 Cooling water

02.3.1 General

In order to prevent corrosion, scale deposits or other deposits in closed circulating water systems, the water must be treated with additives.

Before treatment, the water must be limpid and have a hardness below 10 d°H, a chloride content of less than 80 mg/l and a pH value above 7. Further, the use of approved cooling water additives is mandatory.

Caution! Distilled water without additives absorbs carbon dioxide from the air, which involves great risk of corrosion.

Sea water will cause severe corrosion and deposit formation even if supplied to the system in small amounts.

Rain water has a high oxygen and carbon dioxide content; great risk of corrosion; unsuitable as cooling water.

If risk of frost occurs, please contact the engine manufacturer for use of anti-frost additives.

Caution! The use of glycol in the cooling water is not recommended, if it is not necessary.

02.3.2 Additives

As additives, use products from well-known and reliable suppliers with vast distribution nets. Follow thoroughly the instructions of the supplier.

Attention! The use of emulsion oils, phosphates and borates (sole) is not recommended.

The table below shows the qualities of some usual cooling water additives. Some commercially available water treatment products are also listed.

In an emergency, if compounded additives are not available, treat the cooling water with sodium nitrite ($NaNO_2$) in portions of 5 kg/m^3. To obtain a pH value of 9, add caustic soda (NaOH), if necessary.

Attention! Sodium nitrite is toxic.

02.3.3 Treatment

When changing the additive or when entering an additive into a system where untreated water has been used, the complete system must be cleaned (chemically) and rinsed before fresh treated water is poured into the system. If, against our recommendations, an emulsion oil has been used, the complete system must be absolutely cleaned of oil and greasy deposits.

Evaporated water should be compensated by untreated water; if treated water is used the content of additives may gradually become too high. To compensate for leakage or other losses, add treated water.

In connection with maintenance work calling for drainage of the water system, take care of and reuse the treated water.

Summary of the most common cooling water additives			
Additive	**Advantages**	**Disadvantages**	**Suitability**
Sodium nitrite	- good efficiency, if dosage is controlled carefully - small active quantities, 0.5 % by mass - cheap	- suitable as additive except in air cooled heat ex-changers with large soft solder surfaces - **toxic** - risk of spot corrosion when too low concentration	
Nitrite + borate	- no increased risk of corrosion at over doses - innocuous for the skin	- tendency to attack zinc coverings and soft solde-rings - **toxic:** lethal dosage 3 - 4 g solid nitrite - risk of spot corrosion when too low concentration	
Sodium chromate or potassium chromate	- good efficiency - small active quantities, 0.5 % by mass - reasonable price - simple determination of concentration (comparison of colour with test solution) - available anywhere	- increased risk of corrosion when too low concentra-tion: spot corrosion - injurious for the skin - **toxic:** lethal dosage 1 g - prohibited for use in fresh water generators intended for house-keeping purposes	- suitable as additive for purposes where the toxic effect can be tolerated. **Caution at use and thorough control are necessary**
Sodium silicate	- not toxic - harmless to handle	- not active when water velocity exceeds 2 m/s - commercial products very expensive - increased risk of corrosion when too low concen-tration; spot corrosion	- limited suitability
Sodium molybdate	- not toxic - harmless to handle	- more expensive than toxic additives - increased risk of corrosion, if insufficiently dosed - can cause deposit formation (molybdates can collect to ferrous sulphates)	
Organic and inorcanic synergistic based	- not toxic	- more expensive than sodium nitrite and molybdate based additives - big active quantitives by mass	

Approved cooling water treatment products	
Supplier	**Product designation**
BetzDearborn Europe Interleuvenlaan 25 B-3001 Heverlee Belgium	CorrShield NT 4293 (ex-Dearborn 547)
Drew Ameroid Marine Division Ashland Chemical Company One Drew Plaza Boonton, NJ 07005, USA	Drewgard 4109 Maxigard DEWT-NC powder Liquidewt Vecom CWT Diesel QC-2
Houseman Ltd The Priory, Burnham Slough SL 1 7LS, UK	Cooltreat 651
Maritech AB P.O. Box 143 S-29122 Kristianstad, Sweden	Marisol CW
Nalco Chemical Company One Nalco Centre Naperville, Illinois 60566 - 1024 USA	Nalco 39 (L) Nalcool 2000
Nalfleet Marine Chemicals P.O.Box 11 Winnington Avenue Northwich Cheshire, CW 8 4DX, UK	Nalfleet EWT 9-108 Nalfleet CWT 9-131C liquid Nalcool 2000
Rohm & Haas (ex-Duolite, Diaprosim) La Tour de Lyon 185, Rue de Bercy 75579 Paris, Cedex 12, France	RD11 RD11M RD25
S.A. Texaco Belgium N.V. Techologiepark - Zwijnaarde 2 B-9052 Ghent/ Zwijnaarde, Belgium	Havoline XLI (ex- ETX 6282)
Tampereen Prosessi-Insinöörit Keisarinviitta 22 FIN-33960 Tampere, Finland	Ruostop XM
Unitor ASA P.O. Box 300 Skøyen N-0212 Oslo, Norway	Dieselguard NB Rocor NB liquid
Vecom Holding BV PO Box 27 3140 AA Maassluis, Holland	Vecom CWT Diesel QC-2

Attention! **Ask the supplier of the treatment product for instructions about treatment procedure, dosage and concentration control.**

Most suppliers will provide a test kit for the concentration control.

02.4 Chemical cleaning of charge air cooler air side

02.4.1 General

Cleaning of the air side should be done early enough to avoid accumulations of soot and oil on the fins, which form a hard crust that is difficult to remove, as well as a deposition of other crack products that form a sulphuric acid (Compound with condensate) when left on the fins and tubes for some time.

Generally an increase of pressure drop (Δp) over the cooler with 100 mmH_2O compared to a new/clean cooler means that the cooler needs cleaning. The pressure drop should be measured at 100 % load or at least always at the same high load level.

02.4.2 Ultrasonic cleaning

Cleaning with ultrasonic equipment is recommended as it gives the best cleaning result.

02.4.3 Chemical cleaning

We recommend chemical cleaning of the air side while the cooler is removed, see section 15.5.

02.4.4 Recommended detergents

The instructions and handling guidelines provided by the manufacturer of the detergent in question should always be observed when using the chemical.

Recommended cleaning detergents	
Supplier	**Product designation**
Basol Ltd	Basol 77
Clensol Ltd	Industrial Clegris
Drew Ameroid Marine Division Ashland Chemical Company One Drew Plaza Boonton, NJ 07005, USA	Ameroid ACC9
Henkel KGaA Düselldorf	P3-Grato 90
Houseman Ltd The Priory, Burnham Slough SL 1 7LS, UK	H.D. Powder W.1.H.D.S phenol
Nalco Chemical Company One Nalco Centre Naperville, Illinois 60566 - 1024 USA	Nalfleet ACC
Vecom Holding BV PO Box 27 3140 AA Maassluis, Holland	Vecom B-85

02A. Environmental Hazards

02A.1 General

Fuel oils, lubricating oils and cooling water additives are environmentally hazardous. Take great care when handling these products or systems containing these products. Detailed information and handling instructions can be found in the text below.

02A.2 Fuel oils

Prolonged or repetitive contact with the skin may cause irritation and increase the risk of skin cancer (polyaromatic hydrocarbons, etc.). Fumes, like hydrogen sulphide or light hydrocarbons, that are irritating for eyes and respiratory organs may be released during loading/bunkering. Fuel oils are mainly non-volatile burning fluids, but may also contain volatile fractions. Risk for fire and explosion. May cause long-term harm and damages in water environments. Risk of contamination of the soil and the ground water. Take every appropriate measure to prevent water and soil contamination.

02A.2.1 Handling

- Isolate from ignition sources, like sparks from static electricity for example.
- Avoid breathing evaporated fumes (may contain hydrogen sulphide, etc.) during pumping and opening of storage tanks for example. Use gas mask if necessary.
- The handling and storage temperatures must not exceed the flash point of the product. Should be stored in tanks or containers designed for flammable fluids.
- Must not be let into the sewage system, water systems or onto the ground.
- Methane may during long-term storage be formed in tanks, due to bacterial activities. Risk of explosions during unloading or storage tank opening for example.
- Cloths, paper or any other absorbent material used to soak up spills are fire hazards. Do not allow these to accumulate.
- Waste that contains the product is hazardous and has to be disposed of according to directives issued by the local or national environmental authorities. Collection, regeneration and burning should be handled by authorized disposal plants.

02A.2.2 Personal protection equipment

- **Respiratory organs protection:** Oil mist: Use respirator, combined particle and gas filter. Evaporated fumes (hydrogen sulphide, etc.): Use respirator, inorganic gas filter.
- **Hands protection:** Strong, heat and hydrocarbon resistant gloves (nitrile rubber for example).
- **Eye protection:** Wear goggles if splash risk exists.
- **Skin and body protection:** Wear facial screen and covering clothing as required. Use safety footwear when handling barrels. Wear protecting clothes if hot product is handled.

02A.2.3 First aid measures

- **Inhalation of fumes:** Move victim to fresh air, keep warm and lying still. Give oxygen or mouth to mouth resuscitation as needed. Seek medical advice after significant exposures. Inhalation of oil mist: Seek medical advice.
- **Skin contact:** Hot oil on the skin should be cooled immediately with plenty of cold water. Wash immediately with plenty of water and soap. Do not use solvents, the oil is spread and may be absorbed into the skin. Remove contaminated clothing. Seek medical advice if irritation develops.
- **Eye contact:** Rinse immediately with plenty of water, for at least 15 minutes and seek medical advice. If possible, keep rinsing until eye specialist has been reached.
- **Ingestion:** Rinse mouth with water. Do not induce vomiting, in order not to risk aspiration into respiratory organs. Seek medical advice.

Note! **Complete safety data sheets for the specific products used at your installation should be available from the fuel oil delivering company.**

02A.3 Lubricating oils

Fresh lubricating oils normally present no particular toxic hazard, but all lubricants should always be handled with great care. Used lubricating oils may contain significant amounts of harmful metal and PAH (polyaromatic hydrocarbons) compounds. Avoid prolonged or repetitive contact with the skin. Prevent any risk of splashing and keep away from heat, ignition sources and oxidizing agents. Risk of long term contamination of the soil and the ground water. Take every appropriate measure to prevent water and soil contamination.

02A.3.1 Handling

- Ensure adequate ventilation if there is a risk of release of vapours, mists or aerosols. Do not breathe vapours, fumes or mist.
- Keep away from flammable materials and oxidants.
- Keep away from food and drinks. Do not eat, drink or smoke while handling.
- Use only containers, piping, etc. which are resistant to hydrocarbons. Open the containers in well ventilated surroundings.
- Immediately take off all contaminated clothing.
- Empty packaging may contain flammable or potentially explosive vapours.
- Cloths, paper or any other absorbent material used to recover spills are fire hazards. Do not allow these to accumulate. Keep waste products in closed containers.
- Waste that contains the product is hazardous and has to be disposed of according to directives issued by the local or national environmental authorities. Collection, regeneration and burning should be handled by authorized disposal plants.

02A.3.2 Personal protection equipment

- **Hand protection:** Impermeable and hydrocarbon resistant gloves (nitrile rubber for example).
- **Eye protection:** Wear goggles if splash risk exists.
- **Skin and body protection:** Wear facial screen and covering clothing as required. Use safety footwear when handling barrels. Wear protecting clothes if hot product is handled.

02A.3.3 First aid measures

- **Inhalation of fumes:** Move victim to fresh air, keep warm and lying still.
- **Skin contact:** Wash immediately with plenty of water and soap or cleaning agent. Do not use solvents (the oil is spread and may be absorbed into the skin). Remove contaminated clothing. Seek medical advice if irritation develops.
- **Eye contact:** Rinse immediately with plenty of water, continue for at least 15 minutes and seek medical advice.
- **Ingestion:** Do not induce vomiting, in order not to risk aspiration into respiratory organs. Seek medical advice immediately.
- **Aspiration of liquid product:** If aspiration into the lungs is suspected (during vomiting for example) seek medical advice immediately.

Note! **Complete safety data sheets for the specific products used at your installation should be available from the lubricating oil manufacturer or your local dealer.**

02A.4 Cooling water additives, nitrite based

The products are toxic if swallowed. Concentrated product may cause serious toxic symptoms, pain giddiness and headache. Significant intake results in greyish/blue discoloration of the skin and mucus membranes and a decreasing blood pressure. Skin and eye contact of the undiluted product can produce intense irritation. Diluted solutions may be moderately irritating.

02A.4.1 Handling

- Avoid contact with skin and eyes.
- Keep away from food and drinks. Do not eat, drink or smoke while handling.
- Keep in well ventilated place with access to safety shower and eye shower.
- Soak liquid spills in absorbent material and collect solids in a container. Wash floor with water as spillage may be slippery. Contact appropriate authorities in case of bigger spills.
- Bulk material can be land dumped at an appropriate site in accordance with local regulations.

02A.4.2 Personal protection equipment

- **Respiratory protection:** Not normally required. Avoid exposure to product mists.
- **Hands protection:** Rubber gloves should be worn (PVC or natural rubber for example).
- **Eye protection:** Eye goggles should be worn.
- **Skin and body protection:** Use protective clothing and take care to minimize splashing. Use safety footwear when handling barrels.

02A.4.3 First aid measures

- **Inhalation:** In the event of over exposure to spray mists move victim to fresh air, keep warm and lying still. If effects persists, seek medical advice.
- **Skin contact:** Wash immediately with plenty of water and soap. Remove contaminated clothing. If irritation persists, seek medical advice.

- **Eye contact:** Rinse immediately with plenty of clean water and seek medical advice. If possible, keep rinsing until eye specialist has been reached.
- **Ingestion:** Rinse mouth with water. Drink milk, fruit juice or water. Do not induce vomiting without medical advice. Immediately seek medical advice. Do not give anything to drink to an unconscious person.

Note! **Complete safety data sheets for the specific products used at your installation should be available from the cooling water additive manufacturer or local representative.**

02A.5 Handling of oil samples

02A.5.1 General

When taking fuel oil or lubricating oil samples the importance of proper sampling can not be over-emphasised. The accuracy of the analysis results is totally dependent on proper sampling and the results will only be as good as the submitted sample.

Use clean sample containers holding approximately 1 litre. Clean sample containers and accessories (IATA carton boxes for transportation, ready made address labels, etc.) are available for example from Wärtsilä local network office. Rinse the sampling line properly before taking the actual sample. Preferably also rinse the sample bottles with the oil a couple of times before taking the sample, especially if "unknown" sample bottles are used. Close the bottles tightly using the screw caps provided. Seal all bottles and record all the separate seal numbers carefully. Put the bottles to be sent for analysing in "Ziploc" plastic bags to prevent any spillage. Gently squeeze the Ziploc bag to minimise any air content prior to sealing.

The background information for the fuel/oil sample is as important as the sample itself. Oil samples with no background information are of very limited value. The following data are essential to note when taking the sample:

- Installation name
- Engine type and number
- Engine operating hours
- Lubricating oil brand/fuel oil type
- Lubricating oil operating hours
- Where in the system the lubricating oil/fuel oil sample was taken
- Sampling date and seal number of the separate samples if seals are available
- Reason for taking and analysing the sample
- Contact information: Name (of the person who took the sample), telephone, fax, e-mail, etc.

Use for example the ready made "Oil Analyse Application" form, see Instruction Manual attachments .
Observe personal safety precautions when taking and handling fuel oil and lubricating oil samples. Avoid breathing oil fumes and mist, use respirator if necessary. Use strong, heat and hydrocarbon resistant gloves (nitrile rubber for example). Wear eye goggles if splash risk exists. Wear facial screen and protecting clothes if hot product is handled.

02A.5.1.1 Lube oil sampling

Lubricating oil samples should be taken with the engine in operation immediately after the lubricating oil filter on the engine. Always take lubricating oil samples before adding fresh oil to the system.

02A.5.1.2 Fuel oil sampling

Fuel oil samples can be drawn from different places in the fuel oil system, "as bunkered" or "before the engine" (after fuel oil separation and filtration) are perhaps the most common sample types. From the engines point of view the most important fuel oil sample is naturally the one which enters the engine, i.e. taken after fuel oil separation and filtration. But if for example fuel oil separator efficiency needs to be checked samples should be taken just before and after the separator. It is not advisable to take samples from tank bottom drain valves, these will probably contain high levels of water and sediment and the samples will not be representative of the bulk phase.

02A.5.2 Dispatch and transportation

Place the bottle with the "Ziploc" bag inside the IATA carton box and fold the box according to the assembly instructions given on the box. Enclose a copy of the "Bunker Receipt", if available, before closing the last flap on the IATA carton.

Check the DNVPS Air Courier Directory and use appropriate label for the IATA carton box to ensure that the sample is forwarded to the nearest DNVPS laboratory. Complete the courier dispatch instructions on the side of the IATA carton. Fill in the DNVPS universal account number (950 500 010) to prevent rejection from the courier company (DHL). Complete the Proforma Invoice Form and tape it to the outside of the IATA carton.

Call the air courier directly at the number as indicated in the Air Courier Directory and request urgent pick-up. When the courier arrives you will need to complete an Airway Bill.

It is recommendable to handle the dispatching of the fuel oil and lubricating oil samples at site. The results will be achieved faster when the dispatching is handled at site and additionally it is illegal to carry fuel oil samples as personal luggage on normal aeroplanes.

Support with interpreting of the analysis results and advice on possible corrective actions is available from Wärtsilä, if needed.

03. Start, Stop and Operation

03.1 Turning of crankshaft

Turning is performed by means of an electrically driven turning device built on the engine.

03.1.1 Electrically driven turning device

The turning device consists of an electric motor which drives the turning gear through a gear drive and a worm gear. There is a control box available, including a cable, which allows the turning to be accomplished from any position near the engine. The turning speed is about 4.8 RPM.

The engaging and disengaging of the turning gear is made by the lever (1). The turning gear is spring-loaded outwards in order to prevent it from meshing with the flywheel when out of operation.

The turning device is provided with a start blocking valve which prevents starting in case the turning gear is meshing. See chapter 21, section 21.1.

For careful adjustment of the crankshaft position there is a hand wheel (2) with which it is possible to perform manual turning.

Electrically driven turning device

1. Lever
2. Hand wheel
3. Vent hole
4. Drain hole
5. Filling hole
6. Gauge glass

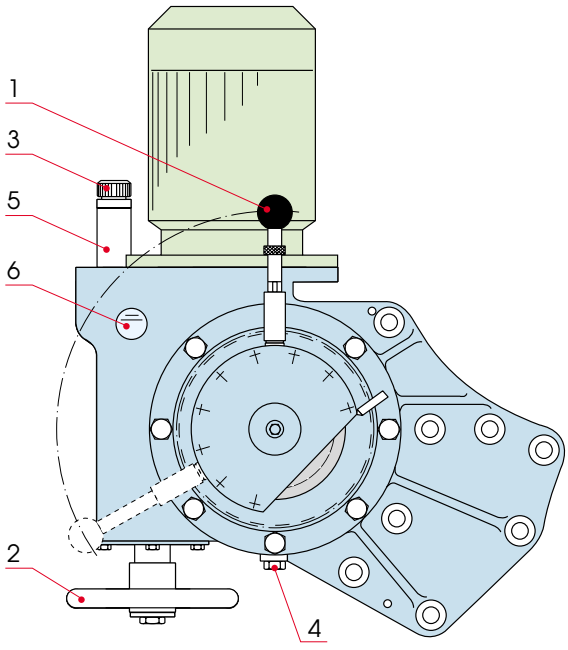


Fig 03-1 3203548935

03.2 Start

Before starting the engine, check that:

- the lubricating oil level is correct
- the fuel system is in running order (correct pressure)
- both cooling water system circuits, LT and HT water circuit, are in running order (correct pressures, circulating water pre-heated and pre-circulated sufficiently to heat the engine)
- the oil level in the governor and turbocharger(s) is correct
- the starting air pressure is 20 bar (normally, 15 bar is still sufficient to start the engine)
- the starting air system is drained of condensate
- the drain pipe of the air cooler casing is open, no leakage.

All covers and protecting shields are to be mounted before starting the engine. Covers should be removed occasionally only for measurements and checks, and they must be immediately mounted again.

Before starting the engine, ensure that possible maintenance and service operations have been finished and that all persons have left the engine room, boiler room and other risk areas.

Note! Never leave the engine running when covers are removed.

Note! Avoid running the engine in gas mode without load. Otherwise there is great risk for misfiring which conduct to unburned gas can enter the exhaust system and may cause an gas explosion in the exhaust system.

03.2.1 Manual start

Before the PLC activates a start requests the engine must be ready for start. Chapter 23., section 23.7 is a list of all the conditions that must be fulfilled to get the engine ready for start.

1 **Start the prelubricating oil pump** to obtain a lubricating oil pressure, above 0.5 bar.

2 **Open the valve in the starting air supply system** and drain condensate via the blow-off valve. Close the blow-off valve when there is no more condensate.

3 **Check that the stop lever** is in work position.

4 **Open the starting air valve,** shut the blow-off valve when there is no more condensate.

5 **Choose the mode of operation** (diesel mode/ gas mode, pilot fuel injection/ no pilot fuel injection). The pilot fuel injection should be omitted only if mono-needle type injectors are installed.

6 Push the start button. If the engine does not start after 20 s the reason should be checked.

Note! Re-start of the engine is possible after 5 minutes waiting, if it is secured that the exhaust system is vented enough. The exhaust system is equipped with automatic ventilation and it will stay open for 5 minutes after the stop. During this time the start will be blocked. The ventilation time may vary depending on the installation.

Note! Despite the safety system, there is a risk of gas explosion. To avoid possible accidents, no-one should remain in the engine room and boiler/silencer room during an engine start.

7 Check immediately after start that the pressure and temperature values are normal. **Check that all cylinders are firing, if not, the engine must be stopped and the misfiring cylinders should be checked.**

03.2.2 Remote and automatic start

See installation specific instructions.

03.3 Stop

03.3.1 Manual stop, gas mode

1 Engines with built-on cooling water pump: Idling of the engine before stopping is not possible. **Engines with separate cooling water pump:** Idling of the engine before stopping is not possible, but the water pump should run for some 5 min more.

2 Stop the engine by pushing the stop button. Normally when the stop order is given the engine starts to decrease the load automatically and when the load is near zero the engine stops. The time of slowing down offers a good opportunity to detect possible disturbing sounds.

03.3.2 Manual stop, diesel mode

1 Engines with built-on cooling water pump: Idle the engine 1 min before stopping. The pre-heating pump to be started. **Engines with separate cooling water pump:** 1 min idling will be enough, but the water pump should run for some 5 min more.

2 Stop the engine by moving the stop lever into stop position. The time of slowing down offers a good opportunity to detect possible disturbing sounds.

03.3.3 General

Caution! When overhauling the engine, make absolutely sure that the automatic start and the priming pump are disconnected. Make also sure that the starting air shut-off valve located before main starting valve is closed. Otherwise it might cause engine damage and/or personal injury.

Move stop lever into STOP position.

The lubricating oil system on a stopped engine should be filled with oil every second day by priming the engine. At the same time, turn the crankshaft into a new position. This reduces the risk of **corrosion** on journals and bearings when the engine is exposed to vibrations.

03.4 Normal operation supervision

If an alarm limit is reached and an alarm is activated, the engine situation is already serious. All necessary countermeasures must be taken to remove this emergency condition and return to normal operating conditions. As the abnormal operating situation may cause damages to the engine, all efforts must be put into returning to the normal operating situation instead of just waiting for an automatic shut down of the engine.

03.4.1 Every second day or after every 50 running hours

1 Read all temperatures and pressures and, at the same time, the load of the engine. All temperatures are more or less dependent on the load, and the lubricating oil, cooling water pressures (built-on pumps) are dependent on the speed. Therefore, always compare the values read with those at corresponding load and speed in the Acceptance Test Records and curves. **Guidance values are stated in chapter 01.**

The charge air temperature should, in principle, be as low as possible at loads higher than 60 %, however, not so low that condensation occurs, see Fig 03-2.

2 Check the indicator for pressure drop over gas and liquid fuel filters. When the pressure drop over the filters increases, the feed pressure to the engine might become too low and the output of the engine must be decreased. Too high of a pressure drop may also result in deformation of filter cartridges.

3 **Check the indicator for pressure drop** over the lubricating oil filters. Too large of a pressure drop indicates clogged filter cartridges, which results in reduced oil filtration when the by-pass valve is open. Reduced oil filtration results in increased wear. Vent filters and, if no improvement, change the cartridges.

4 **Check the oil level** in the oil sump/oil tank. Estimate the appearance and consistency of the oil. A simple control of the water content: A drop of oil on a hot surface (about 150°C), e.g. a hot-plate. If the drop keeps “quiet”, it does not contain water; if it “frizzles” it contains water. Compensate for oil consumption by adding max. 10 % fresh oil at a time.

5 **Check the ventilation** (de-aerating) of the engine cooling water system. Check that the leakage from the telltale hole of the cooling water pumps are normal (slight).

6 **Check that the drain pipes** of the air coolers are open.

7 **Check that the telltale holes** of the oil coolers and the cooling water coolers are open.

8 **Clean the compressor side** of the turbocharger by injecting water. See the instruction manual of the turbocharger.

9 **Running in diesel mode** with no pilot fuel injection, check the quantity of leak fuel.

Condensation in charge air coolers

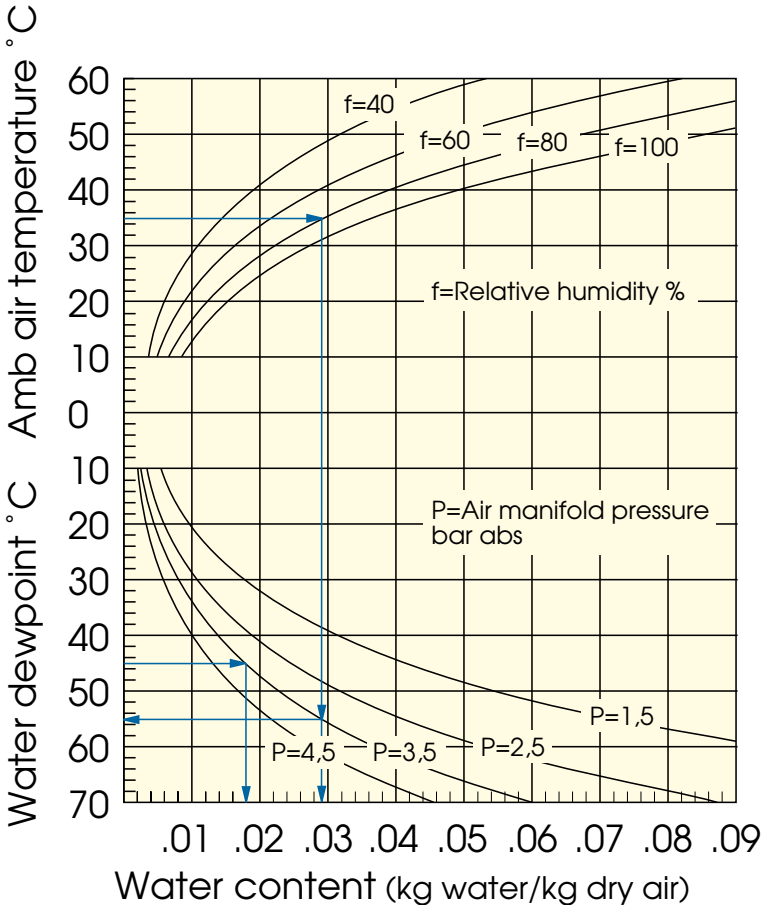


Fig 03-2 3203528930

Example: *If the ambient air temperature is 35°C and the relative humidity is 80 % the water content in the air can be read from the diagram (0.029 kg water / kg dry air). If the air manifold pressure (receiver pressure) under these conditions is 2.5 bar, i.e. absolute air pressure in the air manifold is abt. 3.5 bar (ambient pressure + air manifold pressure), the dew point will be 55°C (from diag.). If the air temperature in the air manifold is only 45°C, the air can only contain 0.018 kg / kg (from diag.). The difference, 0.011 kg / kg (0.029-0.018) will appear as condensed water.*

03.4.2 Once a month or after every 500 running hours

1. **Clean the centrifugal lubricating oil filters.**
2. **Check content of additives** in the circulating water.
3. **Keep the injection pump racks clean.**
4. **Clean the turbine side of the turbocharger.**

03.4.3 In connection with maintenance work

1 Record the following steps and the running hours in the engine log:

- lubricating oil sampling (record also operating time of oil). Lubricating oil analyses without statement of operating time is of limited value ("go - no go" only)
- lubricating oil changes
- cleaning of centrifugal lubricating oil filters
- change of lubricating and fuel oil filter cartridges
- change of parts in connection with maintenance according to chapter 04.

03.4.4 General

1 There is no automatic supervision or control arrangement that can replace an experienced engineer's observations. **LOOK at and LISTEN to the engine!**

2 Strong gas blow-by past the pistons is one of the most dangerous things that can occur in an engine. If gas blow-by is suspected, check the crankcase pressure. If the pressure exceeds 30 mm H_2O, check the crankcase venting system, if in order, pull the pistons!

03.5 Start after a prolonged stop (more than 8 h)

03.5.1 Manual start

1 Check

- the lubricating oil level
- the cooling water level in the expansion tank
- the raw water supply to heat exchangers
- the fuel oil level in the day tank (troublesome and time consuming job to vent the fuel system if the feed pump has sucked air!)
- the starting air pressure — 20 bar
- that the parts of the fuel control shaft system and the injection pump racks move freely. Otherwise **risk of overspeed.**

2 Observe all points in section 03.2.1.

3 Vent lubricating oil filters.

03.6 Start after overhaul

1 Check that the connection between the speed governor, over-speed trip and injection pumps is set correctly (especially the injection pump rack position) and does not jam, that all connections are properly locked and the injection pump racks move freely in the pumps.

2 Check gas system for leakage.

3 Check the cooling water system for leakage, especially:

- the lower part of the cylinder liners
- the oil cooler
- the charge air cooler

4 The speed governor control lever being in max. position and the stop lever in work position. Check that all injection pump racks move to a value less than 5 mm.

5 If the injection pumps, camshaft or its driving mechanism have been touched, check the injection timing.

6 Check/adjust the valve clearances. If the camshaft or its driving mechanism have been touched, check the valve timing of one cylinder, at least (on each cylinder bank in a V-engine). Guidance values, see chapter 06.

7 Vent the fuel oil system if it was opened.

8 Start the priming pump. Vent the lubricating oil filters. Check that lubricating oil appears from all bearings and lubricating nozzles, from the piston cooling oil outlet and from the valve mechanism. Check that there is no leakage from the pipe connections inside or outside the engine.

Note! Observe that the crankshaft has to be turned in order to get oil through all connecting rods.

9 Rags or tools left in the crankcase, untensioned or unlocked screws or nuts (those which are to be locked), worn-out self-locking nuts, **may cause** total breakdown.

Well cleaned oil spaces (oil sump and camshaft spaces) save the oil pump and oil filter.

10 See the instructions in section 03.2 and 03.5 when starting.

03.7 Operation supervision after overhaul

1 At the first start, listen carefully for possible jarring sounds. If anything is suspected, stop the engine immediately, otherwise stop the engine after 1 minutes idling at normal speed. Check at least the temperatures of the main and big end bearing and of all other bearings which have been opened. If everything is in order, restart.

2 Check that there is no leakage of gas, water or lubricating oil. Especially observe the fuel lines and gas valves.

3 After overhauling, the following instructions are especially important:

- Check pressures and temperatures
- Check the automatic alarm and stop devices
- Check the pressure drop over the fuel filter and lubricating oil filter
- Check the oil level in the oil sump/oil tank. Estimate the condition of the oil
- Check the ventilation (de-aerating) of the engine cooling water system
- Check the quantity of leak fuel in diesel mode, pilot pump switched off
- Check the telltale holes of the coolers
- Check the content of additives in the cooling water
- Listen for jarring sounds
- Check the crankcase pressure
- Check the starting air pipes
- Vent the filters.

03.8 Running-in

The running-in of a new engine must be performed according to programme in Fig 03-3. It is also recommended that running-in procedure is performed after following maintenance jobs.

1 After changing piston rings, pistons or cylinder liners, after honing of cylinder liners, follow programme in Fig 03-3 as closely as possible. If the programme cannot be followed, **do not load the engine fully for at least 10 h.**

Avoid "running-in" at continuous and constant low load!

The important thing is to vary the load several times. The ring groove will have a different tilting angle at each load stage, and consequently the piston ring a different contact line to the cylinder liner.

Running-in programme

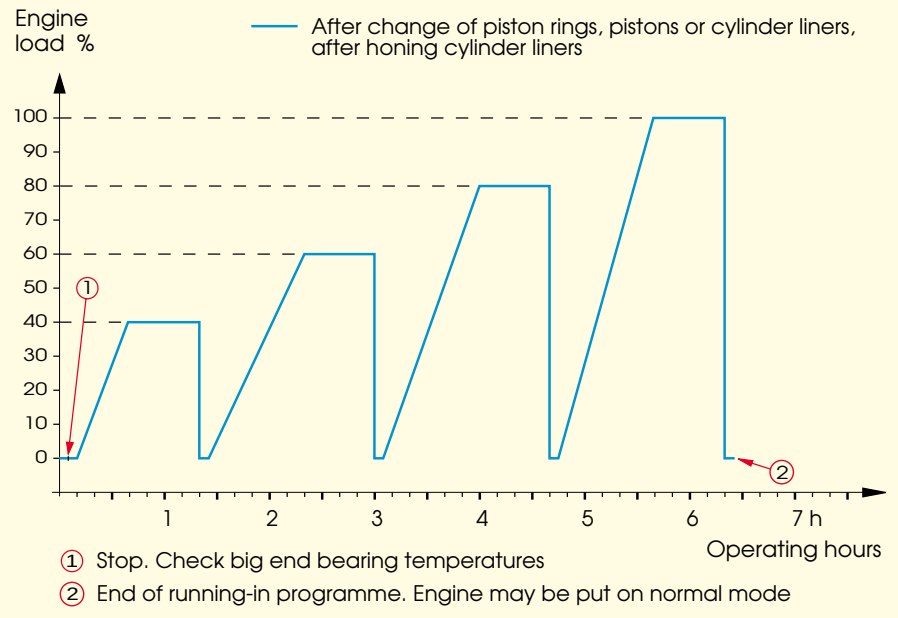


Fig 03-3 3203569701

03.9 Maintenance of turning device

The turning device needs no other maintenance than change of the gear box lubricating oil once during the first year of operation. Approved lubricating oils, see section 02.2.6. After that, the oil should be changed according to chapter 04. Check also that the vent hole (3), Fig 03-1 is open.

1 **Drain old oil,** preferably when warm, through the drain hole (4).

2 **Rinse the gear box** with clean, thinly fluid oil.

3 **Fill the gear box with oil** (according to the table in section 02.2.6) through the filling hole (5) until the oil level reaches the level gauge glass (6). Utmost cleanliness should be observed.

4 **Close the oil holes** and drive the turning device a few revolutions.

5 **Check the oil level** and fill, if necessary.

04. Maintenance Schedule

04.1 General

The maintenance necessary for the engine depends on the operating conditions in the main. The periods stated in this schedule are guidance values only, but must not be exceeded during the guarantee period. It may be possible to lengthen the stated maintenance intervals considerably depending on the engine load. See also the instruction books of the turbocharger separate instructions for additional equipment and chapter 03.

1 **Before any steps are taken,** carefully read the corresponding item in this Manual.

2 **Note the Environmental Hazards** in chapter 02A.

3 **At all maintenance work,** observe the utmost cleanliness and order.

4 **Before dismantling,** check that all systems concerned are **drained or the pressure released**. After dismantling, immediately cover holes for lubricating oil, gas and air with tape, plugs, clean cloth or the like.

5 **When exchanging a worn-out or damaged part** provided with an identification mark stating cylinder or bearing number, mark the new part with the same number on the same spot. Every exchange should be entered in the engine log and the reason should be clearly stated.

6 **Always renew all gaskets, sealing rings and O-rings** at maintenance work.

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

Caution! **When overhauling the engine, make absolutely sure that the automatic start and the priming pump are disconnected. Make also sure that the starting air shut-off valve located before main starting valve is closed. Otherwise it might cause engine damage and/or personal injury.**

04.2	Every second day, irrespective of the engine being in operation or not	
Automatic prelubrication	**Check operation**	03.2 18.9

04.3	Once a week irrespective of the engine being in operation or not	
Start process	**Test start (if the engine on stand-by).**	03.2

04.4	Interval: 50 operating hours	
Air coolers	**Check draining of air coolers** Check that the draining pipes are open, check if any leakage.	15.9 03.4.1
Automation	**Check operating values** Check and record all operating values.	03.4.1
Cooling water system	**Check water level in cooling system** Check the water level in the expansion tank(s) and/or the static pressure in the engine cooling circuits.	19.1.4
Connecting rod	**Check tightening of the connecting rod screws** Check the tightening of the connecting rod screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. **Note!** Pump to stated pressure. Tighten if possible. **Do not loosen!**	11.3.4 07.3
Gas, fuel and lub. oil filters	**Check pressure drop indicators** Replace filter cartridges if high pressure drop is indicated.	03.4.1 17.2 18.7
Governor, actuator	**Check oil level in governor** Check oil level, and look for leaks	02.2.4 22.4.1
Lubricating oil sump	**Check oil level in sump** Check oil level by means of dip stick, compensate for consumption.	18.2 02.2
Main bearings	**Check tightening of main bearing screws** Check the tightening of main bearing screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. **Note!** Pump to stated pressure. Tighten if possible. **Do not loosen!**	10.2.3 07.3
Turbocharger	**Water cleaning of compressor** Clean the compressor by injecting water.	15.3.3
Valve mechanism	**Check valve clearances** Check the valve clearances after 50 hours' running in new and overhauled engines.	12.2.4 06.1

04.5	Interval: 100 operating hours	
Turbocharger	**Water cleaning of turbine** Clean the turbine by injecting water; more often if necessary.	15.3.2

04.6	Interval: 500 operating hours	
Cooling water	**Check water quality** Check content of additives.	19.2 02.3
Control mechanism	**Maintenance of control mechanism** Check for free movement, clean and lubricate.	22.2
Injection and fuel system	**Check clean leak fuel quantity in diesel mode** Check the amount of clean leak fuel from the injection pumps and nozzles running in diesel mode and pilot injection temporary switched off.	03.4.1
Lubricating oil	**Take oil sample** In a new installation or after change to use of a new lubricating oil brand, take samples for analyzing.	02.2.3

04.7	Interval: 1000 operating hours	
Air filter (on-built)	**Clean turbocharger air filter** Remove the filter(s) and clean according to instructions of the manufacturer (more often, if necessary).	15.2
Centrifugal filter	**Clean centrifugal filter(s)** Clean more often if necessary. Remember to open the valve before the filter after cleaning.	18.8.2
Electrical fuel feed pump	**Regrease el. fuel feed pump** Regrease the pump under running condition.	17.9
El. lubricating oil pump	**Regrease prelubricating pump** Regrease the pump under running condition.	18.9
Flexible coupling Geislinger (Oil filled)	**Oil change/check of the coupling** At first interval, change oil of the coupling. Following (1000h) intervals, check oil level. See manufacturers instructions.	
Fuel filter	**Replace fuel oil filter cartridges** Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced earlier if the pressure difference indicator shows too high pressure drop).	17.10.2 17.5 17.6
Fuel system	**Replace pilot fuel oil filter cartridges** Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced earlier if the pressure difference indicator shows too high pressure drop).	17.10.2 17.5 17.6
Gas filter Engine mounted On gas regulating unit	**Replace gas filter cartridges** Clean the filter housing. The engine mounted filter cartridge can be cleaned by pressurized air from inside, replace cartridge if necessary. Gas regulating unit, replace the filter cartridge. Following intervals for both filters 4000 hours.	 17.1 17.2
Valves	**Check valve condition** Check that the inlet and exhaust valves move freely in their guides. This should preferably be done when the engine has been out of operation for a couple of hours. Check valve clearances.	12.4 06.1

04.8	Interval: 2000 operating hours	
Air cooler(s)	**Check water side of charge air cooler(s)** The first time check and possible cleaning of the **waterside.** If in good condition and deposits insignificant: future intervals 4000 running hours.	15.9
El.-pneu. overspeed trip device	**Check el.-pneumatic overspeed trip device** Check function and tripping speed in diesel mode.	22.6.3 06.1
Gas system	**Maintenance of gas system** Make the leak test.	 17.3
Governor	**Change oil in governor** Change lubricating oil.	02.2.4 22.4.1
Lubricating oil filter	**Replace lub. oil filter cartridges** Drain the filter housings. Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced earlier if the pressure difference indicator shows too high pressure drop.)	18.7.2 18.2
Lubricating oil	**Change lubricating oil** Change oil in a new installation (wet sump installations). Take samples for analyzing. If the analyzing values are positive and if the oil supplier or engine manufacturer so recommend, the intervals between changes can be based on regular analyzing. In wet sump installations the oil change intervals may be in the order of 6000 hours or more. Clean all oil spaces when changing lub. oil.	18.2 02.2
Pilot fuel pump	**Regrease pilot fuel pump coupling** Add new grease in the coupling.	16.5.1 16.5.2

04.9	Interval: 4000 operating hours	
Air cooler(s)	**Clean the charge air cooler(s)** Clean and pressure test. Look carefully for corrosion. Measure the pressure difference over the charge air cooler before and after cleaning. Use U-gauge.	15.9
Automation	**Check connectors and cables** Check mounting and connections. Apply contact lubricant to contact surfaces. Check tightness of connections. Check condition of cables, wires and cable glands. Replace damaged connectors and cables.	23.14 23.15
Camshaft	**Inspect contact faces of camshaft** Check the contact faces of the cams and tappet rollers. Check that the rollers rotate. Rotate the engine with the turning gear.	14.1.3 03.1
Control mechanism	**Check control mechanism** Check for wear in all connecting links between the governor and all injection pumps.	22.2
Crankshaft	**Check crankshaft alignment** Check alignment, use form No. WV98V036. Alignment check is performed on a warm engine.	11.2.2
Crankshaft	**Check thrust bearing clearance** Check axial clearance.	11.2.3 06.2

Continue

Cooling water spaces	**Inspect jacket water spaces on engine with cooled turbocharger** Inspect turbocharger cooling water ducts for possible deposits. If the deposits are 1mm or thicker, inspect the water side of one cylinder liner through the plug in the engine block. If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.2 19.2 19.1.2 02.3 10.5
	Inspect jacket water spaces on engine with uncooled turbocharger Inspect the water side of one cylinder through the plug in the engine block. If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.2 19.2 19.1.2 02.3 10.5
Flexible coupling Geislinger (Oil filled)	**Oil change of the coupling** Change oil of the coupling. See manufacturers instructions.	
Gas filter Engine mounted On gas regulating unit	**Replace gas filter cartridges** Clean the filter housing. Replace the engine mounted filter cartridge. Gas regulating unit, replace the filter cartridges.	17.1 17.2
Injection valves	**Replace injection valves** **Recommendation:** Replace the complete fuel injection valves after 6000 h at the latest.	16.6
Starting air system	**Clean the starting air filter** Clean the filter and replace sealing's.	
Valves and piston rings	**Check cylinder tightness** Check cylinder tightness (valves, piston rings) with a pneumatic test.	12.A
Wastegate	**Check the wastegate valve and actuator** Change the positioner pilot valve.	

04.10	Interval: 8000 operating hours	
Automation	**Functional check of safety system** Check function of the alarm and automatic stop devices including electronic overspeed trip device.	23.7 01.2 06.1
Exhaust manifold	**Check for leaks** Replace parts if necessary.	20.
Fuel system	**Check and adjustment of fuel system**	17.8
Gas regulating unit	**Overhaul of gas pressure regulating and safety shut-off valves** See manufacturers instructions.	
Governor driving gear	**Inspect governor driving gear** Replace parts if necessary.	22.4.2 06.2

Continue

Lube oil coolers	**Clean the lube oil cooler** If the lube oil temperature before the engine is within normal operating values (Section 01.1), the interval can be prolonged. Unnecessary opening of the plate cooler should be avoided. Clean the lube oil cooler before the alarm limit is reached. Examine carefully for corrosion.	18.5 19.2
Pilot fuel pump	**Change grease in the pilot fuel pump coupling** Change grease and check the clearance.	16.5.1 16.5.2
Starting motors	**Check the starting motors** Check the starting motors gear wheels and flywheel gear rim. Check oil level, and look for leaks.	 21.2

04.11	Interval: 12000 operating hours
HT-water pump	**Inspect HT-water pump** Dismantle and check. Replace worn parts.
HT-water pump driving gear	**Inspect HT-water pump driving gear** Replace parts if necessary.
HT-water thermostatic valve	**Clean and inspect HT-water thermostatic valve** Clean and check the thermostatic element, valve cone-casing and sealing's.
LT-water pump	**Inspect LT-water pump** Dismantle and check. Replace worn parts.
LT-water pump driving gear	**Inspect LT-water pump driving gear** Replace parts if necessary.
LT-water thermostatic valve	**Clean and inspect LT-water thermostatic valve** Clean and check the thermostatic element, valve cone-casing and sealing's.
Lube oil pump	**Inspect the lube oil pump** Replace parts if necessary.
Lube oil pump driving gear	**Inspect lube oil pump driving gear** Replace parts if necessary.
Oil thermostatic valve	**Clean and inspect oil thermostatic valve** Clean and check the thermostatic element, valve cone-casing and sealing's.
Turbocharger Napier Na-chargers	**Inspect turbocharger bearings** Check and change if necessary. See manufacturers instructions.
Turbocharger ABB TPL-chargers	**Inspect turbocharger bearings** Check and change if necessary. See manufacturers instructions.

04.12	Interval: 16000 operating hours	
Camshaft	**Inspect camshaft bearings** Replace if necessary.	10.4.1 06.2
Camshaft driving gear	**Inspect intermediate gears** Replace parts if necessary.	13.1 06.2
Connecting rods	**Replace big end bearing** Replace big end bearing. Inspect mating surfaces. Measure the big end bore, use form No. 3211V012.	11.3.3 06.2
Connecting rods	**Inspect the small end bearings** Inspect the small end bearings. Replace if necessary.	 11.3.3 06.2
Crankshaft	**Inspect main bearings** Inspect one main bearing. If in bad condition, check/change all main bearings. Note the type of bearing in use and do the inspection accordingly.	10.2.2 06.2
Cylinder heads	**Overhaul of cylinder head** Dismantle and clean the under side, inlet and exhaust valves and ports. Inspect cooling spaces and clean, if necessary. Grind the valves. Inspect the valve rotators. Check rocker arms. Replace the O-rings in the valve guides and on the exhaust valve seat rings. Replace the O-rings at bottom of cylinder head screws at every overhaul. Replace the knocking sensors by new ones.	12.2.3 12.2 12.3 14.1.3
Cylinder liners	**Inspect the cylinder liners** Measure the bore using form No. 3210V020, replace liner if wear limits are exceeded. **Hone the liners.** Inspect anti-polishing ring. Turn the ring upside down after first period. Change the ring every second period.	10.5.1 06.2
Cylinder liners	**Inspect cylinder liner water side** Pull all cylinder liners. If the deposits are thicker than 1 mm, clean all liners and the engine block water space. Replace the O-rings in the bottom part by new ones at every overhaul.	19.2 10.5
Flexible coupling (Oil filled)	**Check the flexible coupling** Dismantle and check flexible coupling acc. to manufacturers recommendations.	
Fuel feed pump	**General overhaul of fuel feed pump** Inspect pump and replace gaskets. Replace worn parts.	17.9
Gas admission valves Woodward	**Replace the main gas admission valves** Replace also the female connector	17.4 17.5
Gas system	**Maintenance of gas system** Replace sealing's in pipe connections, check sealing faces for wear and corrosion. Make the leak test.	 17.3
Governor drive	**Check governor drive bearing** Check governor driving shaft bearing clearance in situ.	22.4.2 06.2
Governor	**General overhaul of the governor** Can be sent to engine manufacturer for overhaul.	

Continue

Booster servomotor for governor	**General overhaul of the booster servomotor** Replace worn parts. See manufacturers instructions.	
Hydraulic jack	**Check function** Replace O-rings in the hydraulic jack if they are leaking when lifting the main bearing cap.	10.2.1
Pilot fuel pump	**Replace pilot fuel pump** Replace the pilot fuel pump.	
Pistons	**Inspect the pistons** Composite pistons must be dismantled for inspection of mating surfaces between piston skirt and piston crown. Inspect and clean oil spaces.	
Pistons, piston rings	**Inspect pistons and replace piston rings** Pull, inspect and clean. Check the height of the ring grooves, use form No. 3211V021. Check the retainer rings of the gudgeon pins. Replace complete set of piston rings. Note the running-in programme.	11.3.3 11.3 06.2 03.8
Turning device	**Change oil in turning device** Regrease the drive shaft.	02.2.6 03.9
Valve mechanism	**Check valve mechanism parts** Check tappets.	14.1.3 06.2
Vibration damper Viscous type	**Take oil sample from vibration damper** Take oil sample for analyzing.	11.2.1

04.13	Interval: 24000 operating hours	
Engine fastening bolts	**Check tightening of engine fastening bolts** Replace if necessary.	07.3
Exhaust manifold	**Check expansion bellows** Replace if necessary.	20.2
Flexible coupling (Oil supply from engine)	**Check the flexible coupling** Dismantle and check flexible coupling acc. to manufacturers recommendations.	
Injection pumps	**Overhaul of injection pumps** Clean and inspect injection pumps, replace worn parts. Replace the erosion plug.	16.3.4
Turbocharger	**Replace turbocharger bearings** Replace turbocharger bearings. See manufacturers instructions.	15.2

04.14	Interval: 32000 operating hours	
Connecting rods	**Replace connecting rod screws** Replace connecting rod screws at latest 32 000 h with new ones.	11.3.3 06.2
Turbocharger Napier	**Check rotor balance** Check rotor balance every 32 000 hours or every 4 years. See manufacturers instructions.	15.2 15.5

04.15	Interval: 48000 operating hours	
Camshaft driving gear	**Inspect intermediate gear bearings** Replace parts if necessary.	13.1 06.2
Crankshaft	**Inspect crankshaft** Inspect the crankshaft for wear.	 06.2
Engine foundation Flexible mounted	**Check flexible elements of engine foundation** Replace if necessary.	
Flexible coupling	**Check the flexible coupling** Dismantle and check flexible coupling according to manufacturers instructions. Replace spring packs/inner star if necessary.	
Turbocharger	**Replace rotor** Lifetime dependent of operating conditions. See manufacturers instructions.	15.2

05.Maintenance Tools

05.1 General

Maintenance of a engine requires some special tools developed in the course of engine design. Some of these tools are supplied with the engine, and others are available through our service stations or for direct purchase by the customer.

Tool requirements for a particular installation may vary greatly, depending on the use and service area. Standard tool sets are therefore selected to meet basic requirements.

This list presents a comprehensive selection of tools for the Wärtsilä Vasa 32 engine family.

Tool sets are grouped in order to facilitate selection for specific service operations. This makes the job of the end-user much easier.

05.1.1.Use of this list

1 **Read the corresponding item** in this Instruction Book before any maintenance work is started.

2 **Check with list** below that all the maintenance tools are available.

3 **Check** that necessary spare parts and consumable parts are available.

05.1.2.Ordering of Maintenance tools

1 **Find the part(s)** that interests you in the following pages.

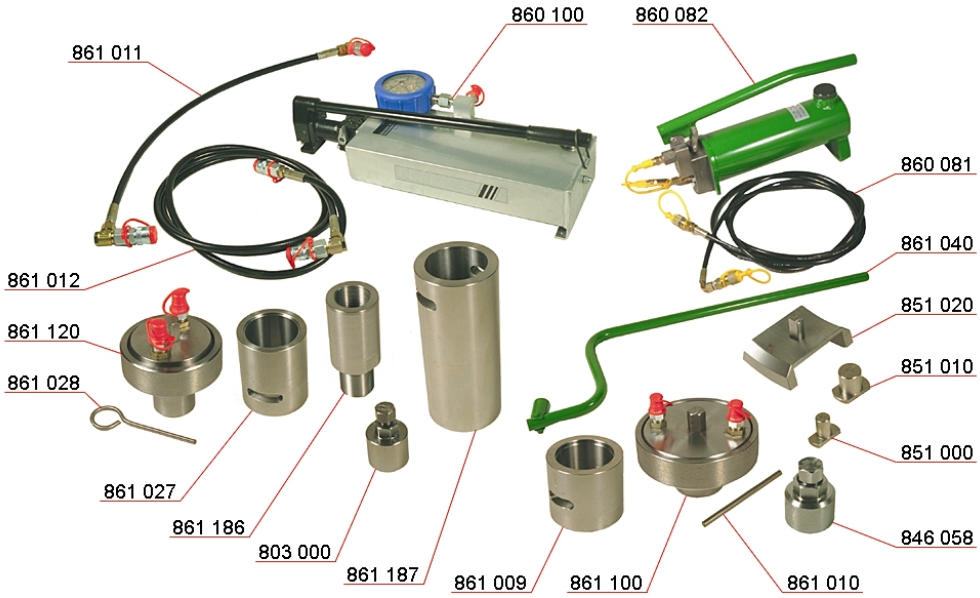
2 **Select the tools or parts required,** note that tools which are part of standard deliveries are mentioned in the installation specific delivery lists. You can use the code number in the following page when ordering.

3 **Make a note of the specifications** and other information as stated in the “Inquiry/Order List”.

4 **Send the order** to your local service station printed on the Inquiry/Order List. All commercial terms are stated in the Inquiry/Order List. When possible, state installation name and engine number(s) when ordering.

Note! **This chapter includes all available tools for above mentioned engine types. See also the installation specific tool lists. Some of the tools are applicable for certain cylinder numbers and with certain engine mounted equipment.**

Main Bearings 100

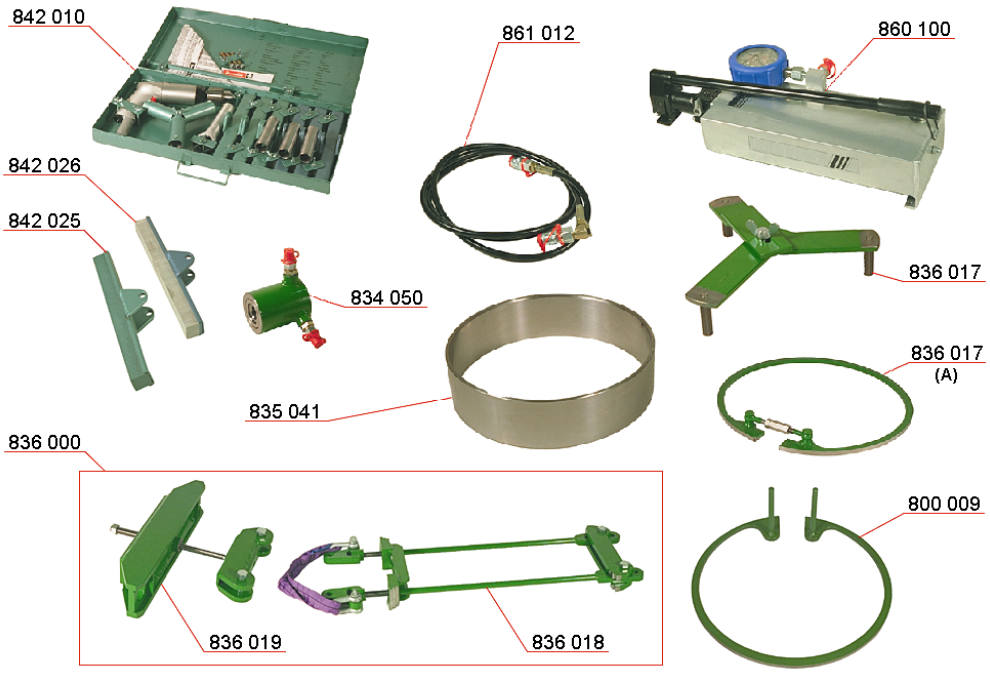


Code	Description	Drawing No.
803000	Stud remover M42	4V80D0012
846058	Stud remover M56	3V84G0189
851000	Turning tool for main bearing shell	4V85B0023
851010	Turning tool for main bearing shell	4V85B0016
851020	Turning tool for thrust washers & bearing shell	3V85B0015
860081	Flexible hose 3000 mm, (low p. pump) **(1)**	
860082	Low pressure pump (150 bar) **(1)**	1V86A0018
860100	High pressure pump (1000 bar) **(1)**	4V86A0033
861009	Distance sleeve M56	3V86B0039
861010	Pin for tightening of nuts M56	4V86B0002
861011	Flexible hose 800 mm **(1)**	
861012	Flexible hose 3000 mm **(1)**	
861027	Distance sleeve M42	3V86B0046
861028	Pin for tightening of nuts M42	4V86B0011
861040	Lifting tool for hydraulic cylinders M56	3V86B0052
861100	Hydraulic cylinder M56 **(1)**	3V86B0079
861120	Hydraulic cylinder M42 **(1)**	3V86B0078
861186	Extension piece M42 for main bearing side screws **(2)**	4V86B0133
861187	Extension piece M42 for main bearing side screws **(2)**	3V86B0134

(1) Including quick couplings

(2) Only for flexible mounted engines equipped with rubber cushions in V-configuration.

Cylinder Liner 100



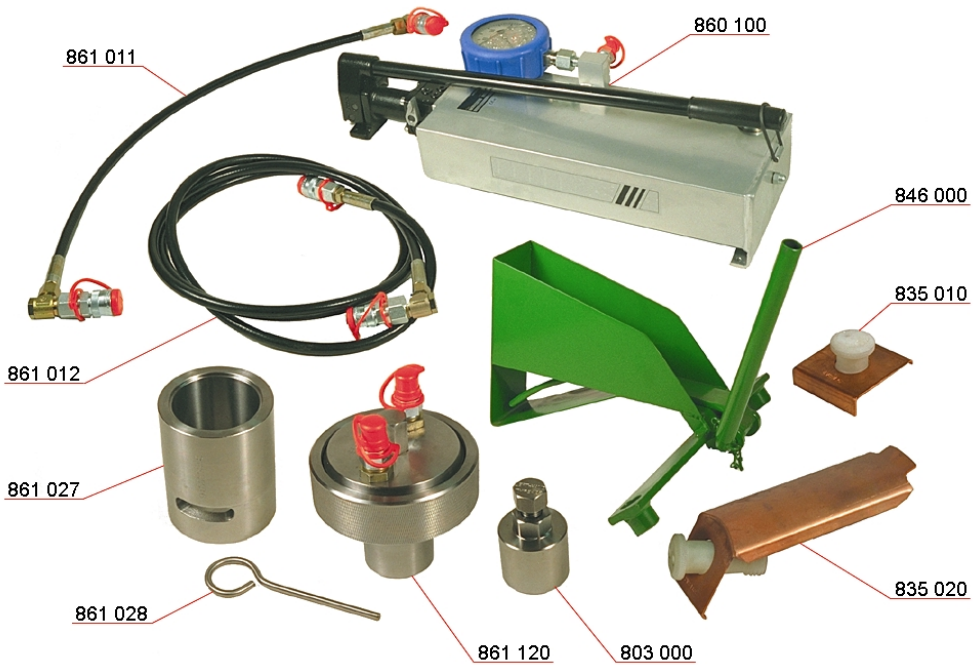
Code	Description	Drawing No.
800009	Dismantling tool for antipolishing ring **(1)**	2V83G0077
834050	Hydraulic extractor	3V83E0061
835041	Assembly tool for antipolishing ring	3V83F0105
836000	Suspending & removing tool, complete	
836017	Dismantling tool for antipolishing ring **(2)**	3V83G0073
836018	Lifting tool	3V83G0078
836019	Extractor **(3)**	
842010	Honing equipment	2V84C0031
842025	Honing stones 25x25x250, including holder, coarse	
842026	Honing stones 25x25x250, including holder, fine	
860100	High pressure pump (1000 bar) **(3)**	4V86A0033
861012	Flexible hose 3000 mm **(3)**	

(1) Only for 32 DF

(2) Code 836017 marked with A only for 34 SG

(3) Including quick couplings

Connecting Rod, O-Profile 110



Code	Description	Drawing No.
803000	Stud remover M42	4V80D0012
835010	Protecting sleeve for connecting rod tooth **(1)**	4V83F0062
835020	Protecting sleeve for connecting rod tooth **(1)**	2V83F0063
846000	Lifting tool for big end bearing cap **(1)**	1V84G0191
860100	High pressure pump (1000 bar) **(2)**	4V86A0033
861011	Flexible hose 800 mm **(2)**	
861012	Flexible hose 3000 mm **(2)**	
861027	Distance sleeve M42	3V86B0046
861028	Pin for tightening of nuts M42	4V86B0011
861120	Hydraulic cylinder M42 **(2)**	3V86B0078

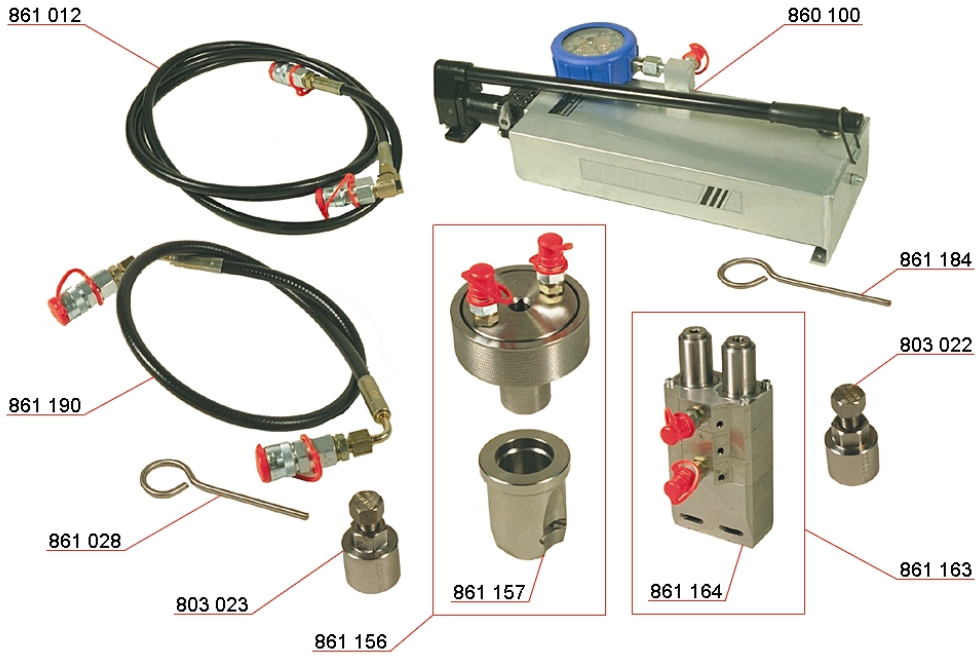
(1) Only needed for V-engine
(2) Including quick couplings

Connecting Rod, H-Profile 110

Code	Description	Drawing No.
803005	Stud remover M45x3	3V80D0020
835010	Protecting sleeve for connecting rod tooth **(1)**	3V83F0082
835020	Protecting sleeve for connecting rod tooth **(1)**	2V83F0083
835030	Mounting screw M45x3	3V83F0084
835040	Locking nut for mounting screw	4V83F0085
846000	Lifting tool for big end bearing cap **(1)**	1V84G236
860100	High pressure pump (1000 bar) **(2)**	4V86A0033
861011	Flexible hose 800 mm **(2)**	
861012	Flexible hose 3000 mm **(2)**	
861028	Pin for tightening of nuts M45	4V86B0011
861039	Distance sleeve M45x3, long **(3)**	3V86B0102
861039	Distance sleeve M45x3, short **(1)**	3V86B0136
861130	Hydraulic cylinder M45x3 **(2)**	3V86B0139
861141	Extension piece **(3)**	3V86B0137

(1) Only needed for V-engine
(2) Including quick couplings
(3) Only for In-line engine

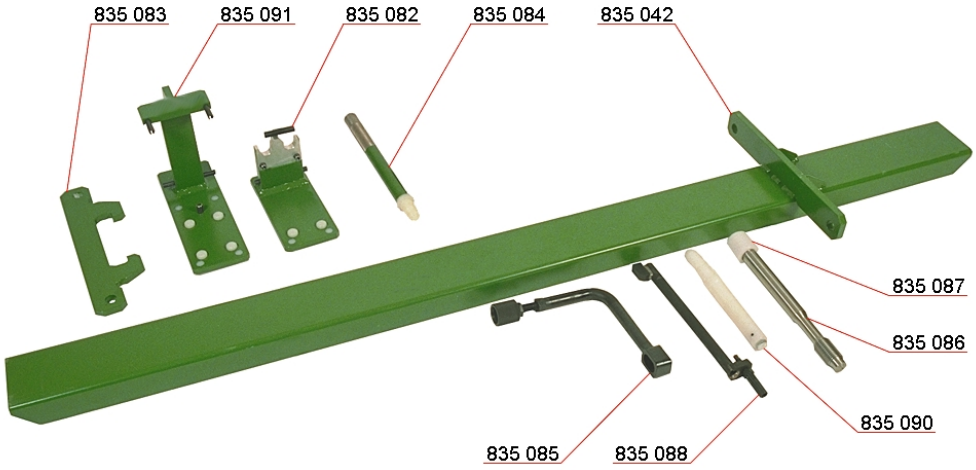
Connection Rod, Marine Head 110



Code	Description	Drawing No.
803022	Stud remover M30	4V86G0026
803023	Stud remover M24	4V80D0030
860100	High pressure pump (1000 bar) **(1)**	4V86A0033
861012	Flexible hose 3000 mm **(1)**	
861028	Pin for tightening of nuts M30	4V86B0011
861156	Hydraulic tool M30 **(1)**	3V86B0186
861157	Distance sleeve M30	2V86B0187
861163	Hydraulic tools M24 **(1)**	2V86B0201
861164	Distance piece M24	2V86B0204
861184	Pin for tightening of nuts M24	4V86B0034
861190	Flexible hose 1100 mm **(1)**	

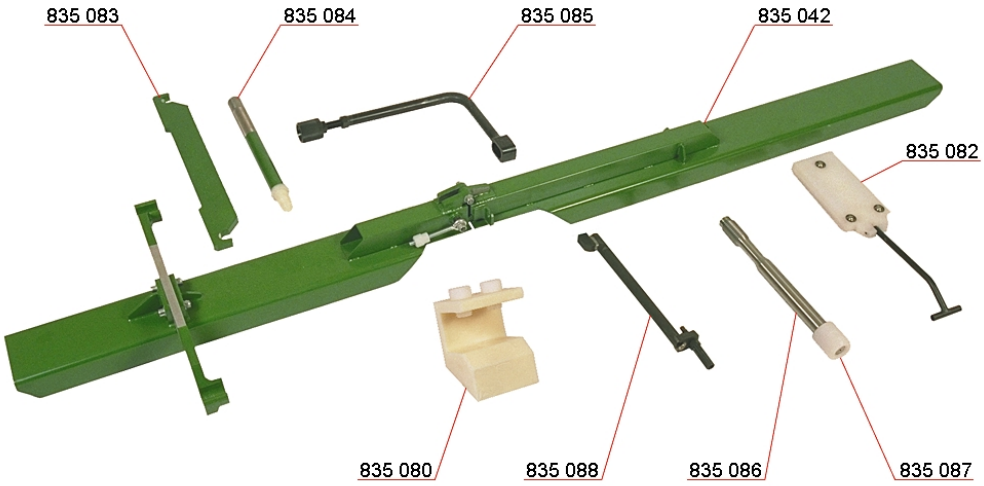
(1) Including quick couplings

Connection Rod, Marine Head, R-eng. 110



Code	Description	Drawing No.
835042	Assembly rail	1V83F0215
835082	Sledge	2V83F0212
835083	Support	2V83F0214
835084	Support arm	3V83F0163
835085	Support arm	3V83F0217
835086	Mounting screw M30	3V83F0180
835087	Protecting cap for screw M30	4V83B0269
835088	Limiter for piston	3V83F0178
835090	Fastening arm	3V83F0211
835091	Sledge	1V83F0213

Connection Rod, Marine Head, V-eng. 110



Code	Description	Drawing No.
835042	Assembly rail	2V83F0171
835080	Protecting cover **(1)**	3V11T0718
835082	Sledge	2V83F0165
835083	Support	3V83F0166
835084	Support arm	3V83F0163
835085	Support arm	3V83F0177
835086	Mounting screw M30	3V83F0180
835087	Protecting cap for screw M30	4V86B0269
835088	Limiter for piston **(1)**	3V83F0178

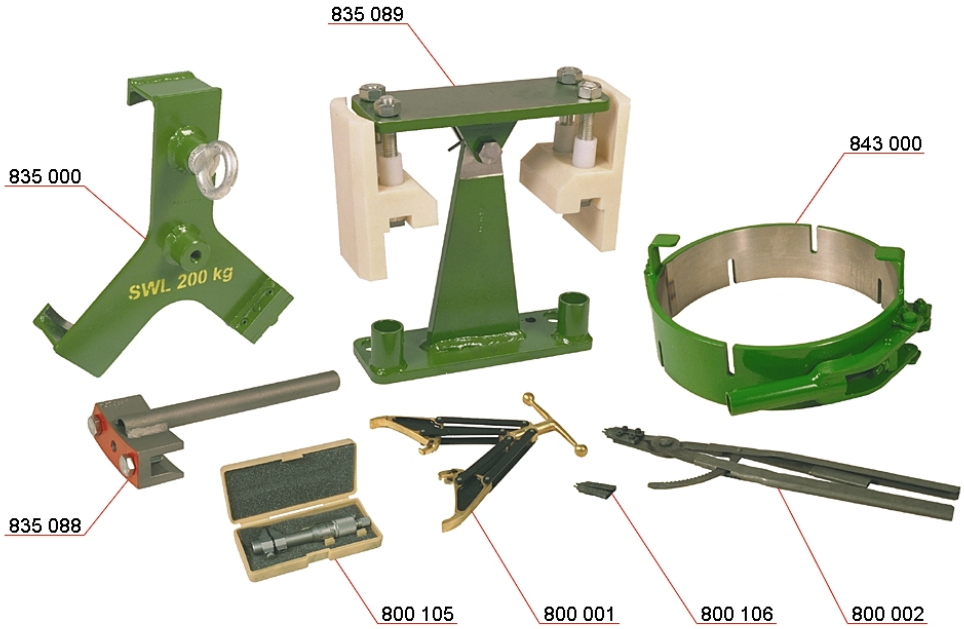
(1) Not for 32 DF and 34 SG

Piston 110

Code	Description	Drawing No.
800001	Piston ring pliers	4V84L0018
800002	Pliers for securing ring	4V84L0016
800105	Measurement tool, micrometer 5-30 mm	
800106	Spare tips for pliers 800002, straight	
802000	Tap M12	
835000	Lifting tool **(1)**	2V83F0058
835000	Lifting tool **(2)**	3V83F0159
843000	Clamp tool for piston rings	1V84D0011

(1) for 32 and 32 GD
(2) for 32 LN and 32 LNGD

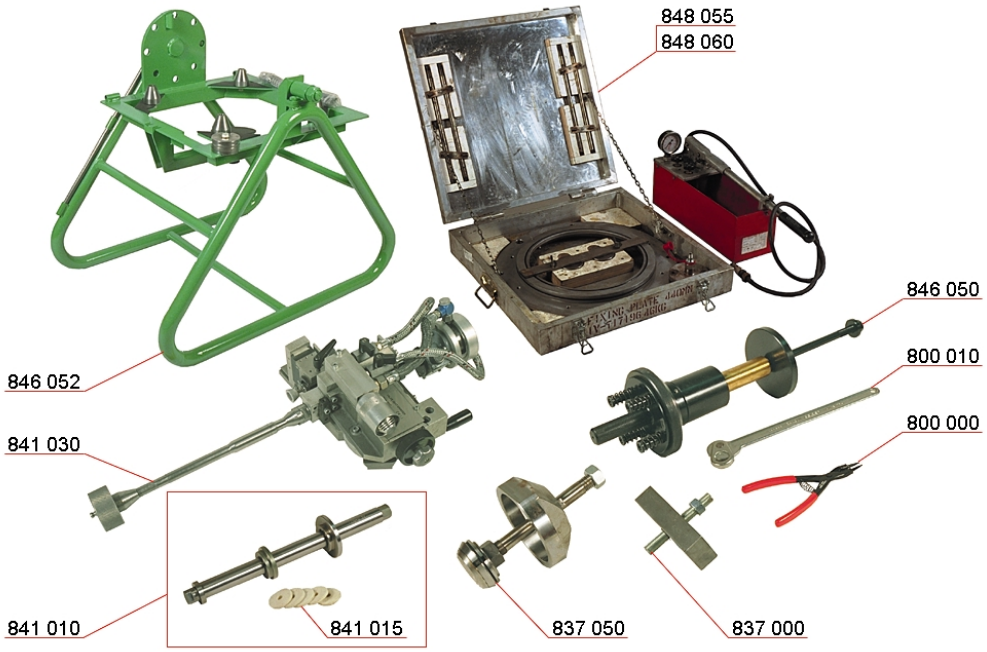
Piston, 32DF and 34SG 110



Code	Description	Drawing No.
800001	Piston ring pliers	4V84L0018
800002	Pliers for securing ring	4V84L0016
800105	Measurement tool, micrometer 5-30 mm	
800106	Spare tips for pliers 800002, straight	
835000	Lifting tool **(1)**	2V83F0192
835000	Lifting tool **(2)**	1V83F0221
835088	Limiter for piston	3V83F0204
835089	Extension for connecting rod	1V83F0190
843000	Clamp tool for piston rings	1V84D0043

(1) Only for 34 SG
(2) Only for 32 DF

Cylinder Head 120



Code	Description	Drawing No.
800000	Pliers for securing ring	
800010	Stud remover 5-20	4V80L04-1
837000	Removing tool for injection & starting valve **(1)**	4V83H0077
837050	Extractor for exhaust valve seat ring	3V-T19189
841010	Grinding tool for seal surface, injection valve **(1)**	3V84B0117
841015	Felt washer for grinding tool **(1)**	4V84B0111
841030	Valve seat grinder	4V84B0130
846050	Mounting tool for seat rings (inlet & exhaust)	2V-T17415/2
846052	Service trestle for cylinder head	0V-T22387
848055	Pressure test tool for water jacket D=450 mm	3V-T029310
848060	Pressure test tool for water jacket D=440 mm	3V-T022401

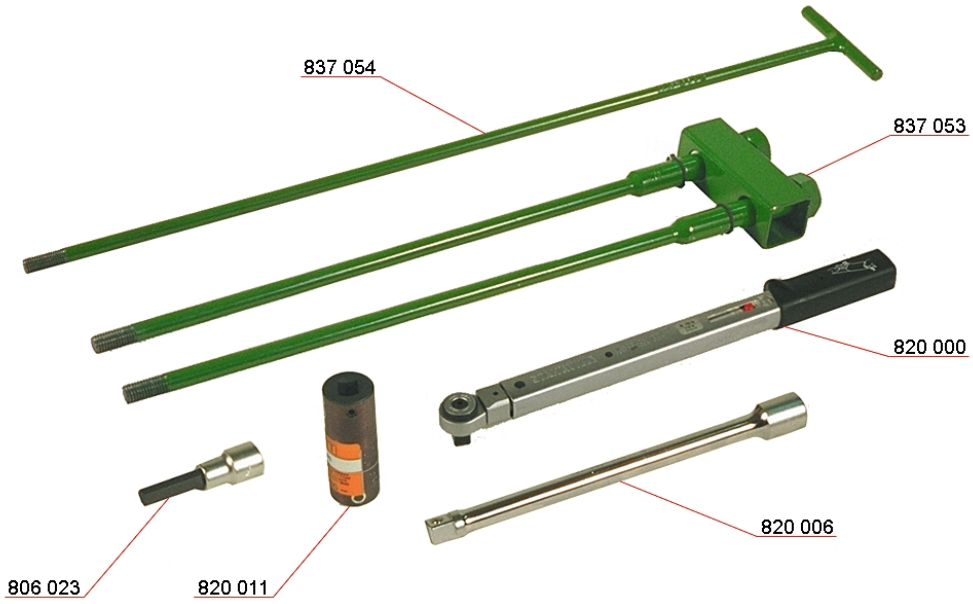
(1) Not for 32 DF and 34 SG

Cylinder Head 120

Code	Description	Drawing No.
808000	T-wrench for indicator valve **(1)**	4V80K0006
832000	Lifting tool	1V83C0060
834000	Mounting & dismantling tool for valves	3V84G0352
834050	Hydraulic extractor	3V83E0061
841000	Grinding tool for valves	4V84B0108
848000	Valve clearance feeler gauge	3V84K0035
860100	High pressure pump (1000 bar) **(2)**	4V86A0033
861009	Distance sleeve M56	3V86B0039
861010	Pin for tightening of nuts M56	4V86B0002
861011	Flexible hose 800 mm **(2)**	
861012	Flexible hose 3000 mm **(2)**	
861100	Hydraulic cylinder M56 **(2)**	3V86B0079

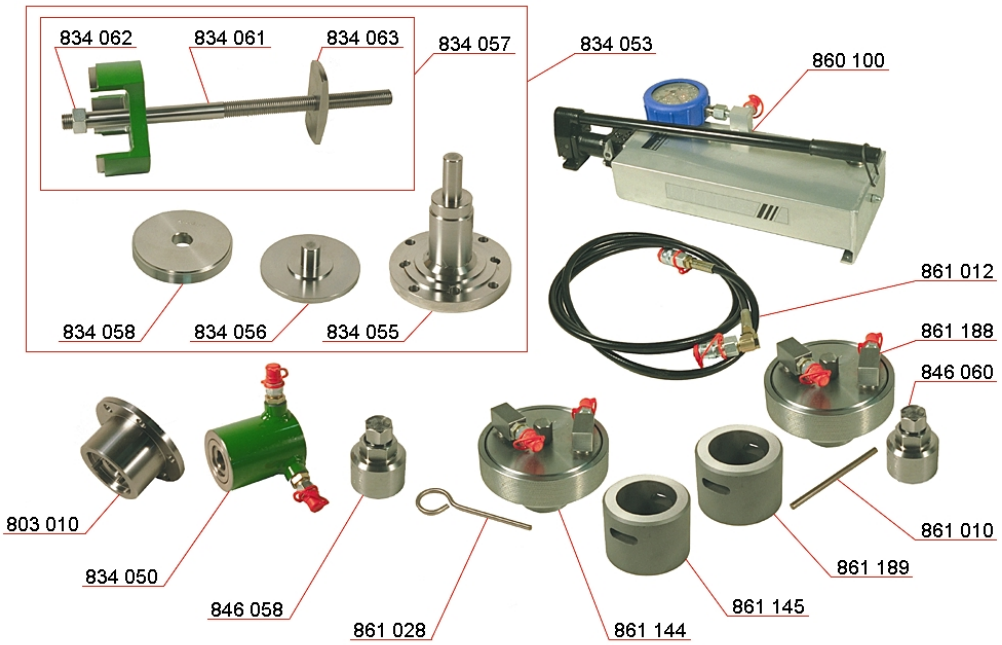
(1) Not for 32 DF and 34 SG
(2) Including quick couplings

Tools for Pre Chamber, V-engine 120



Code	Description	Drawing No.
806023	Bit, hexagon socket screw 10 with 1/2" square drive	4V80L0001
820000	Torque wrench 20-100 Nm	4V92K0207
820006	Extension bar B12.5x250	
820011	Spark plug socket	4V12T0273
837053	Extractor	3V83H0176
837054	Extractor for check valve	3V83H0175

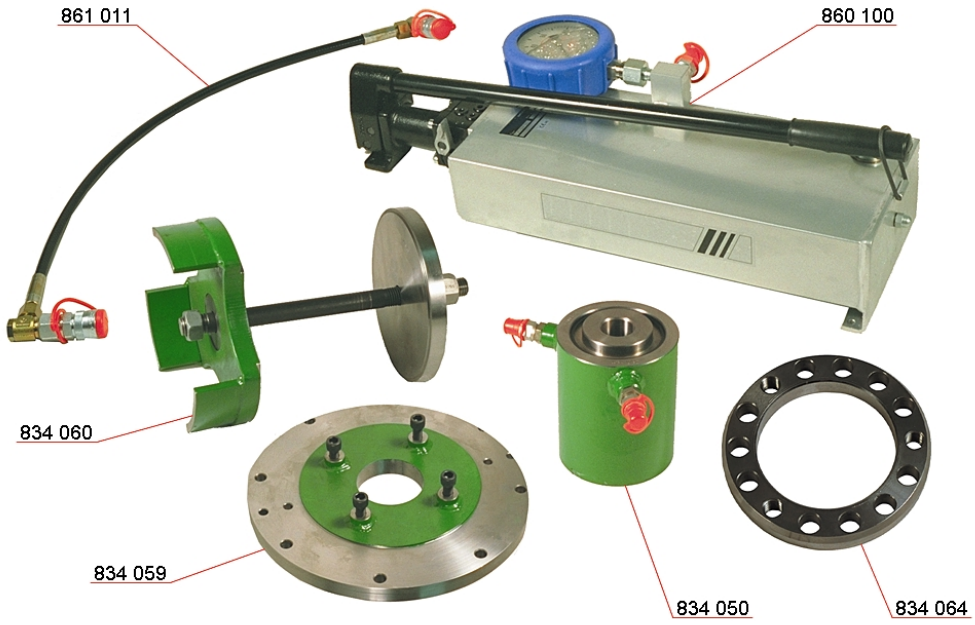
Tools for Intermediate Gear 130



Code	Description	Drawing No.
803010	Mounting tool for shaft	3V80D0013
834050	Hydraulic extractor **(1)**	3V83E0061
834053	Mounting & dismantling tool for bearing	
834055	Mounting tool	3V83E0078
834056	Mounting tool	4V83E0080
834057	Mounting tool	3V83E0133
834058	Mounting tool	3V83E0134
834061	Stud for 834057	
834062	Nut for 834057	
834063	Extractor for 834057	3V83E0079
846058	Stud remover M56	3V83G0189
846060	Stud remover M48	3V84G0251
860100	High pressure pump (1000 bar) **(1)**	4V86A0033
861010	Pin for tightening of nuts M56	4V86B0002
861012	Flexible hose 3000 mm **(1)**	
861028	Pin for tightening of nuts M48	4V86B0011
861144	Hydraulic cylinder M56 **(1)**	3V86B0150
861145	Distance sleeve M56	3V86B0135
861188	Hydraulic cylinder M48 **(1)**	2V86B127
861189	Distance sleeve M48	3V86B0125

(1) Including quick couplings

Tools for Planetary Gear, R-engine 130



Code	Description	Drawing No.
834050	Hydraulic extractor **(1)**	3V83E0061
834059	Mounting tool	3V83E0135
834060	Mounting tool	3V83E0137
834064	Guiding ring	3V84G0377
860100	High pressure pump (1000 bar) **(1)**	4V86A0033
861011	Flexible hose 800 mm **(1)**	

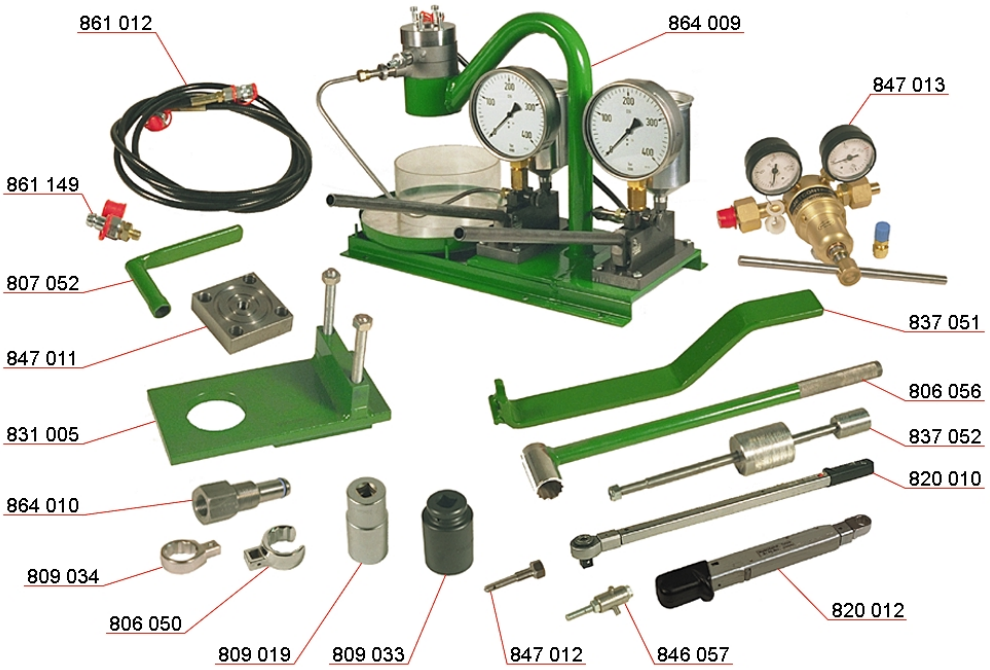
(1) Including quick couplings

Injection Equipment 160

Code	Description	Drawing No.
806050	Flare nut wrench for tightening, 36 mm	4V80G0032
809018	Long socket wrench 24 x 12.5L with 1/2"	
809019	Long socket wrench 27 x 12.5L	
809022	Long socket wrench 41 x 20L with 3/4"	
820001	Torque wrench 70-330 Nm	4V80L0006
831000	Eye bolt for lifting	4V83B0001
845020	Nozzle cleaning kit, complete	
845021	Brass wire brush	4V84L0014
845022	Shaft for nozzle needles	4V84L0015
845023	50 nozzle needles	4V84L0013
862000	Funnel for flowing	3V86C0029
863000	Limiter for fuel rack movements	4V86D0004
864000	Testing tool for injection valve	
864006	Pipe	3V86E0029
864011	Pressure gauge (400 bar)	
864012	Pressure gauge (1000 bar) **(1)**	

(1) Only for 32 LN and 32 LNGD

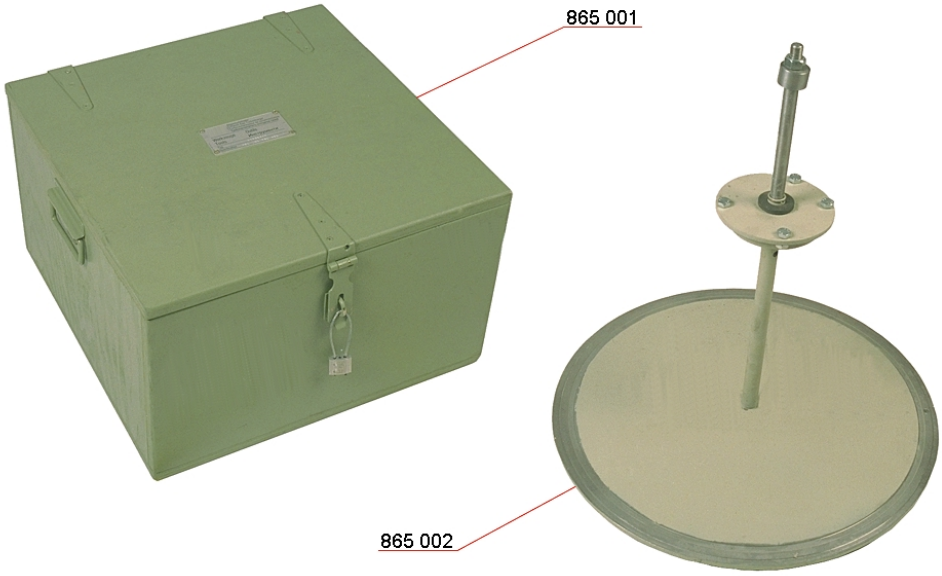
Tools for Multi-Needle injection Valve 160



Code	Description	Drawing No.
806050	Flare nut wrench for tightening, 36 mm	4V80G0032
806056	Tightening tool for gas injection valve	4V80G0035
807052	Socket wrench	4V80H0017
809019	Long socket wrench 27 x 12.5L	
809033	Long socket wrench 56 x 12.5L	
809034	Box wrench head 13	4V92K0208
820010	Torque wrench 75-400 Nm	4V92K0207
820012	Torque wrench 8-40 Nm	4V92K0207
831005	Fixing tool for injection valve	2V84G0263
837051	Lifting tool	3V83H0163
837052	Extractor for gas connection pipe	3V83H0162
846057	Assembly tool for gas nozzle	4V84G0334
847011	Flange for pressure test	3V84H0057
847012	Plug for connection piece	4V31E0212
847013	Pressure reducing valve	4V84H0068
861012	Flexible hose 3000 mm **(1)**	
861149	Quick coupling, male	4V86A0034
864009	Testing tool for injection valve	1V86E0091
864010	Adapter for nitrogen gas fuel connection	4V86E0110

(1) Including quick couplings

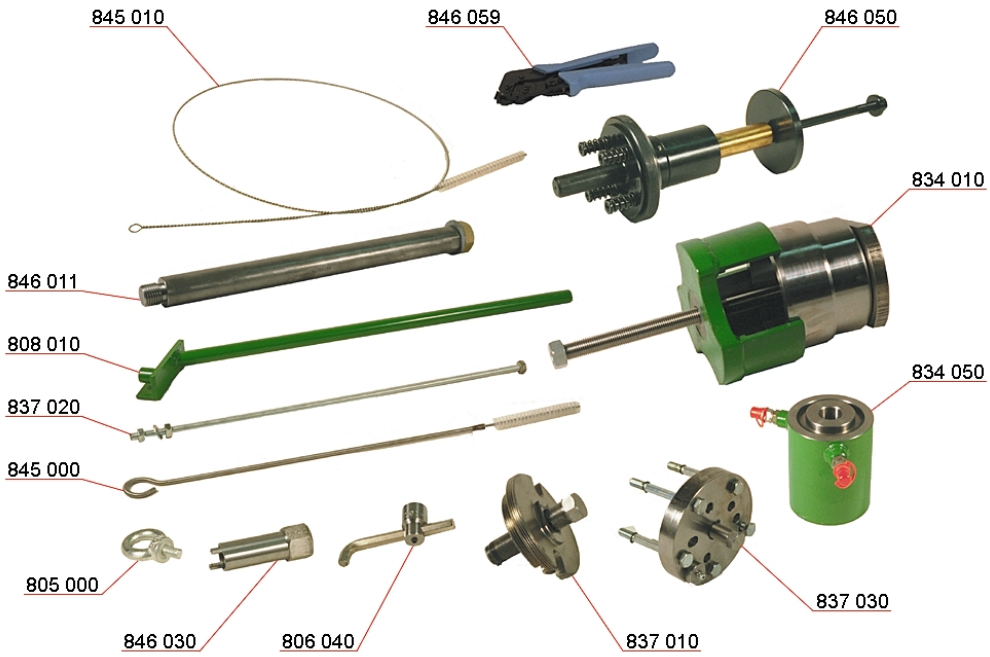
Turbocharger 372



Code	Description	Drawing No.
865001	Maintenance tools **(1)**	
865002	Blanking tool for turbocharger **(1)**	

(1) State engine number, turbocharger type and serial number / HT-number when ordering.

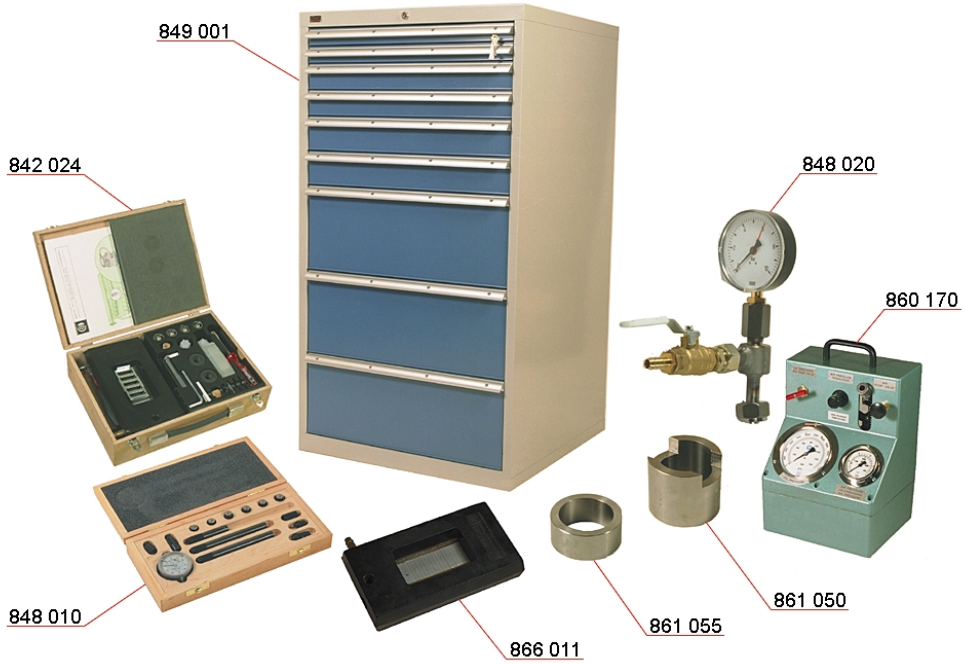
Miscellaneous Tools 900



Code	Description	Drawing No.
805000	Eye bolt screw M10	
806040	Special key for camshaft flange screws	4V80G0017
808010	Resetting tool for overspeed trip	2V80K0009
834010	Mounting & removing tool bearing bush **(1)**	
834050	Hydraulic Extractor	3V83E0061
837010	Extractor for water pump impeller	
837020	Mounting tool for overspeed trip & elastic link rod	4V83H0073
837030	Extractor for water pump impeller	
845000	Brushes for cleaning of charge air cooler (3-pack)	4V84F0007
845010	Brushes for cleaning of lubricating oil cooler (3-pack)	4V84F0006
846011	Mounting screw for plate heat exchanger	4V84G0234
846030	Adjusting tool for mec. overspeed trip device release	4V84G0232
846050	Mounting tool for seat rings (inlet & exhaust)	2V-T17415/2
846059	AMP hand crimping tool	4V84G0475

(1) Two versions. Specify inner diameter (150 or 165) of camshaft bearing bush when ordering.

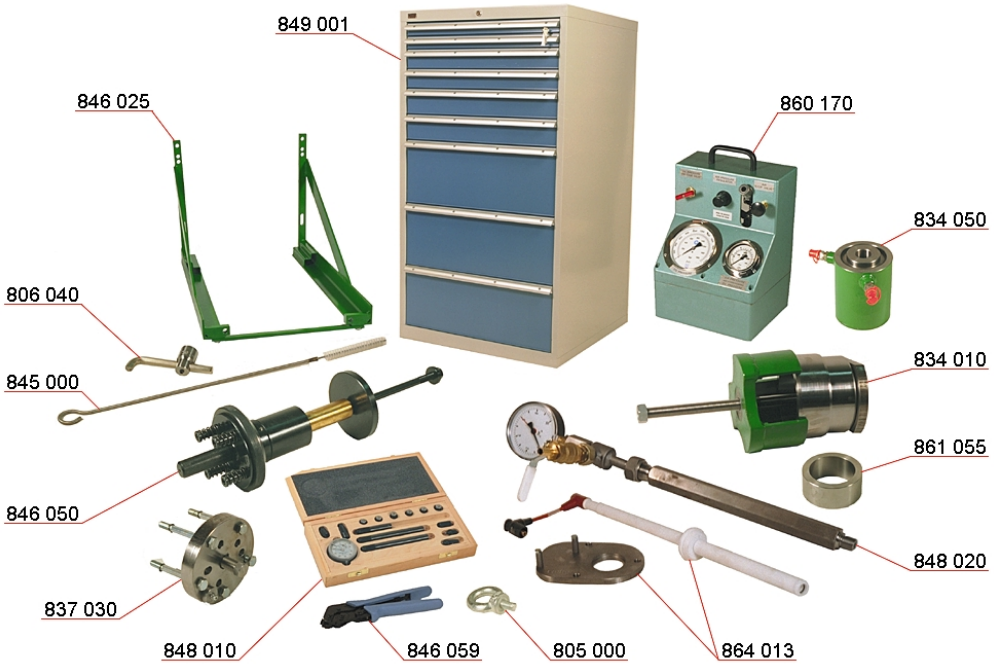
Miscellaneous Tools 900



Code	Description	Drawing No.
842024	Service-box for schaller oil mist detect **(1)**	
848010	Measure gauge for crankshaft deflection	4V84L0012
848020	Checking tool for cylinder / valves tightness	
849001	Tool locker	4V80L0003
860170	Air operated hydraulic unit	4V86B0107
861050	Distance sleeve for small counterweight mounting **(2)**	4V86B0048
861055	Distance sleeve for big counterweight mounting **(3)**	4V86B0081
866011	U-manometer for measuring of crankcase pressure	4V86G0037

(1) Only for 32 and 32 LN
(2) Only for 9R32
(3) Only for 4, 6 ,8R and V-engines

Miscellaneous Tools for 32 DF and 34 SG 900

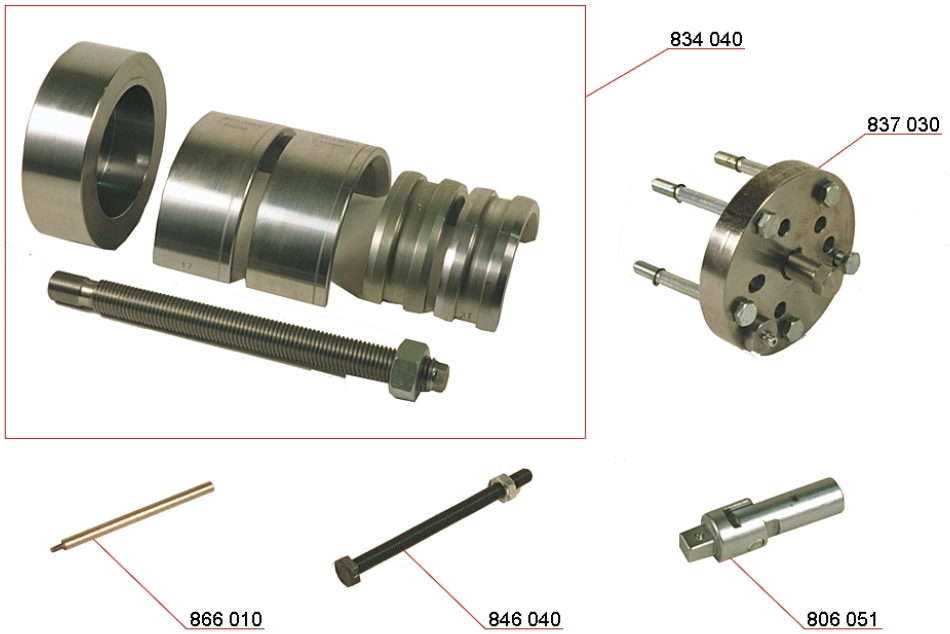


Code	Description	Drawing No.
805000	Eye bolt screw M10	
806040	Special key for camshaft flange screws	4V80G0017
808010	Mounting & removing tool bearing bush **(1)**	2V83H0173
834050	Hydraulic Extractor	3V83E0061
837030	Extractor for water pump impeller	
845000	Brushes for cleaning of charge air cooler (3-pack)	4V84F0007
846025	Mounting tool for charge air cooler	2V84G0219
846050	Mounting tool for gas seat rings (inlet & exhaust)	2v-T17415/2
846059	AMP hand crimping tool	4V84G0475
848010	Measure gauge for crankshaft deflection	4V84L0012
848020	Checking tool for cylinder / valves tightness **(2)**	
849001	Tool locker	4V80L0003
860170	Air operated hydraulic unit	4V86B0107
861055	Distance sleeve for big counterweight mounting	4V86B0081
864013	Testing tool for ignition timing **(2)**	2V86G0042

(1) Two versions. Specify inner diameter (150 or 165) of camshaft bearing bush when ordering.

(2) Only for 34 SG

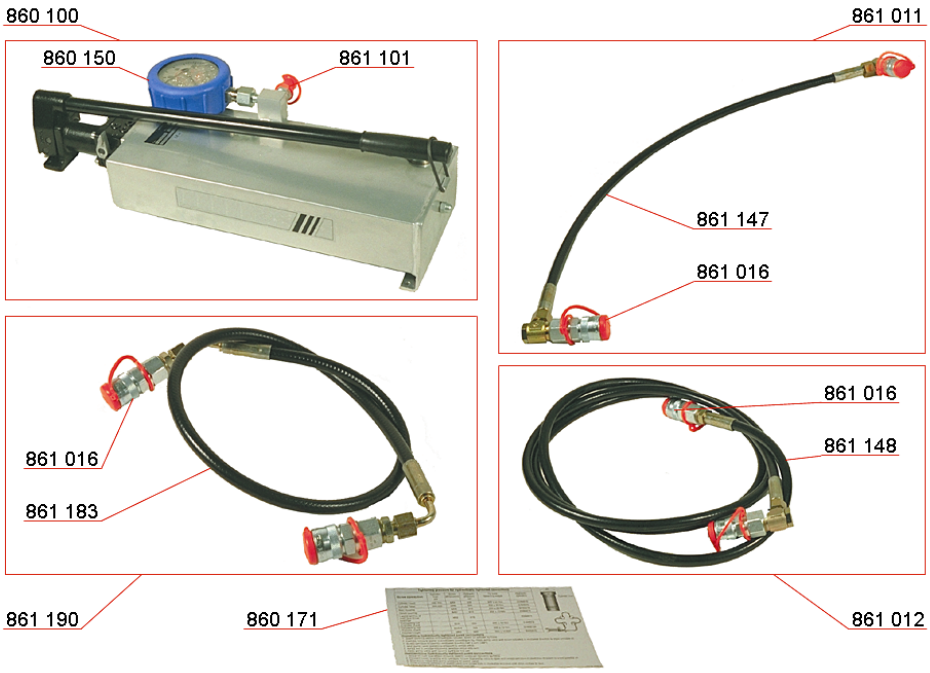
Additional Tools for V-eng. and 4R32 900



Code	Description	Drawing No.
806051	Swivel head 3/4" square drive	4V80H0020
834040	Mounting & removing tool for balancing shaft **(1)**	
837030	Extractor for water pump impeller	3V-T19189
846040	Dismantling tool for thermostat valve	4V84G0218
866010	Intermediate piece for measuring gauge	4V86G0033

(1) Only for 4R32

High Pressure Pump 900



Code	Description	Drawing No.
860100	High pressure pump (1000 bar) **(1)**	4V86A0033
860150	Manometer	4V51L0085
860171	Sign plate	3V52B0126
861011	Flexible hose 800 mm **(1)**	
861012	Flexible hose 3000 mm **(1)**	
861016	Quick coupling, female	4V86A0035
861101	Quick coupling, male	4V86A0034
861147	Flexible hose 800 mm	4V86A0068
861148	Flexible hose 3000 mm	4V86A0067
861183	Flexible hose 1100 mm	4V86A0055
861190	Flexible hose 1100 mm **(1)**	

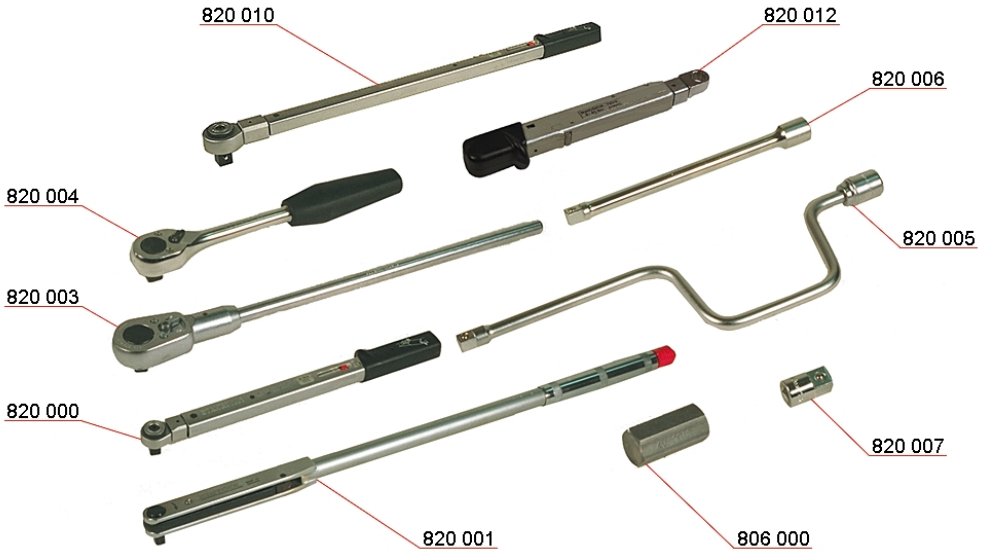
(1) Including quick couplings

Low Pressure Pump 900

Code	Description	Drawing No.
860074	Straight male stud	4V34L0135
860076	Quick coupling, male	4V86A0012
860079	Quick coupling, female	4V86A0012
860080	Flexible hose 3000 mm	4V86A0067
860081	Flexible hose 3000 mm **(1)**	
860082	Low pressure pump (150 bar) **(1)**	1V86A0018

(1) Including quick couplings

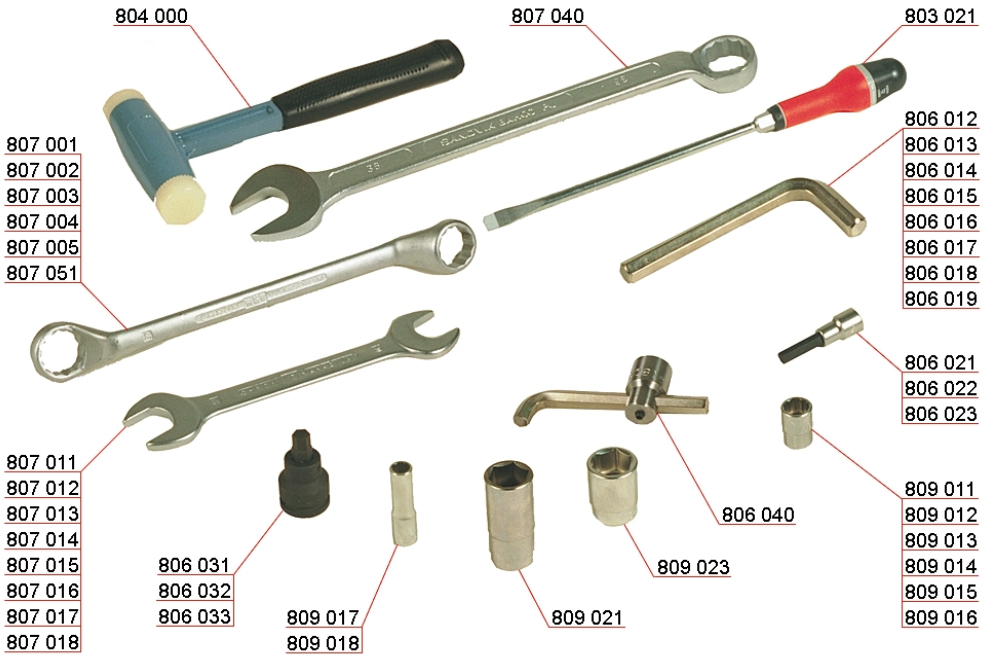
Tightening Tools 900



Code	Description	Drawing No.
806000	Hexagon bar kW 27	4V80G0018
820000	Torque wrench 20-100 Nm	4V92K0207
820001	Torque wrench 70-330 Nm	4V80L0006
820003	Ratchet handle 20 x 630 with 3/4" square drive	4V80K0014
820004	Ratchet handle 12.5 x 300 with 1/2" square drive	
820005	Speed brace B12.5 x 500	
820006	Extension bar B12.5 x 250, 1/2" square drive	
820007	Adapter socket wrench A20 x 12.5 with 3/4"x 1/2"	
820010	Torque wrench 75-400 Nm **(1)**	4V92K0207
820012	Torque wrench 8-40 Nm **(1)**	4V92K0207

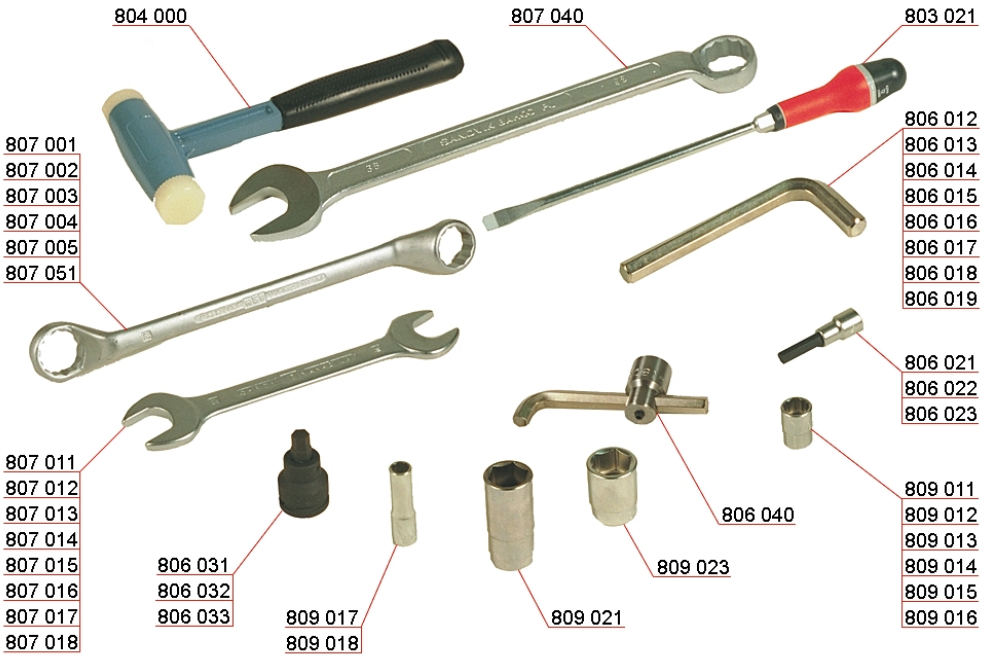
(1) Only for 32 GD and 32 LNGD

Hand Tools 900



Code	Description	Drawing No.
803021	Screw driver 2 x 12M	4V84L0019
804000	Non recoiling hammer D40	4V80L0005
806012	Key for hexagon socket screw 4	
806013	Key for hexagon socket screw 5	
806014	Key for hexagon socket screw 6	
806015	Key for hexagon socket screw 8	
806016	Key for hexagon socket screw 10	
806017	Key for hexagon socket screw 12	
806018	Key for hexagon socket screw 14	
806019	Key for hexagon socket screw 17	
806021	Bit, hexagon socket screw 6, 1/2" square drive	4V80L0001
806022	Bit, hexagon socket screw 8, 1/2" square drive	4V80L0001
806023	Bit, hexagon socket screw 10, 1/2" square drive	4V80L0001
806031	Bit, hexagon socket screw 14, 3/4" square drive	4V80L0001
806032	Bit, hexagon socket screw 17, 3/4" square drive	4V80L0001
806033	Bit, hexagon socket screw 19, 3/4" square drive	4V80L0001
806040	Special key for hexagon socket screw 10	4V80G0017
809017	Long socket wrench 13 x 12.5L with 1/2" square drive	
809018	Long socket wrench 24 x 12.5L with 1/2" square drive	
809021	Long socket wrench 30 x 20L with 3/4" square drive	
809023	Socket wrench with 30 x 20 3/4" square drive	

Hand Tools 900



Code	Description	Drawing No.
807001	Box wrench 10-11	
807002	Box wrench 12-14	
807003	Box wrench 13-17	
807004	Box wrench 19-22	
807005	Box wrench 30-32	
807011	Engineers wrench 10-11	
807012	Engineers wrench 12-14	
807013	Engineers wrench 13-17	
807014	Engineers wrench 19-22	
807015	Engineers wrench 24-27	
807016	Engineers wrench 30-32	
807017	Engineers wrench 36-41	
807018	Engineers wrench 46-50	
807040	Combination wrench AL 36	
807051	Box wrench 24-27	
809011	Socket wrench 10 x 12.5 with 1/2" square drive	
809012	Socket wrench 13 x 12.5 with 1/2" square drive	
809013	Socket wrench 17 x 12.5 with 1/2" square drive	
809014	Socket wrench 19 x 12.5 with 1/2" square drive	
809015	Socket wrench 24 x 12.5 with 1/2" square drive	
809016	Socket wrench 27 x 12.5 with 1/2" square drive	

06. Adjustments, Clearances and Wear Limits

06.1 Adjustments

Valve timing

The valve timing is fixed and cannot be changed individually, cylinder by cylinder.

Valve timing

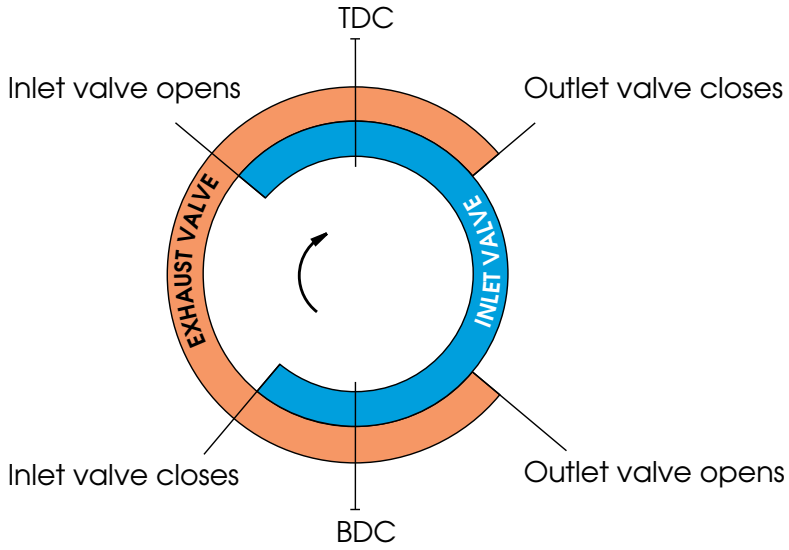


Fig 06-1 3206549232

Other set values:

- Valve clearances, cold engine: inlet valves 0.7 mm
  exhaust valves 1.2 mm
- Fuel delivery commencement: See test records
- Opening pressure of main fuel injection valve 350 bar
  Supply pressure of pilot fuel to injection valve 900 bar

Tripping speed of electronic overspeed trip device:

Nominal speed	WECS internal tripping speed	Redundant tripping speed
720 RPM	828 ± 10 RPM	850 ± 10 RPM
750 RPM	862 ± 10 RPM	885 ± 10 RPM

06.2 Clearances and wear limits (at 20°C)

Part, measuring point		Drawing dimension (mm)		Normal clearance (mm)	Wear limit (mm)
		Max.	Min.		
03	Turning device driving gear backlash drive gear/ flywheel gear rim	1.20	0.30		
10	Main bearing clearance (also flywheel bearing)			0.270-0.374	
	Journal, diameter	300.000	299.968		299.8
	Journal, out of circularity	0.015			0.05
	Journal, taper	0.015/100			0.025/100
	Main bearing shell thickness Trimetal shells Bimetal shells	 7.390 7.390	 7.370 7.370		Section 10.2.2 7.32 mm
	Bore of main bearing housing	315.032	315.000		
	Assembled bearing bore	300.342	300.270		
	Thrust bearing, axial clearance			0.200-0.410	
	Thrust washer thickness	14.850	14.800		14.60
	Camshaft bearing clearance			0.130-0.210	0.36
	Camshaft diameter	165.000	164.975		
	Camshaft bearing bush, thickness	7.435	7.420		
	Camshaft bearing housing, bore	180.025	180.000		
	Assembled bearing bore	165.200	165.145		165.25
	Camshaft thrust bearing housing, bore	85.035	85.000		
	Assembled bearing bore	75.125	75.060		75.25
	Camshaft thrust bearing clearance			0.060-0.144	
	Camshaft thrust bearing, axial clearance			0.250-0.700	1.0
	Cylinder liner, diameter	320.107	320.050		top: 320.80 bottom: 320.30
	Cylinder liner, out of cylindricity at TDC	0.03			0.25
	Anti-polishing ring, wall thickness	7.25	7.20		
11	Big end bearing clearance			0.210-0.304	
	Crank pin, diameter	270.000	269.968		
	Crank pin, out of circularity	0.015			0.05
	Crank pin, taper	0.015/100			0.025/100
	Big end bearing shell thickness Bimetal shells (Al- based)	 5.915	 5.900		Section 11.3.3 5.84 mm
	Big end bore ovality	282.032	282.00		281.90 0.10
	Assembled bearing bore	270.272	270.210		
	Gudgeon pin bearing clearance			0.090-0.169	
	Gudgeon pin diameter	150.000	149.986		
	Small end bore	169.955	169.930		
	Assembled bearing bore	150.155	150.090		150.180
	Connecting rod axial clearance in piston			0.5 -1.0	
	Small end bearing bush, thickness	9.930	9.910		
	Bore diameter in piston St/Sg	150.070	150.050		150.100
	Clearance gudgeon pin - piston St/Sg			0.05-0.084	

	Part, measuring point	Drawing dimension (mm) Max.	Drawing dimension (mm) Min.	Normal clearance (mm)	Wear limit (mm)
	Compression ring end gaps (C102) (C67)			0.8 -1.20 1.25 -1.60	
	Oil scraper ring end gaps (C79)			1.20 -1.50	
	Piston ring height clearance: Compression ring I Compression ring II Oil scraper ring			 0.150-0.192 0.150-0.202 0.063-0.115	 0.5 0.5 0.3
	Piston ring groove height: Groove I Groove II Groove III	6.110 6.120 8.080	6.090 6.090 8.050		6.45 6.45 8.30
12	Valve guide diameter assembled	24.135	24.100		24.25
	Valve stem diameter	24.000	23.979		23.95
	Valve stem clearance			0.100-0.156	0.30
	Valve seat deviation relative guide (max. value)	0.10			
	Inlet valve seat bore in cylinder head	112.022	112.000		
	Exhaust valve seat bore in cylinder head outer bore inner bore	 122.025 110.022	 122.000 110.000		
13	**Intermediate gear of camshaft drive** bearing clearance (34) axial clearance			 0.102-0.179 0.33 -0.52	Section 10.2.2a 0.70
	Bearing diameter in situ	120.157	120.102		
	Bearing journal diameter	120.000	119.978		
	Camshaft driving gear backlash:				
	Crankshaft gear wheel (1)/ intermediate gear wheel (3)			0.148-0.716	
	Intermediate gear wheel / large intermediate gear wheel (10)			0.178-0.582	
	Small intermediate gear wheel (11)/ camshaft gear wheel (12)			0.178-0.582	
	Base tangent length:				
	- crankshaft gear wheel	159.799	159.746		
	- intermediate gear wheel	134.913	134.845		
	- large intermediate gear wheel	159.859	159.783		
	- small intermediate gear wheel	61.520	61.452		
	- camshaft gear wheel	135.570	135.494		

Part, measuring point		Drawing dimension (mm)		Normal clearance (mm)	Wear limit (mm)
		Max.	Min.		
14	Valve tappet, diameter	79.940	79.910		
	Guide diameter	80.046	80.00		
	Diameter clearance			0.060-0.136	
	Tappet roller bore diameter	38.025	38.00		
	Bush diameter, outer	37.975	37.959		37.90
	Bush diameter, bore	30.028	30.007		30.08
	Tappet pin diameter	29.993	29.980		
	Bearing clearance roller-bush bush-tappet pin			0.025-0.066 0.014-0.048	
	Rocker arm bearing diameter, in situ	70.109	70.032		70.4
	Bearing journal diameter	70.000	69.981		
	Bearing clearance			0.032-0.128	
	Yoke pin diameter	29.935	29.922		
	Yoke bore diameter	30.021	30.000		30.1
	Diameter clearance			0.065-0.099	
16	Nozzle needle lift Main needle Pilot needle	 0.70 0.19	 0.65 0.16		 0.76 0.25
17	Fuel feed pump (engine driven) backlash for driving gear			0.85 -0.95	
18	Lubricating oil pump diameter of shaft	49.92	49.895		
	Bush hole diameter	50.076	50.030		
	Bearing clearance			0.085-0.190	0.25
	Axial clearance			0.20 -0.30	
	Backlash for driving gear - R32 - V32			0.382-0.634 0.446-0.625	
	Base tangent length - R32 for driving gear - V32	86.662 86.064	86.626 86.016		
19	Water pump backlash - R32 for driving gear - V32			0.573-0.745 0.586-0.760	
	Base tangent length - R32 - V32	53.801 61.228	53.759 61.186		53.60
21	Backlash for starting motor drive			0.5-0.8	
22	Driving shaft for governor	20.000	19.979		
	Bearing for driving shaft	20.053	20.020		
	Bearing clearance			0.020-0.074	0.15
	Axial clearance			0.10 -0.15	
	Backlash for driving gear			0.10 -0.20	0.30
	Control shaft	30.000	29.967		
	Control shaft bearing	30.072	30.020		
	Clearance			0.20 -0.105	0.25

07. Tightening Torques and Use of Hydraulic Tools

07.1 Tightening torques for screws and nuts

Note! **See section 07.3 for hydraulically tightened connections!**

The position numbers in the tables below refer to the corresponding figures A to J, which are located in the engine according to Fig 07-1. Threads and contact faces of nuts and screw heads should be oiled with lubricating oil unless otherwise stated. Note that locking fluids are used in certain cases. Molycote or similar low friction lubricants must not be used for any screws or nuts. Great risk of overtensioning of screws.

1 Nm = 0.102 kpm

Tightening torques

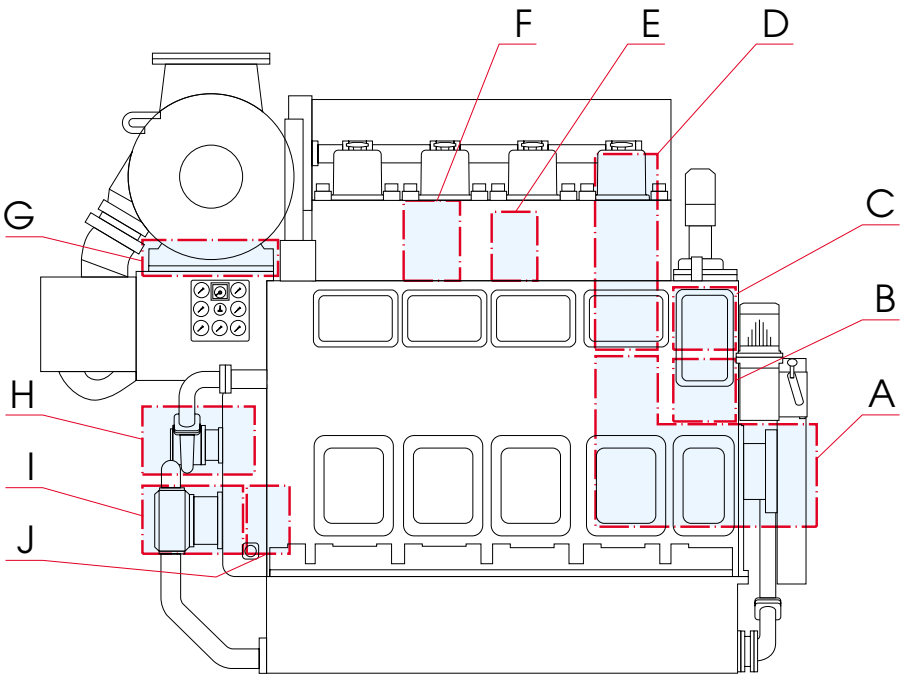


Fig 07-1 3207129801

A: Crankshaft and flywheel, Piston

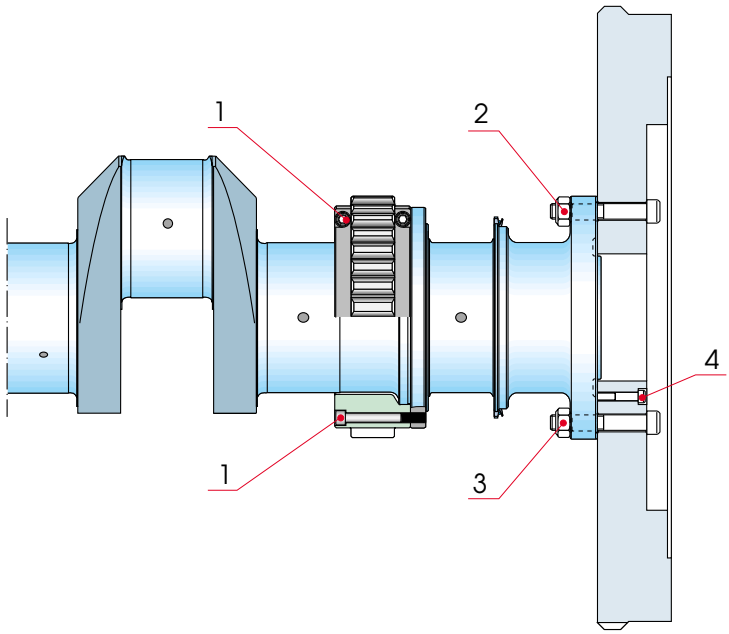
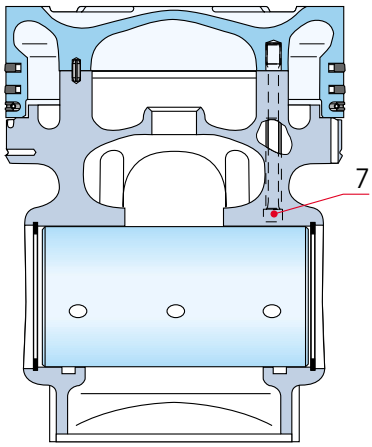


Fig 07-2 3207849045



3207909701

Pos.	Screw connection	Torque (Nm)
1.	Split gear on crankshaft, all M20 screws. **Apply Loctite 262 on threads,** see section 07.2	600±30
2.	Flywheel screws, M30	1200±60
3.	Flywheel screws, fitted screws	650±30
4.	Flywheel screws, M16	200±15
	Piston	
7.	Piston crown connection screws. 1. Lubricate threads and contact surfaces with Molykote Paste G-n Plus. 2. Pre-tighten the screws crosswise. (Only when new screws). 3. Tighten the screws crosswise further with an angle of (Only when new screws). 4. Loosen the screws. (Only when new screws). 5. Pre-tighten the screws crosswise. 6. Tighten the screws crosswise further with an angle of 7. Test for the right tightness. Screw should not move when tightening by 250 Nm torque.	80 Nm +130° 80 Nm 90°±5°

B: Intermediate gear

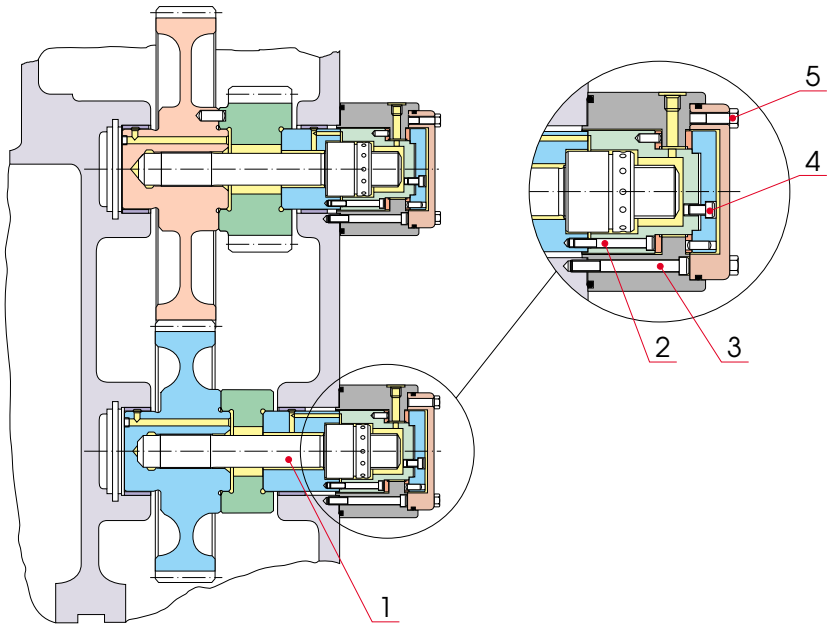


Fig 07-3 3207579045

Pos.	Screw connection	Torque (Nm)
1.	Centre screws, M56	200±10
2.	Shaft screws, M8	23±1
3.	Fastening screws, M12	85±5
4.	Shaft plate screws, M10. **Apply Loctite 242 on threads,** see section 07.2	45±5
5.	Cover screws, M10.	45±5

Note **See section 07.3 for hydraulically tightened connections!**

C: Camshaft and control mechanism

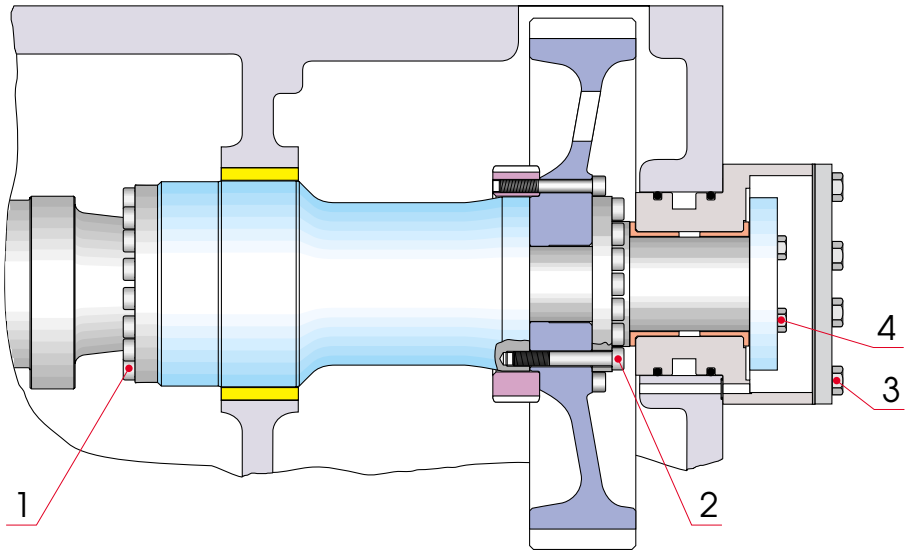
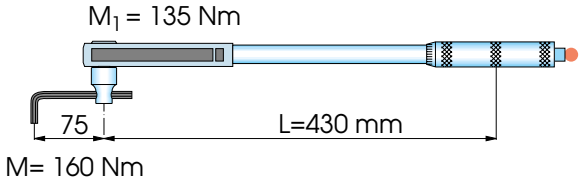


Fig 07-4 3207588935

Pos.	Screw connection	Torque (Nm)
1.	Camshaft flange connection screws. Torque wrench setting with tool 4V80G17 (806040). The screws are treated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	160±5 **135**
2.	Camshaft gear, flange connection screws. **Apply Loctite 242 on threads,** see section 07.2	130±5
3.	Housing fastening screws	85±5
4.	Pressure plate, fastening screws to camshaft. **Apply Loctite 242 on threads,** see section 07.2	45±5

Note! Torque wrench settings must be recalculated if another tool combination than 4V80G17 (item 17-37 in chapter 05) and torque wrench (item 16-02 in chapter 05) is used for the camshaft flange connection.



$$M_1 = 160 * \frac{L}{L+75}$$

D: Cylinder head

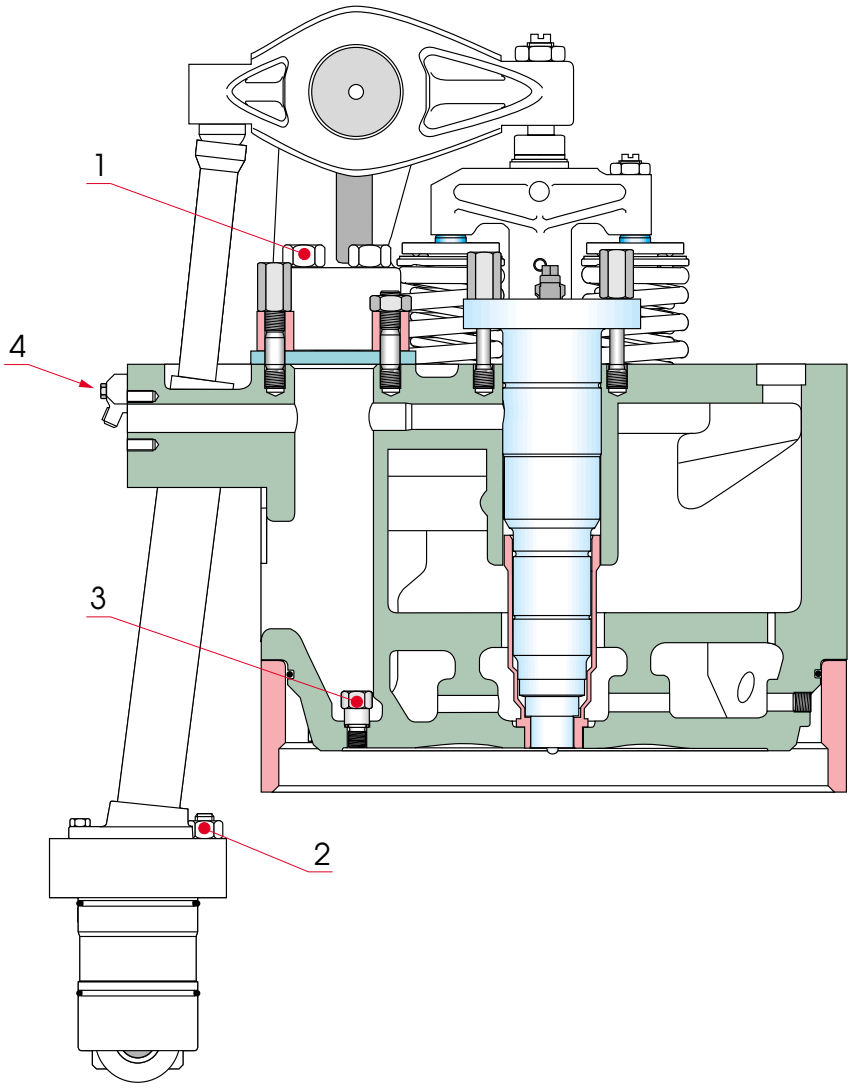


Fig 07-5 3207109801

Pos.	Screw connection	Torque (Nm)
1.	Rocker arm console, fastening nuts. When re-assembling stud bolts apply Loctite 270 on threads, see section 07.2	250±10
2.	Nuts for valve tappet guide block	200±10
3.	Plug for cylinder head with steel seal ring "old" design with copper seal ring	 45±5 25±1
4.	Screw for knocking sensor	20±5

D: Main gas admission valve

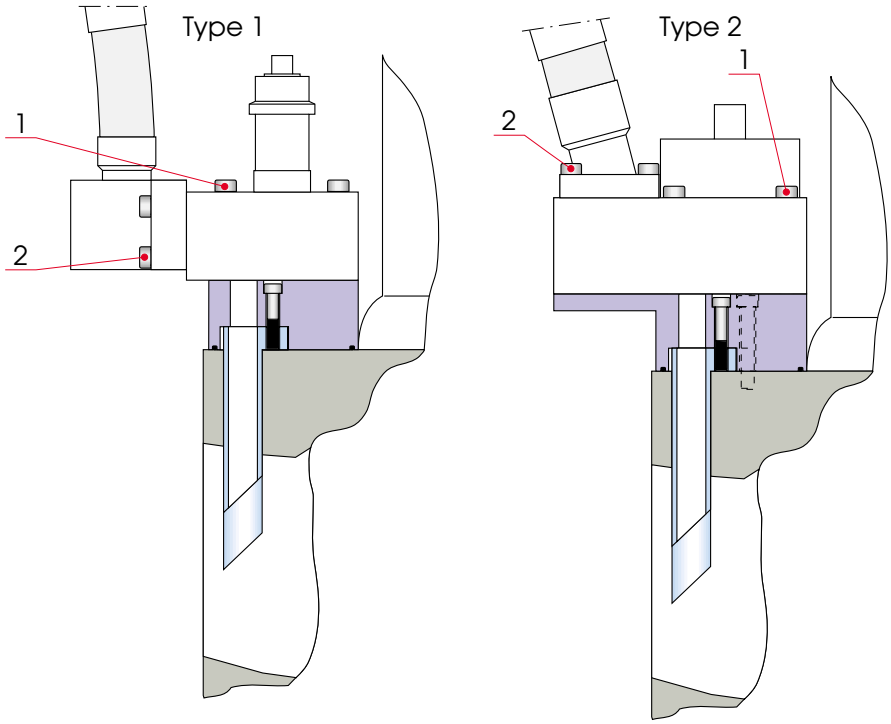


Fig 07-6 3207059720

Screw connection		Torque (Nm)	
		Type 1	Type 2
1.	Valve fastening screws	20-2	25±5
2.	Screws for pipe connections	25±5	25±5

E: Injection pump

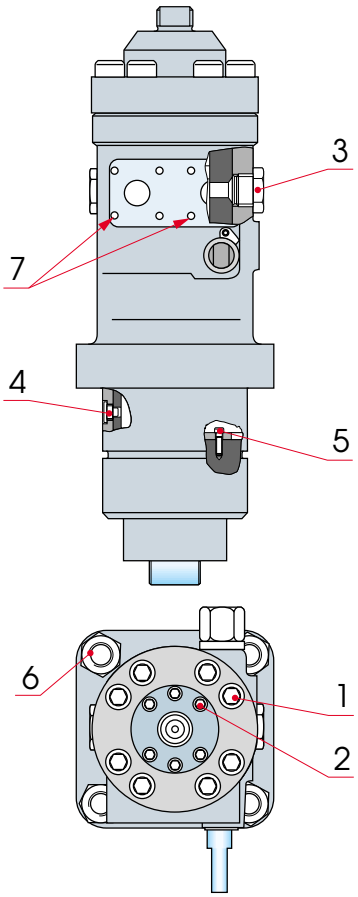


Fig 07-7 3207899520

Pos.	Screw connection	Torque (Nm)
		L'Orange PEO G030
1.	Screws for pump element flange **Note!** Tighten the screws crosswise in steps	80±5 0..15..40..80
2.	Injection pump, head piece **Note!** Tighten the screws crosswise in steps	100+10 0..20..60..100
3.	Erosion plug	200±20
4.	Side screw	15+3
5.	Grub screw	12+3
6.	Nuts for injection pump fastening flange	250±10

F: Fuel injection valve

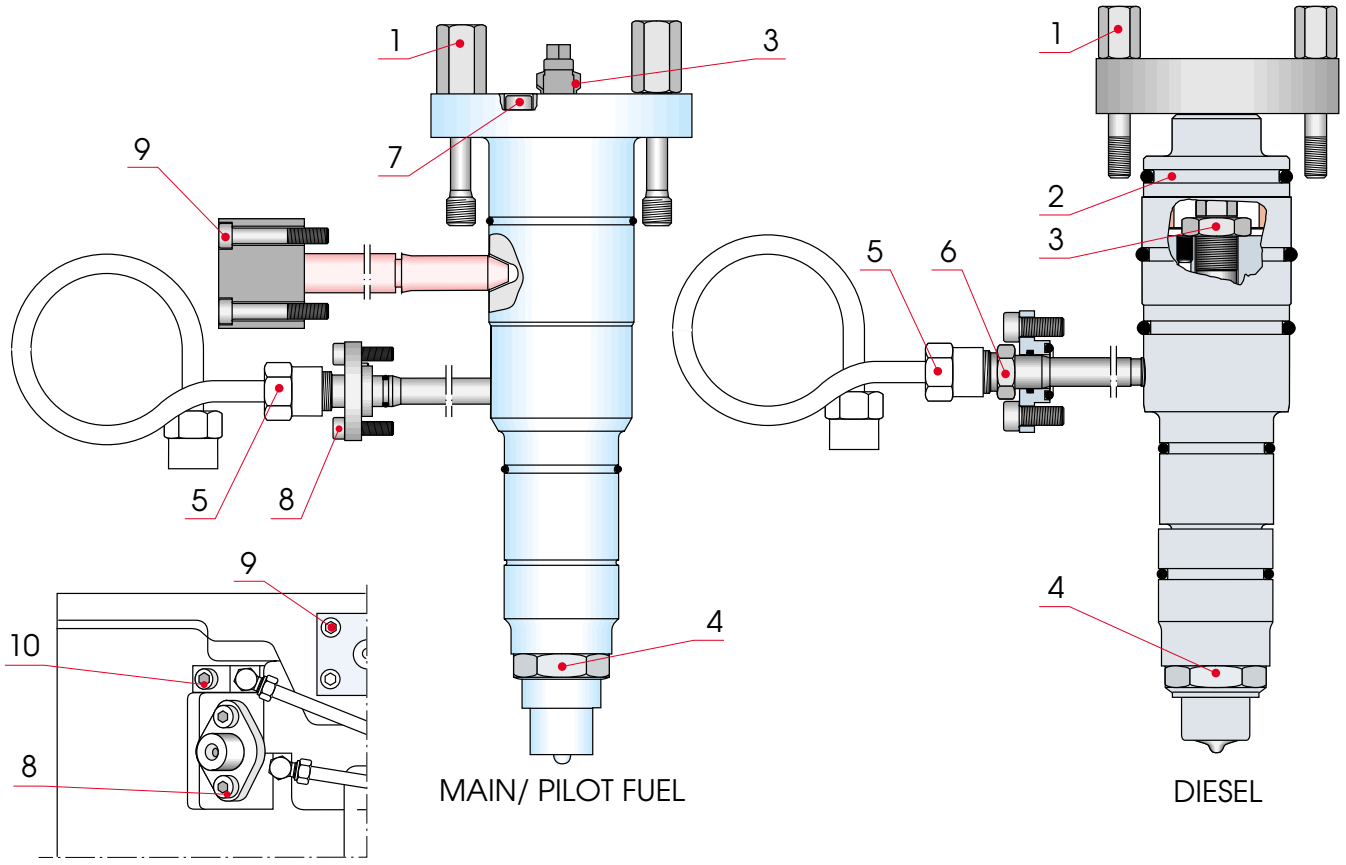


Fig 07-8 3207119801

Pos.	Screw connection	Torque (Nm)	
		Main / Pilot fuel	Diesel Lórange
1.	Injection valve fastening nuts	130±10	130±10
2.	Injection valve/cap		120±10
3.	Injection valve/counter nut	200±20	200±20
4.	Nozzle cap nut	600±30	320±5
5.	Injection pipe cap nuts	80±5	80±5
6.	Connection piece to nozzle holder		95±5
7.	Fastening screw for top body	70±5	
8.	Flange screws	50±5	
9.	Fastening screws for connection piece	17±2	
10.	Fastening screw for nozzle cooling connection piece	25±2	

G: Turbocharger fastening screws

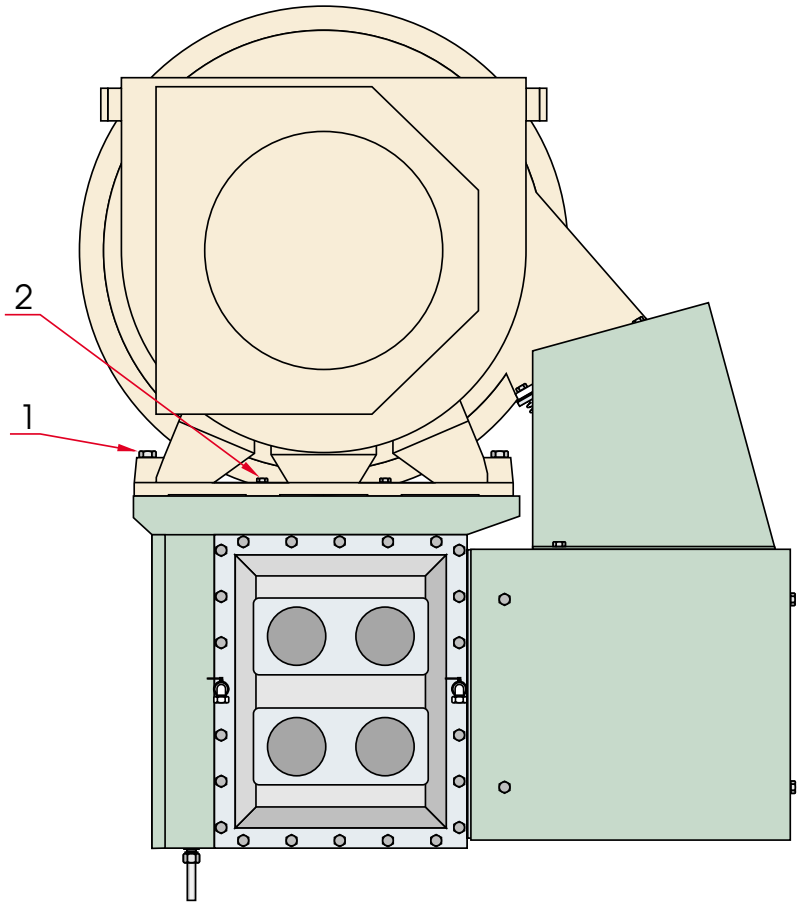


Fig 07-9

3207879519

Turbocharger type	Screw pos.1 Torque (Nm)	Screw pos.2 Torque (Nm)
VTR-254	266±10	77±5
VTR-304	580±30	108±5
VTR-354	650±30	580±30
NA-295	585±30	-
NA-355	585±30	-

H, I: Engine driven pumps

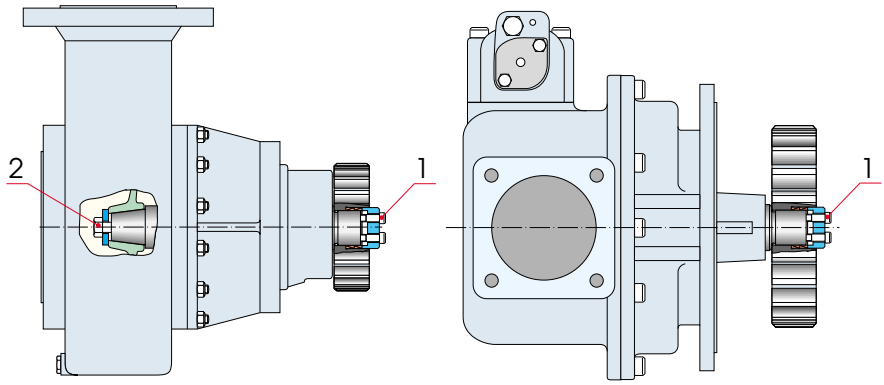


Fig 07-10 3207629045

Pos.	Screw connection	Torque (Nm)
1.	Driving gear of engine driven pumps: — Lubricating oil pump — Water pump in-line engine — Water pump V-engine	 75±5 23±1 50±3
2.	Impeller nut for HT and LT water pump: — in-line engine — V-engine	 120±5 150±5

J: Free end of crankshaft

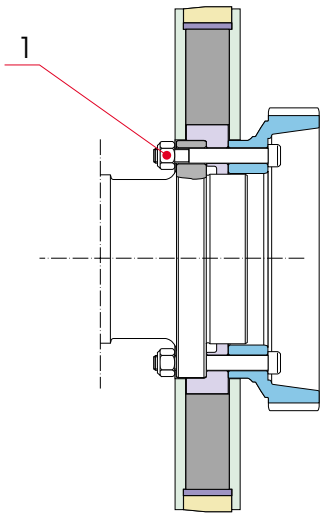


Fig 07-11 3207648935

Pos.	Screw connection	Torque (Nm)
1.	Screws of pump driving gear at free end of crankshaft	600±30

We recommend the use of torque measuring tools also when tightening other screws and nuts. The following torques apply to screws of the strength class 8.8; when oiled with lubricating oil or treated with Loctite.

Screw dimension	Width across flats of hexagon screws (mm)	Key width of hexagon socket head screws (mm)	Torque	
			(Nm)	(kpm)
M8	13	6	23	2.3
M10	17	8	45	4.6
M12	19	10	80	8.1
M16	24	14	190	19.3
M20	30	17	370	37.5
M24	36	19	640	65.0

07.2 Use of locking fluid

When using locking fluid (Loctite), clean parts carefully in degreasing fluid and let then dry completely before applying locking fluid.

07.3 Hydraulically tightened connections

07.3.1 Tightening pressures for hydraulically tightened connections

Hydraulically tightened connections

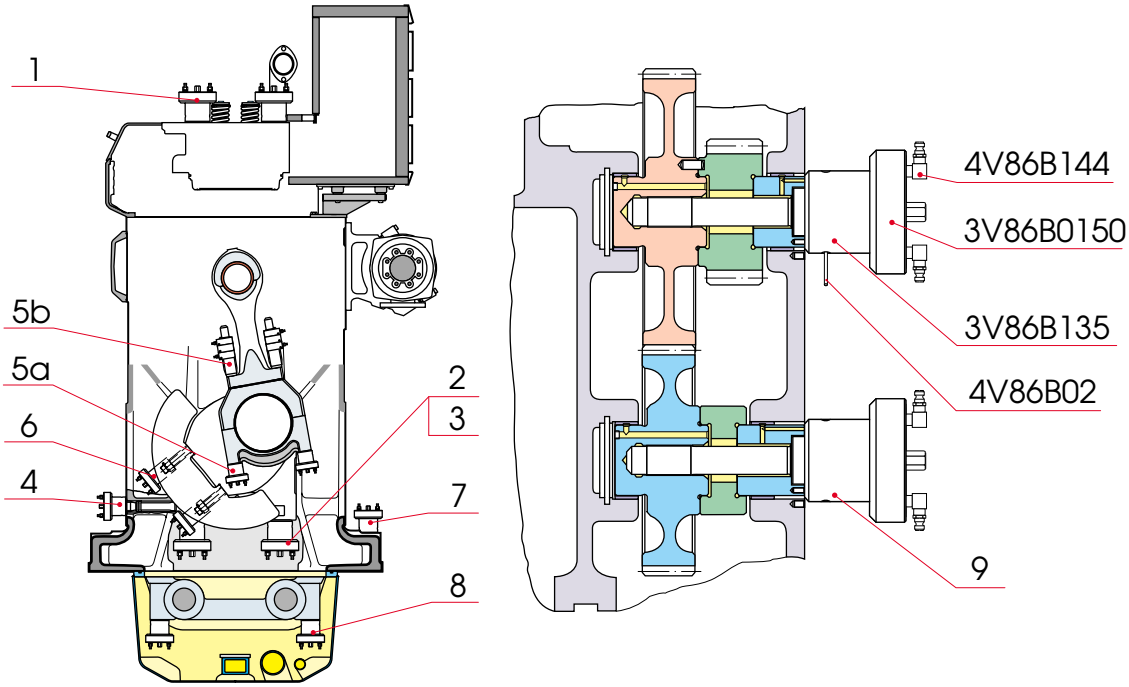


Fig 07-12 3207979544

Pos.	Screw connection	Max. hydraulic pressure (bar)		Hydraulic cylinder
		tightening	loosening	
1.	Cylinder head screws M56: - outer diameter of cylinder liner 450 mm	500	520	3V86B79
2.	Main bearing screws M56	615	635	3V86B79
3.	Thrust bearing screws M42	615	635	3V86B78
4.	Lateral screws of main bearings and thrust bearing M42	615	635	3V86B78
5.	Connecting rod screws : 5a. M30 tightening in two steps First step Second step 5b. M24	 300 600 750	 620 770	 3V86B186 2V86B201
6.	Counterweight screws M42	600	620	3V86B78
7.	Engine fastening screws M42	x)		3V86B78
8.	Fastening screws M42 for balancing shaft bearing bracket	715	735	3V86B78
9.	Intermediate gears M56	660	680	3V86B150

x) Pos. 7 see installation instructions.
The stud bolts are tightened to the casting at the following torques:

Screw dimension	Tightening torque (Nm)
M56 Cylinder head	400±20
M56 Main Bearing	300±10
M42 and M48 x 3	200±10
M24 and M30 Connecting rod	100±10

Exception! **Screws acc. to pos. 4 and 7.**
Pos. 4 see chapter 10, section 10.2.3.

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

If it is impossible to turn the nuts, when the maximum hydraulic pressure is reached: check for corrosion in threads; check tool condition and manometer error.

07.3.2 Filling, venting and control of the high pressure hydraulic tool set

The hydraulic tool set consists of a high pressure hand pump with an integrated oil container, hoses fitted with quick-couplings and non-return valves, cylinders and a pressure gauge mounted on the hand pump but not connected to the pressure side of the pump.

The components are coupled in series with the pressure gauge being the last component thus securing that every cylinder is fed with the correct pressure.

The non-return valves in the hoses are integrated with the quick-couplings and are opened by the pins located in the centre of the male and female parts. If these pins get worn the coupling must be replaced because of the risk of blocking.

- In the high pressure hydraulic tool set it is recommended to use a special hydraulic oil or in any case an oil with a viscosity of about 2°E at 20°C.
- During the filling of the container of the high pressure pump it is recommendable to couple the set according to scheme B, Fig 07-13. Before filling, open the release valve (2) and empty the cylinders (4) by pressing the piston and cylinder together. After that, the container can be filled through the filling plug (1).
- After filling, vent the system by pressing in, with a finger, the centre pin of the female part of the last quick-coupling, the coupling being disconnected from the pressure gauge. Keep on pumping until airfree oil emerges from the coupling.
- Check the pressure gauge of the hydraulic tool set regularly. For this purpose a comparison pressure gauge is delivered. This

pressure gauge can be connected to the plug hole (7), the outlet hose of the pump being connected direct to the pressure gauges.

07.3.3 Dismantling hydraulically tightened screw connections

1 **Attach distance sleeves and hydraulic cylinders** according to Fig 07-13 A. Screw on cylinders by hand.

2 **Connect the hoses to the pump and cylinders** according to scheme Fig 07-13 B. Open the release valve (2) and screw cylinders in clockwise direction to expel possible oil.

3 **Screw the cylinders** in counter-clockwise direction about half a revolution (180°), otherwise the nut is locked by the cylinder and impossible to loosen.

4 **Close the release valve and pump pressure** to the stated value.

5 **Screw the nut** in counter-clockwise direction about half a revolution with the pin.

6 **Open the release valve and remove the hydraulic tool set.**

7 **Screw off the nuts** by hand.

Hydraulic cylinder

1. Filling plug
2. Release valve
3. Hose
4. Hydraulic cylinder
5. Hose
6. Pressure gauge
7. Plug hole

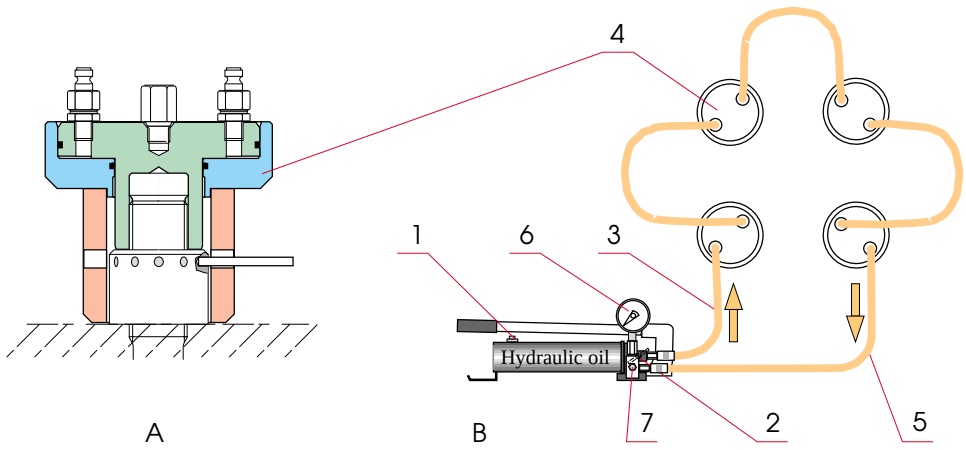


Fig 07-13 3207528935

07.3.4 Reassembling hydraulically tightened screw connections

Check that the threads and contact surfaces are clean and free from particles.

1 **Screw on nuts and attach distance sleeves.** Screw on cylinders by hand.

2 **Connect the hoses to the pump and cylinders.** Check that the release valve is open and screw the cylinders in clockwise direction to expel possible oil.

3 **Close the release valve and pump pressure** to the stated value.

4 **Screw the nuts** in a clockwise direction until in close contact with the face. Use the pin intended for this purpose and tighten the nut as much as possible without breaking the pin. Keep the pressure constant at the stated value.

5 **Open the release valve and remove the hydraulic tool set.**

To ensure that the nut will be properly tightened, the pressure can be raised in two steps. Pump the pressure to 300 bar and screw the nut in a clockwise direction until in close contact with the face. Increase the pressure further to the stated pressure, and screw the nut until in close contact with the face again. This time the nut should move just a limited angle but approximately the same angle for all nuts of the same kind.

Note! **Ensure that all screw connections that have been opened are properly tightened and locked, if necessary, before the engine is started.**

07.3.5 Hydraulic tool for connecting rod shank screws

Hydraulic tool, hose connection and tool section

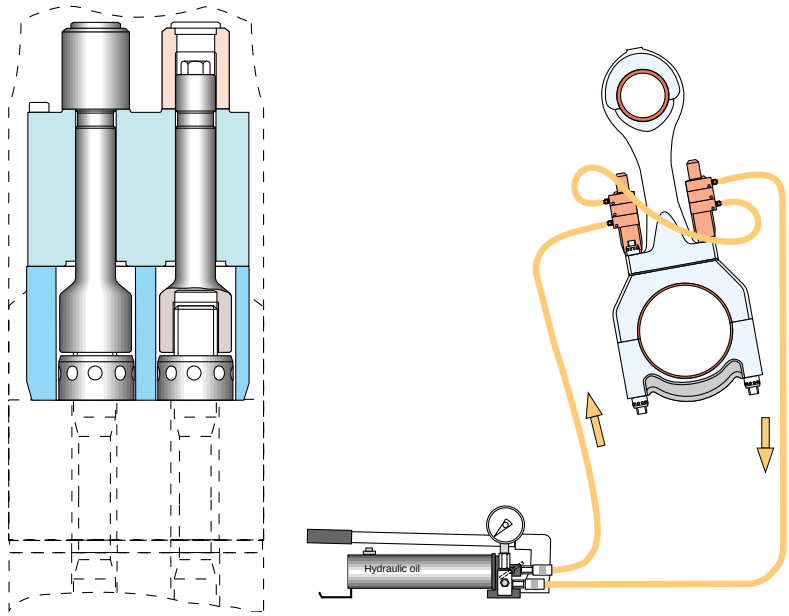


Fig 07-14 3207889520

07.4 Use of hydraulic extractor cylinder

For some power demanding operations a hydraulic extractor cylinder is used. In connection with this cylinder, the hydraulic high pressure hand pump is utilized, coupling scheme acc. to Fig 07-15.

Hydraulic extractor cylinder

1. Hydraulic cylinder
2. Expansion ring

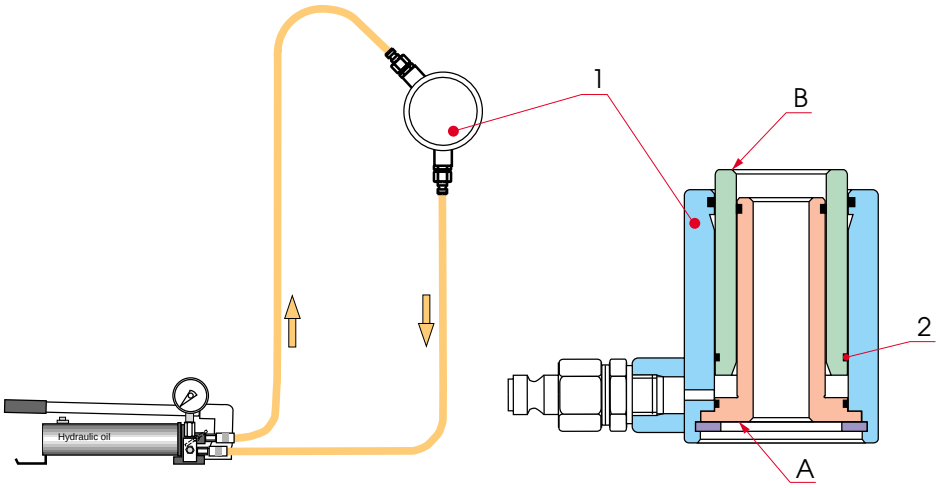


Fig 07-15 3207538935

According to the design of the cylinder, the outer cylinder (1) must not be loaded, but the force is created between the surfaces A and B.

The piston is prevented from running out of the cylinder by an expansion ring (2). The strength of this ring is limited, and it is recommended to be careful when operating at the end of the stroke.

The effective area of the piston is 14.42 cm^2 which gives the following relation between pressure and force.

Relation between pressure and force

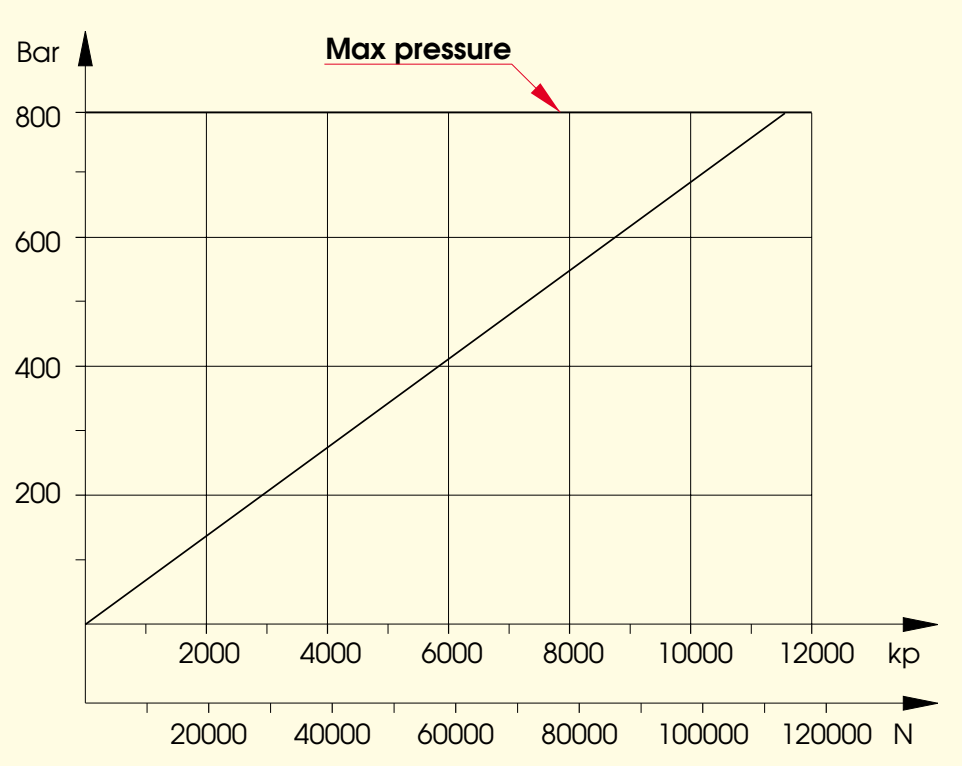


Fig 07-16

3207548935

07.5 Low pressure pump for lifting purposes in the crankcase

A special low pressure pump (150 bar) is delivered for lifting tools used in the crankcase. Normal engine oil, which is used in the engine lubricating system (sump) must be used in this pump because the drain oil from the tools is led to the sump of the engine.

08. Operating Troubles

08.1 Trouble shooting

Preventive measures, see chapter 03. and 04. Some possible operating troubles require prompt action. Operators should acquire knowledge of this chapter for immediate action when needed.

Trouble Possible reason	See chapter, section
1. Crankshaft does not rotate at starting attempt	
a) Control system indicates start blockings - low lub. oil pressure - low starting air pressure - low HT temperature before engine - turning device engaged - emergency stop activated	23.7
b) Engine in shutdown or emergency stop mode	23.7
c) Communication to external system not running	
d) Incorrect CCU configuration	
e) MCU not restarted after power disconnection	
f) Starting automation outside engine faulty	
g) Starting motor faulty	08.2
2. Crankshaft rotates but engine fails to fire	
a) Too low speed	
b) Starting fuel limiter wrongly adjusted (incorrect software setting)	23.
c) Very low air and engine temperatures (preheat circulating water!)	
d) Gas fuel supply restricted or blocked	17.
e) Charge air system restricted or blocked	15.
f) TDC/speed sensor failure or wrongly adjusted	
g) Pilot fuel injection failure	16., 17., 23.
h) Gas fuel and charge air pressure difference too high	
Start in diesel mode:	
i) Fuel and injection system not vented, pipe connections between injection pumps and valves not tightened	17.
j) Fuel filter clogged	17.
k) Three-way cock of fuel filter wrongly set, valve in fuel inlet pipe closed, fuel day tank empty, fuel feed pump not started or faulty	17.
3. Engine fires irregularly, some cylinders do not fire at all	
a) Faulty main gas admission valve - jamming when closed - damaged wiring or electrical connector - gas fuel and charge air pressure difference too high	17.4., 17.5
b) Faulty pilot fuel injector	16.
c) Incorrect ignition timing - incorrect software setting - TDC/speed sensor wrongly adjusted	23.8

d)	Incorrect air-fuel ratio (too lean) - incorrect software setting - malfunction of throttle or wastegate valve - Insufficient charge air pressure - air intake clogged - turbocharger compressor dirty - charge air cooler clogged on air side - turbocharger turbine badly fouled	23.9
e)	Faulty CCU	
f)	12…18-cylinder engines. It may be troublesome to make these fire on all cylinders when idling, due to the small quantity of fuel gas required. **In normal operation this is acceptable.**	
g)	See point 2c	
	In diesel fuel operation:	
h)	Injection pump control rack wrongly adjusted	22.3
i)	Injection pump control sleeve does not mesh properly with rack (may cause overspeed if set in direction towards increased fuel quantity)	16.2.4
j)	Injection pump faulty (plunger or tappet sticking; delivery valve spring broken, delivery valve sticking, constant pressure relief valve leaking)	16.
k)	Injection valve faulty; nozzle holes clogged	16.
4.	**Engine speed not stable**	
a)	Misfire in cylinder - Faulty main gas admission valve (3a) - Faulty pilot fuel injector (3b)	
b)	Incorrect ignition timing - incorrect software setting - TDC/speed sensor wrongly adjusted	23.8
c)	Incorrect air-fuel ratio (too lean) - incorrect software setting - malfunction of throttle or wastegate valve - insufficient charge air pressure (see point 3d)	23.9
d)	Incorrect software setting of speed control parameters	23.11
e)	Fuel gas pressure too low	17., 23.8
f)	Fuel oil pressure too low	17.
5.	**Knocks or detonations occur in engine (if reason cannot be found immediately, stop the engine!)**	
a)	Big end bearing clearance too large (loose screws!)	06.2 pos. 11, 07.3, 11.3.4
b)	Valve springs or injection pump tappet spring broken	12.
c)	Inlet or exhaust valve jamming when open	
d)	Too large valve clearances	06.1, 12.2.4
e)	One or more cylinders overloaded	
f)	Tappet guide block or injection pump loose	14.1.4, 07.1
g)	Initial phase of piston seizure	
h)	Incorrect air-fuel ratio (too rich) - incorrect software setting - malfunction of throttle or wastegate valve - insufficient charge air pressure (see point 3d)	23.9
j)	Faulty main gas admission valve - jamming when open - particles in gas fuel system	17.4., 17.5
k)	Incorrect ignition timing - incorrect software setting - TDC/speed sensor wrongly adjusted - Faulty pilot fuel injector	23.8

l)	Changes in gas fuel characteristics (gas with lower methane number)	02.1
6.	**Dark exhaust gases**	
a)	Late injection (wrongly set camshaft drive)	06.1, 16.2.3, 13.2.2
b)	See points 3b, c, d, e	
c)	Insufficient charge air pressure: - air intake clogged - turbocharger compressor dirty - charge air cooler clogged on air side - turbocharger turbine badly fouled **Note!** Engines starting on heavy fuel may smoke if left idling.	Test Records 15.2 15.2, 04.4 15.5.2 04.5
7.	**Engine exhaust gases blue-whitish or gray-whitish**	
a)	Excessive lubricating oil consumption due to: gas blow-by past piston rings; worn or broken oil scraper rings or worn cylinder liners; sticking compression rings; compression rings turned upside-down; ring scuffing (burning marks on sliding surfaces)	03.4.5, 11.3.3
b)	Gray-whitish exhaust gases due to water leakage from exhaust boiler, turbocharger	
8.	**Exhaust gas temperature of all cylinders abnormally high**	
a)	Engine overloaded	
b)	Charge air temperature too high - charge air cooler clogged on water side or dirty on air side - water temperature to air cooler too high, water quantity insufficient - engine room temperature abnormally high	Test Rec, 01.2 15.5, 15.5.2 01.3 01.3
c)	Excessive deposits in cylinder head inlet or exhaust ports	
d)	Exhaust pipe pressure after turbine high	04.4, 04.5, 15.3
e)	Leakage in charge air system	
f)	Leakage in exhaust gas system	
g)	Incorrect air-fuel ratio (too rich) - incorrect software setting - malfunction of throttle or wastegate valve - insufficient charge air pressure (see point 3d)	23.9
9.	**Exhaust gas temperature of one cylinder above normal**	Test Records
a)	Exhaust valve - jamming when open - "negative" valve clearance - sealing surface blown by (burned)	
b)	Faulty main gas admission valve - jamming when open - particles in gas fuel system	17.4., 17.5
c)	Leakage in cylinder head inlet	
d)	Faulty pilot fuel injector	16.
e)	Injection pump faulty	16.
10.	**Exhaust gas temperature of one cylinder below normal**	
a)	Faulty exhaust gas temperature transducers	23., 03.4.1
b)	Leakage in gas fuel system	17.
c)	When idling, see point 3g	03.4.1
d)	Misfire in cylinder -	
e)	Incorrect air-fuel ratio (too lean) - incorrect software setting - malfunction of throttle or wastegate valve - insufficient charge air pressure (see point 3d)	23.9

f)	Faulty main gas admission valve - stacked in close position - damaged wiring or electrical connector - gas fuel and charge air pressure difference too high	17.4., 17.5
g)	Faulty pilot fuel injection valve - sticking needle - pilot nozzle hole clogged	16.
h)	Leaky injection pipe or pipe fittings	16.
11.	**Lubricating oil pressure lacking or too low**	01.2
a)	Faulty pressure transducers	23.1.1
b)	Lubricating oil level in oil sump too low	01.1, 18.2
c)	Lubricating oil pressure control valve out of adjustment or jamming	18.4
d)	Three-way cock of lubricating oil filter wrongly set	18.7
e)	Leakage in lubricating oil suction pipe connections	18.1
f)	Lubricating oil viscosity too low	02.2.1, 02.2.3
g)	Lubricating oil pipes inside engine loose or broken	18.
12.	**Too high lubricating oil pressure**	
a)	See points 12a and c	
13.	**Too high lubricating oil temperature**	01.2
a)	Faulty temperature transducer	
b)	Insufficient cooling water flow through oil cooler (faulty pump, air in system, valve closed), too high raw water temperature	19.1.2 01.3
c)	Oil cooler clogged, deposits on tubes	18.5
d)	Faulty thermostat valve	18.6
14.	**Abnormally high cooling water outlet temperature,** difference between cooling water inlet and outlet temperatures too large	01.2
a)	One of temperature transducer faulty	
b)	Circulating water cooler clogged, deposits on tubes	
c)	Insufficient flow of cooling water through engine (circulating water pump faulty), air in system, valves closed	19.3, 19.4 03.4.1
d)	Thermostat valve faulty	19.4.2
15.	**Water in lubricating oil**	02.2.3, 03.4.1
a)	Leaky oil cooler	18.5
b)	Leakage at cylinder liner O-rings (always pressure test when cooling water system has been drained or cylinder liners have been dismantled)	
c)	Faulty lubricating oil separator. See separator instruction book!	02.2.3
16.	**Water in charge air receiver** (escapes through drain pipe in air cooler housing)	15.5
a)	Leaky air coolers	
b)	Condensation (too low charge air cooling water temperature)	03.4.1, Fig 03-2
17.	**Engine looses speed or power**	
a)	Engine overloaded or too fast load increase	23.11
b)	See points 4e, 5g	
18.	**Engine stops**	
a)	Shortage of fuel	
b)	Automatic shutdown or emergency stop from control system	23.7

c)	Power failure to electronic equipment	
19.	**Engine does not stop although remote stop signal is given**	
a)	Faulty wiring. Stop by means of closing the shut-off valve in the gas supply system	
20.	**Engine does not stop although stop lever is set in stop position or remote stop signal is given**	
a)	Injection pump control rack wrongly set (3b, c) Trip overspeed trip device manually. If the engine does not stop immediately, block fuel supply as near the engine as possible (e.g. by fuel filter three-way cock). Before restarting the engine, the fault must be located and corrected. **Great risk of overspeed.**	
b)	The engine driven by generator or propeller or by another engine connected to same reduction gear	
21.	**Engine overspeeds and does not stop although overspeed trip device trips**	
a)	Injection pump control rack wrongly set (3b,c). **Load the engine, if possible.** Block fuel supply, e.g. by means of fuel filter three-way cock.	
b)	An overspeeding engine is hard to stop. Therefore, check regularly the adjustment of the control mechanism (the injection pump rack positions): 1) the stop lever being in stop position or the overspeed trip device being tripped and the speed governor at max. fuel admission 2) the stop lever and the overspeed trip being in work position and the speed governor in stop position. This control should be done always when the control mechanism or the injection pumps have been touched.	22.3

08.2 Trouble shooting for air starter

Pos.	Trouble	
	Fault	Solution
1.	**Motor will not run**	
a)	No air supply.	Check for blockage or damage to air supply lines or tank.
b)	Damaged motor assembly.	Inspect motor assembly and power train and repair or replace if necessary.
c)	Foreign material in motor and/or piping.	Remove motor assembly and/or piping and remove blockage.
d)	Blocked exhaust system.	Remove housing exhaust cover and check for blockage.
e)	Defective control valve or relay valve.	Replace control valve or relay valve.
2.	**Loss of power**	
a)	Low air pressure to starter.	Check air supply.
b)	Restricted air supply line.	Check for blockage or damage to air lines.
c)	Relay valve malfunctioning.	Clean or replace lines or relay valve. Lube relay valve.
d)	Exhaust flow restricted.	Check for blocked or damaged piping. Clean or replace piping. Check for dirt or foreign material and clean or remove. Check for ice build-up. Melt ice and reduce moisture build-up to starter.
e)	Damaged motor assembly.	Replace motor assembly.
3.	**Drive will not engage**	
a)	No pressure to drive housing port.	Check air supply.
b)	Internal drive housing ports blocked.	Remove blockage.
c)	Fluid in drive unit components.	Remove fluid.
d)	Damaged or worn piston assembly, O-ring or seals.	Replace damaged or worn parts.
e)	O-rings and seals dry.	Re-lube O-rings and seals.
4.	**Motor runs, pinion engages, but does not rotate flywheel**	
a)	Damaged or broken drive train.	Disassemble drive train and replace worn or damaged parts.
b)	Damaged starter valve.	Disassemble starter valve and replace worn or damaged parts.
5.	**Excessive butt engagement**	
a)	Damaged drive pinion or flywheel.	Inspect drive pinion and flywheel and replace if necessary.
b)	Damaged Starter Drive or components	Inspect drive components and replace worn or damaged parts.
c)	Low air pressure.	Check air supply.
d)	Wrong drive pinion.	Replace with proper drive pinion.
6.	**Oil blowing out of exhaust**	
a)	Oil in air supply line.	Inspect air line and remove source of oil.
b)	Splash deflector retaining screw or pipe plug missing.	Install splash deflector retaining screw or pipe plug.
c)	Worn or damaged rotor seals or static O-rings.	Replace static seals on outside of motor or send motor to manufacturer to be rebuilt.
7.	**Oil leaking from gear case**	
a)	Worn or damaged O-rings.	Replace O-rings.

Continue

b) Loose joints.	Make sure that joints fit properly and that starter assembly cap screws are tightened to 60 ft.-lb (81 Nm). Make sure that all seals and O-rings fit and seal properly at their perimeters. If they do not, replace with new seals and O-rings.
c) Excessive high-speed operation.	Operate according to recommendations.
d) High number of start cycles.	Replace worn components.
e) Loose or leaking pipe plugs.	Tighten or replace pipe plugs.
f) Splash deflector retaining loose or pipe plug missing.	Tighten splash deflector retaining screw or replace pipe plug.

09. Specific Installation Data

09.1 General

All test reports and certificates are collected in series 8 Quality records. The specific installation data can be found from binder 7A 02 01.

10. Engine Block with Bearings, Cylinder and Oil Sump

10.1 Description

The cast iron engine block is cast in one piece. The jacket water distributing pipes and the charge air receiver are integrated in the engine block. The main bearing caps, which support the underslung crankshaft, are clamped by hydraulically tensioned screws, two from below and two horizontally. The bearing shells are axially guided by lugs to provide correct assembly.

A combined flywheel/thrust bearing is located at the driving end. The flywheel bearing shells are of the same type as the main bearings. The four thrust washers guide the crankshaft axially.

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

The cylinder liners, made of special cast iron, have cooling bores in the upper flange. At the upper part the liners are sealed against the block metallically, and at the lower part by two O-rings.

To eliminate the risk of bore polishing, the liner is provided with an anti-polishing ring at the upper part.

The crankcase covers, as well as other covers, tighten against the engine block by rubber sealings and four screws each. On one side of the engine the crankcase covers are equipped with safety valves which relieve the over pressure in case of a crankcase explosion. One cover incorporates the oil filling hole. The crankcase is furthermore provided with a vent pipe including a non-return valve. This pipe should be conducted away from the engine room.

The light, welded oil sump is attached to the engine block from below and is sealed by an O-ring. Suction pipes to the lube oil pump and separator as well as the main distributing pipe for lube oil are incorporated in the oil sump.

From the main distributing pipe the lube oil is led up to the main bearing through a hydraulic jack, by means of which the bearing cap can be lowered and lifted, e.g. when inspecting the bearings.

10.2 Main bearings

10.2.1 Dismantling of the main bearing

1 **Remove two crankcase covers** on each side of the bearing, on both sides of the engine.

2 **Loosen the nuts of the side screws on the bearing** in question and on both adjacent bearings, Fig 10-1 (A).

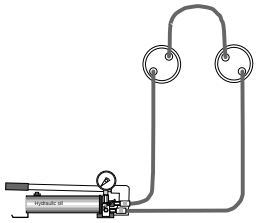
3 **Lift the distance sleeve** 3V86B46 into position on the side screw. One or two nuts can be loosened simultaneously.

4 **Screw on the hydraulic tool 3V86B78** and proceed with opening of the side screw nuts (A).

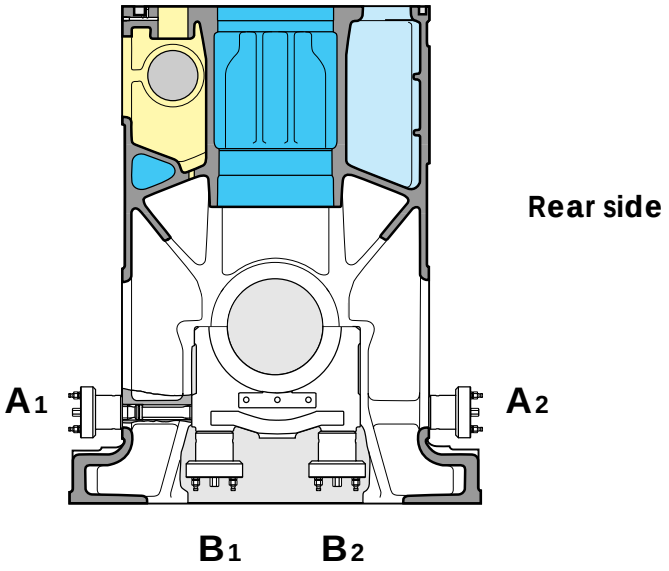
5 **Loosen the nuts of the main bearing screws** on the bearing in question as shown in Fig 10-1 (B).

Use of hydraulic cylinders

DISMANTLING
1. Screw on cylinders by hand
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Screw cylinders 180° counter -clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.



Hydraulic cylinder combination				
Screw		A1 A2	B1 B2	
Hydraulic tool		Main bearing and thrust bearing screws	Main bearing screws	Main bearing screws
Cylinder		3V86B78	3V86B79	3V86B78
Sleeve		3V86B46	3V86B39	3V86B46
Pin		4V86B11	4V86B02	4V86B11
Action/Screw		**Comments**		**Hydraulic pressure**
Loosening	A1 A2	One by one in order according to free choice. Two nuts per side can be loosened simultaneously.		615...635 bar
	B1 B2	Always loosened simultaneously.		615...635 bar
Tightening	B1 B2	Simultaneously handtight with pin 4V86B02 (B11) only.		
	A2	A2 bolt tensioned first with 200 bar hydraulic pressure and the nut turned with pin to contact.		200 bar
	B1 B2	Tightened simultaneously with full hydraulic pressure.		615 bar
	A1A2	Tightened one by one in order according to free choice with full hydraulic pressure.		615 bar

Fig 10-1

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6 **Lift the distance sleeves** 3V86B39 into position and insert the pins 4V86B02.

7 **Lift the hydraulic tool 3V86B79 into position** by using the tool 3V86B52 and proceed with opening of the main bearing nuts (B).

8 **Remove the nuts of the main bearing screws.**

9 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked DOWN, see Fig 10-2.

10 **Unscrew the side screws of the main bearing cap** to be lowered. Use the stud tool 4V80D12.

11 **Lower the main bearing cap** by pumping oil pressure to the hydraulic jack by the hydraulic pump.

12 **Remove the lower bearing shell.**

13 **Insert the turning tool** 4V85B12 (in-line engine) or 4V85B16 (V-engine) into the main bearing journal radial oil hole.

14 **Turn the crankshaft** carefully until the bearing shell has turned 180° and can be removed.

15 **Cover the two main bearing journal radial oil holes with tape.** At least every third main bearing should be in place at the same time to support the crankshaft.

Hydraulic jack

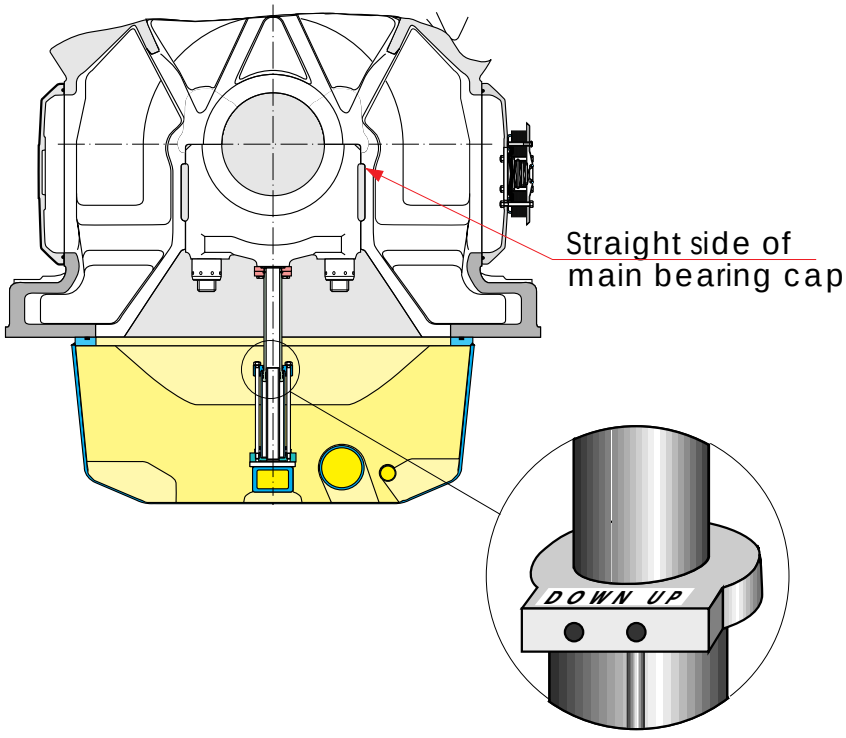


Fig 10-2 3210528932

10.2.2 Inspection of main bearings and journals

Clean the bearing shells and check for wear, scoring and other damages.
a) Trimetal bearings can be used until the overlay is partially worn off. When the under-laying nickel-barrier or the lining material is exposed in any area, the bearing must be replaced.

Never re-install a bearing with the nickel-barrier exposed in any part of the bearing shell.

b) Bi-metal bearings. Wear is settled by measuring the thickness of the lower bearing shells. For this purpose a ball anvil micrometer can be used. The wear limit in section 06.2 must be applied. If the thickness of lower bearing shells have not reached the wear limit and the difference in thickness of all lower bearing shells is max. 0.03 mm, the shells can be used again.

Mark the new bearings with the bearing numbers.

The main bearing journals should be inspected for surface finish. Damaged journals, i.e. rough surface, scratches, marks of shocks etc., should be polished. If, after a longer running period, considerably uneven wear appears, section 06.2, the crankshaft may be reground and used together with thicker bearing shells, see Spare Parts Catalogue.

No scraping or other damage of bearing shells, caps and saddles is allowed. Burrs should be locally removed, only.

10.2.3 Assembling of main bearing

1 **Clean the main bearing shells,** the cap and the journal very carefully.

2 **Take off the protecting tape** from the journal oil holes and lubricate the journal with clean engine oil.

3 **Lubricate the bearing surface,** back side and end faces of the upper bearing shell with clean lubricating oil.

The bearing shell can be completely destroyed (deformed) during the assembly, if it is not lubricated carefully.

4 **Place the end of the bearing shell** in the slot between the journal and the bearing bore, with the lug guiding in the oil groove, and push it **by hand** as far as possible (recommended 2/3 of its length).

5 **Insert the turning tool** 4V85B12 (in-line engine) or 4V85B16 (V-engine) into the main bearing journal radial oil hole and turn the crankshaft **carefully** until the bearing shell has turned into position. Take care that the bearing shell lug slides into the oil groove without being damaged.

Caution! **A bearing shell forced into its place can be completely destroyed due to deformation.**

6 **Remove the turning tool.**

7 **Lubricate the bearing surface** of the lower bearing shell with clean lubricating oil and place it in the bearing cap.

8 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked UP, see Fig 10-2.

9 **Lift the main bearing cap** by pumping oil pressure to the hydraulic jack with the hydraulic pump.

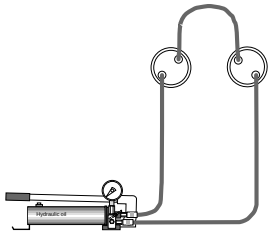
10 **Lubricate the threads of the side screws** (the threads towards the bearing cap) and tighten the screws to the bottom or use the stud tool 4V80D12.

11 **Tighten the nuts by hand.**

12 **Lift the distance sleeves 3V86B46 into position** on the side screws on the **rear side on an in-line engine, or B-bank on an V-engine.** One or two nuts can be tightened simultaneously, Fig 10-1 (A_2).

13 **Screw on the hydraulic tool 3V86B78.**

REASSEMBLING
1. Screw on nuts, attach distance sleeve. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Close the valve and pump pressure to the stated value.
4. Screw the nuts until close contact to face.
5. Open the valve and remove tool set.

14 **Tighten the nut** by the pin 4V86B11 when the hydraulic pressure is **200 bar.**

15 **Lift the distance sleeves 3V86B39 into position** on the bearing cap screws and insert the pins 4V86B02, see Fig 10-1 (B).

16 **Lift the hydraulic tool 3V86B79 into position** by using the tool 3V86B52 and proceed with tightening of the main bearing screws (B).

17 **Lift the distance sleeves 3V86B46 into position** on the side screws on the **rear side on an in-line engine, or B-bank on an V-engine,** straight side of the bearing cap! One or two nuts can be tightened simultaneously, Fig 10-1 (A_2).

18 **Screw on the hydraulic tool 3V86B78** and proceed with tightening of side screw nut (A_2). Tighten to full, stated pressure.

19 **Lift the distance sleeves 3V86B46 into position** on the opposite manoeuvering side screws. One or two nuts can be tightened simultaneously, Fig 10-1 (A_1).

20 **Screw on the hydraulic tool 3V86B78** and proceed with tightening of side screw nuts (A_1). Tighten to full stated pressure.

10.3 Flywheel/thrust bearing

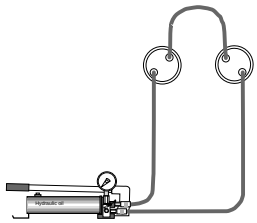
10.3.1 Dismantling of flywheel/thrust bearing

1 **Remove the two crankcase covers** next to the flywheel end, on both sides of the engine. On 4R32, remove the divided end cover inside the flywheel.

2 **Loosen the nuts** of the side screws on the flywheel/thrust bearing and the adjacent main bearing, Fig 10-1 (A).

3 **Lift the distance sleeve 3V86B46 into position** on the side screw. Two nuts can be loosened simultaneously.

DISMANTLING
1. Screw on cylinders by hand
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Screw cylinders 180° counter -clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.

4 **Screw on the hydraulic tool** 3V86B78 and proceed with opening of the side screw nuts (A).

5 **Loosen the nuts of the flywheel/thrust bearing screws** as shown in Fig 10-1 (B).

6 **Lift the distance sleeves 3V86B46 into position** and insert the pins 4V86B11.

7 **Screw on the hydraulic tools** 3V86B78. If necessary, use the lifting tool 3V86B52. Proceed with opening of bearing screws (B).

8 **Remove the nuts of the flywheel/thrust bearing screws.**

9 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked DOWN, see Fig 10-2.

10 **Unscrew the side screws of the flywheel/thrust bearing cap.** Use the stud tool 4V80D12.

11 **Lower the bearing cap** by pumping oil pressure to the hydraulic jack with the hydraulic pump.

12 **Remove the lower bearing shell and the thrust washers.** To remove the thrust washer next to the driving end, an M6 screw can be fitted to each end of the washer, see Fig 10-3.

13 **Insert the turning tool** 3V85B15 into the bearing journal radial oil hole.

14 **Turn the crankshaft carefully** until the bearing shell and the washers have turned 180° and can be removed.

15 **Cover the two bearing journal radial oil holes with tape.**

16 **Check the bearing** in the same way as the main bearings, section 10.2.2. The thrust washers on the same side have to be changed in pairs.

Thrust bearing

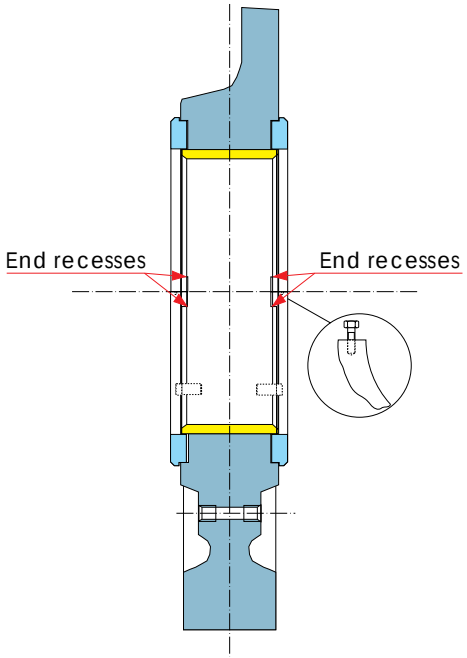


Fig 10-3 3210568935

10.3.2 Assembling of flywheel/thrust bearing

1 **Clean the bearing shells, washers, cap and journal** very carefully.

2 **Take off the protecting tape** from the bearing journal radial oil holes and lubricate the journal with clean engine oil.

3 **Lubricate the bearing surface,** back side and both ends of the upper bearing shell with clean lubricating oil and place the end of the bearing shell in the slot between the journal and the bearing bore. The axial location of the shell is to be secured by keeping the bearing shell end recesses at level with the axial faces in the engine block, see Fig 10-3.

4 **Insert the shell** by hand as far as possible (recommended 2/3 of its length).

5 **Insert the turning tool** 3V85B15 into the bearing journal radial oil hole and turn the crankshaft carefully until the bearing shell has turned into position.

Caution! **A bearing shell forced into its place can be completely destroyed due to deformation.**

6 **Remove the turning tool.**

7 **Lubricate the bearing surfaces and back sides** of the upper thrust washers and push the washers into position by hand. To facilitate the mounting of the washer, the crankshaft can be axially displaced in each direction.

8 **Lubricate the bearing surfaces** of the lower thrust washers and push them into position on the guiding pins in the bearing cap. For mounting the thrust washer next to the driving end an M6 screw can be fitted to each end of the washer, see Fig 10-3.

9 **Lubricate the bearing surface** of the lower bearing shell with clean lubricating oil and place the shell in bearing cap. The axial location of the shell is to be secured by keeping the bearing shell end recesses at level with the axial faces in the cap, see Fig 10-3.

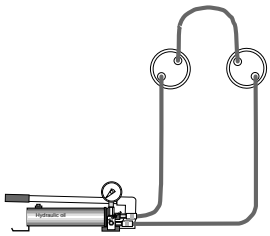
10 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked UP, see Fig 10-2.

11 **Lift the bearing cap** by pumping oil pressure to the hydraulic jack with the hydraulic pump.

12 **Screw the side screws** into the threads of the bearing cap by hand.

13 **Tighten the side screws** to the bottom or by using the stud tool 4V80D12.

REASSEMBLING
1. Screw on nuts, attach distance sleeve. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Close the valve and pump pressure to the stated value.
4. Screw the nuts until close contact to face.
5. Open the valve and remove tool set.

14 **Tighten the nuts of the side screws** on the rear side of the engine as shown in Fig 10-1 (A).

15 **Lift the distance sleeves 3V86B46 into position** on the flywheel/thrust bearing screws and insert the pins 4V86B11, see Fig 10-1 (B).

16 **Screw on the hydraulic tools** 3V86B78. If necessary, use the lifting tool 3V86B52. Proceed with tightening of the bearing screw nuts (B).

17 **Lift the distance sleeve 3V86B46 into position** on the side screw. Two nuts can be tightened simultaneously.

18 **Screw on the hydraulic tool 3V86B78** and proceed with tightening of side screw nuts (A).

10.4 Camshaft bearings

10.4.1 Inspection of the camshaft bearing bush

When the camshaft bearing journal has been removed, the inner diameter of the bearing bush can be measured at site, by using a ball anvil micrometer screw. The wear limit is stated in chapter 06, section 06.2 If the wear limit for one camshaft bearing bush is reached, all camshaft bearing bushes should be replaced. For visual inspection of the camshaft bearing bush, proceed as follows:

1 **Remove both camshaft covers** adjacent to the bearing concerned.

2 **Remove the cover (6)** from the starting air distributor, see chapter 14, Fig 14-2.

3 **Unscrew the rocker arm bracket fastening nuts,** and remove the rocker arm brackets, see Fig 14-1, pos. 1, on the cylinders where the camshaft is to be moved according to step 5, below.

4 **Open the flange connection camshaft piece/bearing journal** towards the driving end of the engine seen from the bearing concerned.

5 **Move the part of the camshaft** located towards the free end of the engine max. 25 mm in the direction of the free end by using a suitable lever.

6 **Check the uncovered part of the bearing bush** by means of a mirror. All camshaft bearing bushes towards the free end of the engine, seen from the bearing concerned, can be checked when the camshaft is in this position.

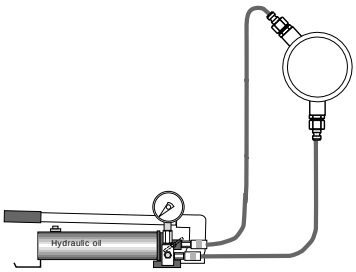
Tool code	Tools are marked with following numbers	
	Inner diameter of camshaft bearing bush (mm)	
	165	150
834010	3283E05	3283E02
834011	2V83H149	3V83H69
834012	3V83H150	3V83H66
834013	2V83H148	3V83H68
834050	3V83E61	3V83E61
836010	4V83G45	4V83G45

10.4.2 Removing of camshaft bearing bush

1 **Remove the camshaft cover,** injection pump, guide block and camshaft piece from the two cylinders adjacent to the bearing concerned. If it is the question of an end bearing, the respective camshaft end piece has to be removed.

2 **Remove the camshaft bearing journal.**

3 **Assemble the removing device** 834010 according to Fig 10-4. Notice the difference in tool assembly for the bearing next to the free end of the engine. When it is a question of an end bearing, insert the guide sleeve 834011, the thicker part being directed towards the middle of the engine.



DISMANTLING
1. Connect hoses, open valve.
2. Tighten the tool assembly.
3. Close the valve and pump to required pressure.
4. Open the valve and remove the tool.

4 **Tighten the hydraulic tool** 834050 by tensioning the pull screw 836010.

5 **Connect the hoses of the hydraulic pump** 2V86A36 to the hydraulic tool.

6 **Pump pressure to the hydraulic tool** to withdraw the bearing bush. **The pressure must not exceed the value stated in chapter 07**, Fig 07-16. If the bearing bush does not move when this pressure is achieved, a light knock on the end flange 834012 can be necessary.

7 **Open the pump valve,** disconnect the hoses of the hydraulic tool and dismantle the removing device.

Removing of camshaft bearing bush

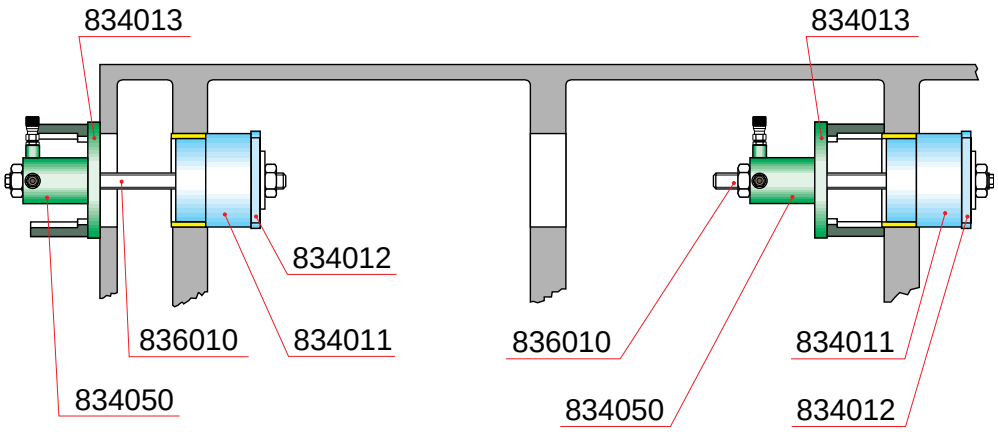


Fig 10-4 321053A9801

10.4.3 Mounting of camshaft bearing bush

1 **Lightly lubricate the new bearing bush** with clean engine oil on the outer surface and put it on the guide sleeve 834011. The notch on the bearing bush side should be positioned downwards, i.e. the oil groove upwards.

2 **Assemble the mounting device** 834010 according to Fig 10-5. Notice the difference in tool assembly for the bearing next to the free end of the engine. When it is a question of an end bearing, insert the guide sleeve 834011, the thinner part being directed towards the middle of the engine.

3 **Tighten the hydraulic tool** 834050 by tensioning the pull screw 836010 lightly.

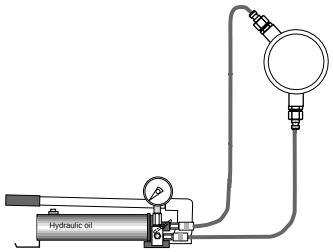
4 **Connect the hoses of the hydraulic pump** 2V86A36 to the hydraulic tool.

5 **Pump pressure to the hydraulic tool** to mount the bearing bush. **The pressure must not exceed the value stated in chapter 07**, Fig 07-16.

6 **Open the pump valve,** disconnect the hoses of the hydraulic tool and dismantle the mounting device.

7 **Lubricate the bearing surface of the bearing bush** and insert the camshaft bearing journal.

8 **Mount the camshaft pieces,** guide blocks, injection pumps and camshaft covers.



REASSEMBLING
1. Connect hoses, open the valve.
2. Tighten the tool assembly.
3. Close the valve and pump to required pressure.
4. Open the valve and remove the tool.

Mounting of camshaft bearing bush

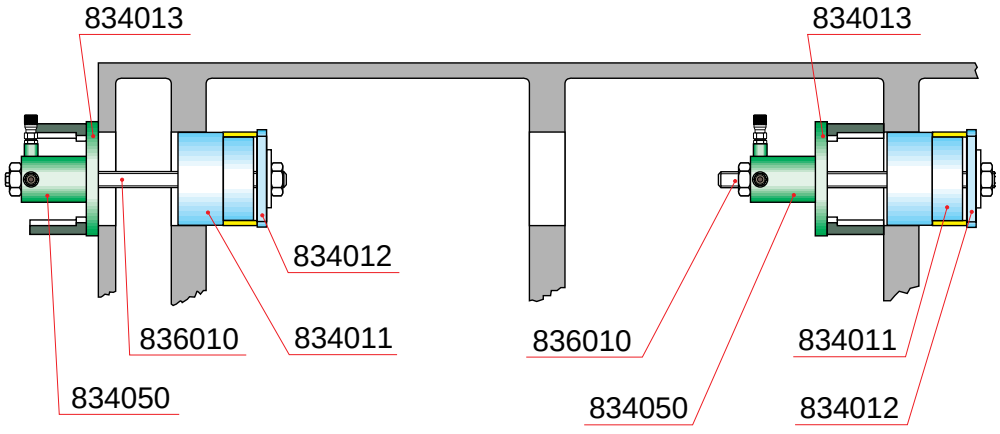


Fig 10-5 321053B9801

10.5 Cylinder liner

10.5.1 Maintenance of cylinder liner

a) **Honing of cylinder liner bore**
Always hone the cylinder liner when new piston rings are mounted. Normally a light honing is sufficient. If the honing is done when the cylinder liner is on its place in the engine block, the crankshaft under the cylinder liner concerned must be covered by plastic film. Honing rests must be prevented from falling into the oil sump of the engine. For the honing process the following instructions are prescribed:

- The honing is to be carried out by means of “Plateau honing”.
- Only ceramic hones with a coarseness of 80 and 400 should be used. The hones with a coarseness of 80 should be used for about 20 strokes or until the polished areas in the cylinder liner are over scraping. The hones with a coarseness of 400 should be used for about 30 strokes to give the correct surface finish.
- The pitch angle of the honing lines in the cross hatch pattern should be about 30°, which is achieved by combining for example 40 strokes/min with a rotational speed of 100 RPM.
- As coolant a honing oil is preferred, but a light fuel oil 2-15 cSt could also be used.
- After honing, the liner bore must be carefully cleaned by using a suitable brush, water (preferably hot) and soap or cleaning fluid, alternatively, light fuel oil. Then dry with a cloth and lubricate with engine oil for corrosion protection.

The honing equipment is delivered with the engine.

b) **Check the inner diameter of the cylinder liner,** use form No. 3210V014.

c) **Cleaning of the cylinder liner water side**
The water side of the cylinder liner can be cleaned of deposits with a wire brush. The cooling bores in the collar can be cleaned by boring with a suitable drill (ø 9.5 - 10 mm).

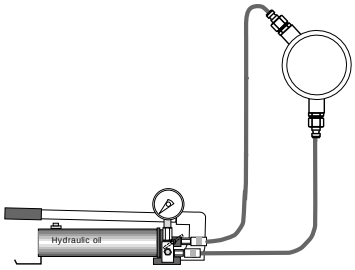
10.5.2 Removing cylinder liner

1 **Drain the engine cooling water** and remove the cylinder head and piston with connecting rod.

2 **Loosen the screw (2)** and remove the holder (1).

3 **Assemble the removing device** 32.83G02 and the hydraulic tool 3V83E61 according to Fig 10-6.

4 **Tighten the hydraulic tool** by tensioning the nut of the pull screw 4V83G45 lightly.



DISMANTLING
1. Connect hoses, open valve.
2. Tighten the tool assembly.
3. Close the valve and pump to required pressure.
4. Open the valve and remove the tool.

5 **Connect the hoses** of the hydraulic pump 2V86A36 to the hydraulic tool.

6 **Pump pressure to the hydraulic tool** to withdraw the cylinder liner. **The pressure must not exceed the value stated in chapter 07**, Fig 07-16.

7 **Open the pump valve,** disconnect the hoses of the hydraulic tool and remove it.

8 **Use the part of the removing device** intended for this purpose to lift the cylinder liner, see Fig 10-6.

10.5.3 Mounting of cylinder liner

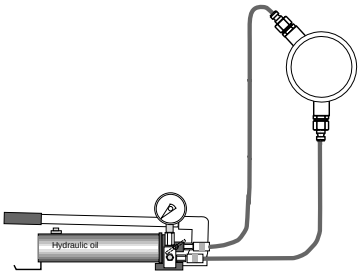
1 **Check that all guide and contact faces** of the engine block and cylinder liner are clean and intact.

2 **Apply a thin layer of non-curing sealing glue,** (Perfect Seal No. 4, Loctite Permatex 1372 or similar) on the upper sealing surface between engine block and cylinder liner. **Note!** Silicone sealant should **not** be used.

3 **Check that the O-ring grooves** of the cylinder liner are clean, and insert new O-rings.

4 **Lubricate the lower O-rings and the sealing faces** with grease and assemble the lifting device, see Fig 10-6.

5 **Lower the liner carefully into the bore** of the engine block. When the lowest O-ring touches the engine block, align the liner so that the mark (3, in Fig 10-6) on the liner is directed towards the driving end of the engine, on the V-engine B-bank towards the free end of the engine. Lower further and press liner into position by hand.



REASSEMBLING
1. Connect hoses, open the valve.
2. Tighten the tool assembly.
3. Close the valve and pump to required pressure.
4. Open the valve and remove the tool.

6 **Check the inner diameter of the cylinder liner,** especially at the level of the guiding surfaces.

7 **Mount the holder** (1) and tighten the screw (2) to the stated torque.

8 **Mount the piston with the connecting rod,** anti-polishing ring and cylinder head, and refill the cooling water.

9 **Check the O-ring seals** from the crankcase side while circulating cooling water. If there is an engine driven cooling water pump, apply 3 bar static pressure.

Removing and lifting of cylinder liner

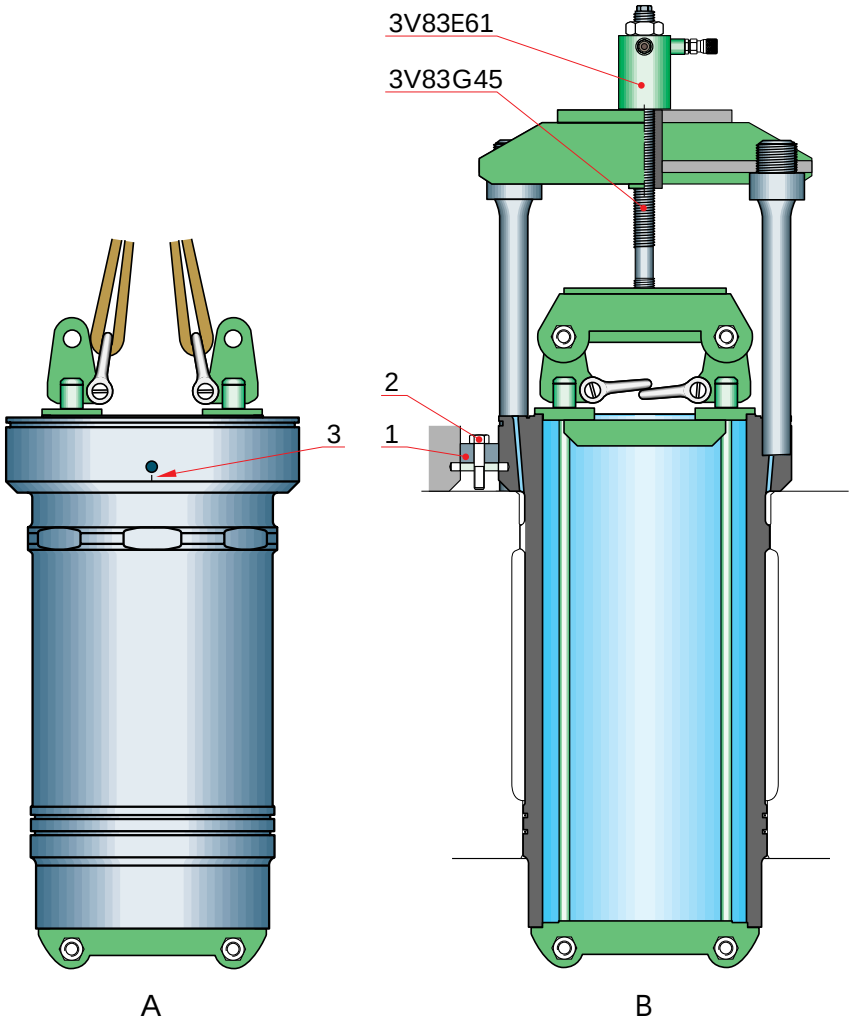


Fig 10-6 3210548930

10.6 Camshaft driving gear bearings

10.6.1 Removing of camshaft driving gear bearing bush

1 **Remove the camshaft gearing** according to section 13.2.

2 **Assemble the removing device** 32.13T01 (834053) according to Fig 10-7.

3 **Proceed according to** section 10.4.2.

Removing of camshaft driving gear bearing bush

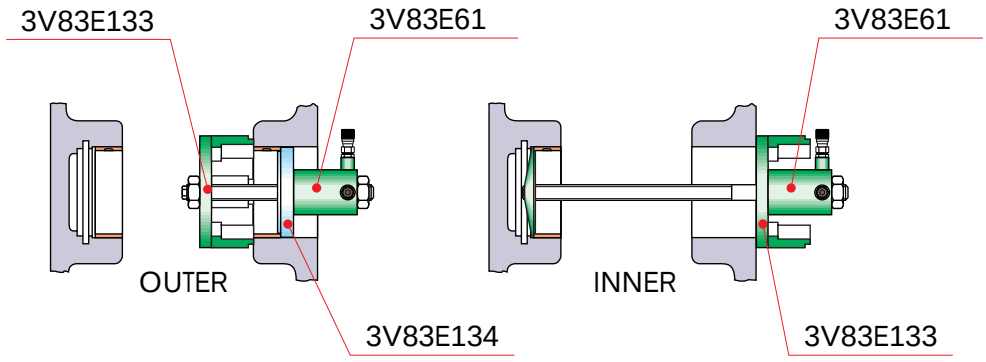


Fig 10-7 3210609908

10.6.2 Mounting of camshaft driving gear bearing bush

1 **Lightly lubricate the new bearing bush** with clean engine oil on the outer surface and put it on the guide sleeve 4V83E80 or 3V83E0134. Note the bearing bush position. Mount the oil groove according to section 13.2.2.

2 **Assemble the removing device** 32.13T01 (834053) according to Fig 10-8.

3 **Proceed according to** section 10.4.3.

Mounting of camshaft driving gear bearing bush

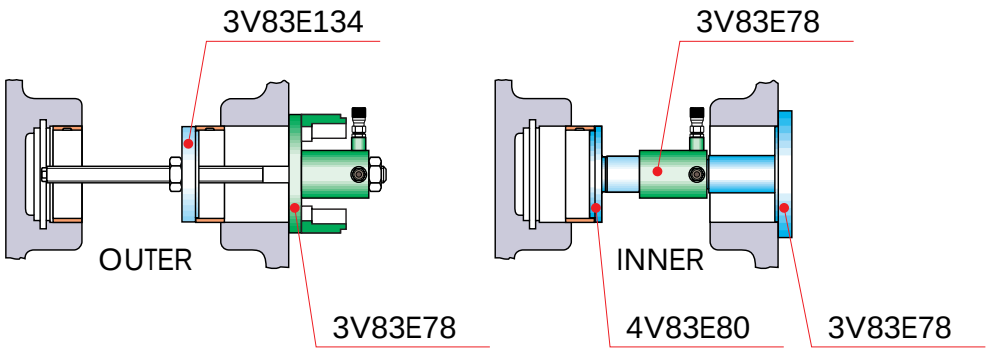


Fig 10-8 3210619908

11. Crank Mechanism: Crankshaft, Connecting Rod, Piston

11.1 Counterbalancing of crankshaft

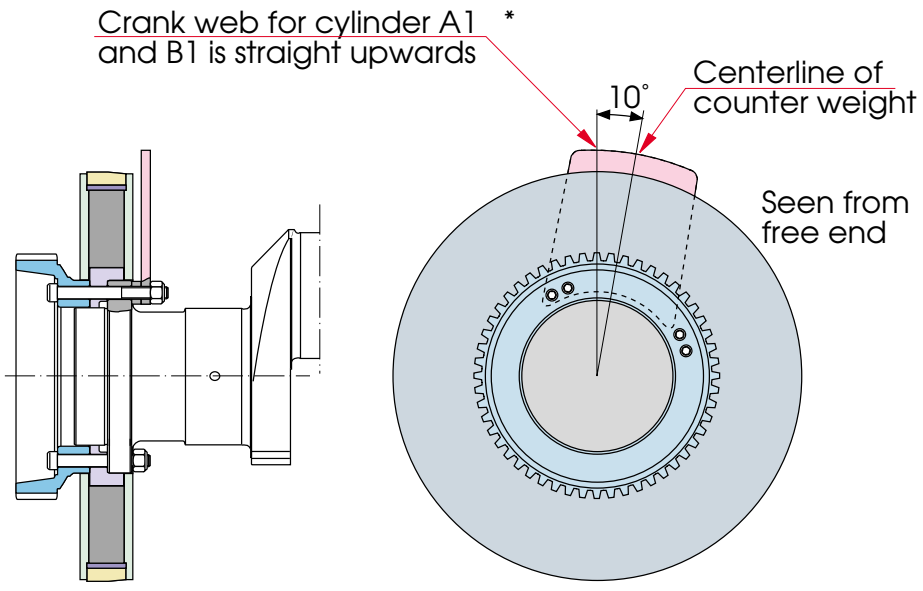
11.1.1 General

The crankshaft is counterbalanced by means of weights on the crank webs. The V-engines have counterweights on all webs.

11.1.2 Counterbalancing of 18-cylinder V-engines

The counterbalancing of the free moment of the 18-cylinder V- engines is accomplished by means of a supplementary weight at the free end of the engine and a specially balanced flywheel. After a possible removal, it is important that the supplementary weight is correctly re-installed, Fig 11-1.

Supplementary weight for 18V34



* For a clockwise rotating engine:
Crankshaft is turned to 25° after TDC for cylinder A1
For a counter-clockwise rotating engine:
Crankshaft is turned to 25° before TDC for cylinder A1

Fig 11-1 3211559045

11.2 Crankshaft

11.2.1 Description of crankshaft

The crankshaft is forged in one piece and provided with counterweights fastened with hydraulically tensioned screws.

At the driving end of the engine, the crankshaft is equipped with a V-ring for sealing off the crankcase, a combined flywheel/thrust bearing and a split gear wheel for camshaft driving.

At the free end, there is a gear for driving of pumps and usually a vibration damper.

The crankshaft can be rotated by a electrical turning device operating the flywheel. Separate instructions for the vibration damper are submitted, if the engine is equipped with such.

11.2.2 Crankshaft alignment

The crankshaft alignment is always done on a thoroughly warm engine, i.e. after running on high enough load during a sufficiently long time to heat up both the engine and the foundation. Recommended values are more than 60% load during more than 6 hours.

The crankshaft alignment should be carried out immediately after the engine is stopped and rapidly but carefully. Only the crankcase cover for the cylinder being measured should be opened and it should be closed immediately after measuring. The crankshaft alignment can be checked either by using a dial indicator or as an alternative an electronic deflection indicator.

By using a dial indicator:

1 **Rotate crank of the first cylinder** near BDC (bottom dead centre) and attach crankshaft dial indicator to the centre marks in the two crank webs. The distance between the indicator and the connecting rod should be as small as possible.

2 **Set indicator at zero.**

3 **Read deflections when rotating crank to rear side,** TDC (top dead centre), operating side and BDC. Record readings in the Measuring Record: “Crankshaft alignment”. **See also work steps for both methods.**

Note! During the alignment procedure the crankshaft should be rotated in the direction of rotation, only. The indicator should not be turned during the measurement.

By using a electronic deflection indicator:

4 **Combine extensions with the transducer (3)** to the required length.

5 **Connect cable (2)** on the measuring unit (1).

6 **Turn on the measuring unit** by pressing Power-button. Push "Light" if needed.

7 **Reset the measuring unit** by pressing Reset-button.

8 **Rotate crank of the first cylinder** near BDC (bottom dead centre) and fit the transducer to the centre marks between two crank webs. The distance between the transducer and the connecting rod should be as small as possible. Fix the cable on the crank web by using suitable bandage or magnetic holder (4), see Fig 11-2.

Dial indicator position and reading

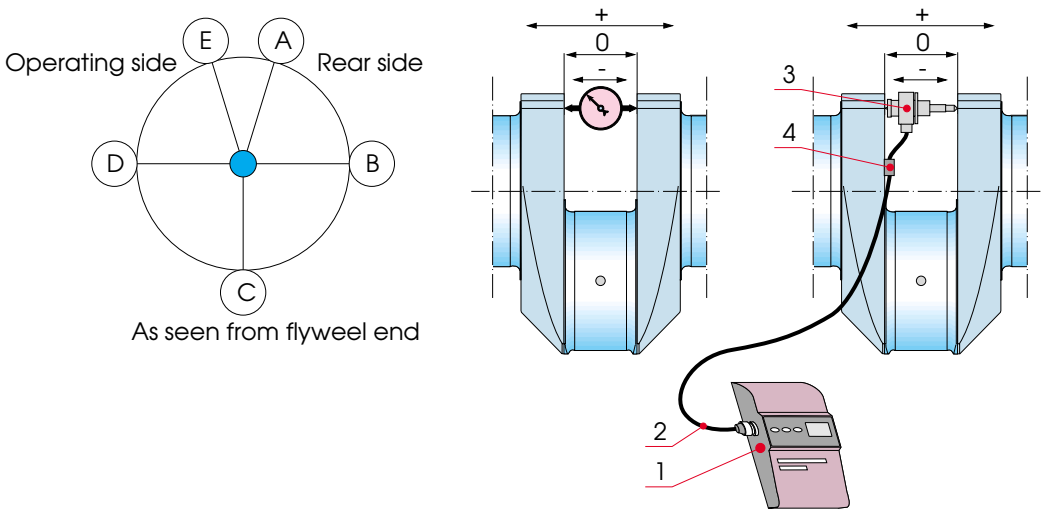


Fig 11-2 3211799901

9 **Adjust the transducer** to a reading somewhere between +0.500 and -0.500 and push "Zero".

10 **Rotate the crank and read deflections** in the marked positions according to Fig 11-2. Starting point for clockwise rotating engine is measuring point "A" and counter-clockwise rotating engine measuring point "E". B is rear side, C is TDC (top dead centre), D is operating side, A and E are BDC (bottom dead centre). Record readings in the Measuring Record: "Crankshaft alignment".
Note, values in 1/100 mm!

Note! **During the alignment procedure the crankshaft should be rotated in the direction of rotation, only.**

For both methods:

11 **Repeat this procedure with other cylinders.**

12 **Following limits of misalignment** are stated for an engine having normal running temperature (within 10 min after running at 60% load, or higher, for 6 h, or more):
a) **on the same crank,** the difference between two diametrically opposed readings must not exceed 0.04 mm after installing or re-aligning. Re-alignment is necessary if this limit is exceeded by more than 0.02 mm.
b) **on two adjacent cranks,** the difference between two corresponding readings must not exceed 0.04 mm. Re-alignment is necessary if this limit is exceeded.
c) **when the crank pin for cyl.1 is at TDC,** the reading should be negative, max. -0.04 mm (-0.06 mm if flex. coupling).
Before re-aligning the engine and the driven machinery, a control measurement of the main bearings should be made.

Note! In an engine having a normal ambient temperature, the corresponding values must be based on experiences from the particular installation.

11.2.3 Measurement of thrust bearing axial clearance

1 **Lubricate the bearings** by running the prelubricating pump for a few minutes and Rotate the crankshaft simultaneously a few revolutions with the turning device.

2 **Apply a measure gauge,** for instance, against the plane end surface of the flywheel.

3 **Move the crankshaft** by a suitable lever in either direction until contact is established with the thrust bearing.

4 **Set the measure gauge at zero.**

5 **Move the crankshaft** in the opposite direction, and read the axial clearance from the measure gauge.

Note! Repeat the movement of crankshaft to ensure that correct clearance is measured.

11.2.4 Cleaning of oil lock at crankshaft seal

1 **Remove the outer plug (1),** Fig 11-3.

2 **Blow through the bores of the oil lock** from outside with compressed air.

There is no need for refilling the oil lock with oil after cleaning.

Oil lock at crankshaft seal

1. Plug

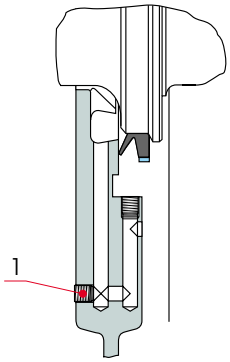


Fig 11-3 3211659601

11.3 Connecting rod and piston

11.3.1 Description of connecting rod and piston

The connecting rod is of a three-piece design, so called “Marine type connecting rod”. The combustion forces are distributed over a maximum bearing area. The relative movements between mating surfaces are minimized.

The connecting rod is forged and machined of alloyed steel and splitted horizontally in three parts to allow removal of piston and connecting rod parts. All connecting rod bolts are hydraulically tightened.

The piston is of the composite type with an aluminum forged skirt and a forged steel crown screwed together. The space, formed between the crown and the skirt, is supplied with lubricating oil for cooling of the crown by means of the cocktail shaker effect. The lubricating oil is led from the main bearing, through the drilling's in the crankshaft, to the big end bearing, and further through the drilling's in the connecting rod, gudgeon pin and piston skirt, up to the cooling space, and from there back to the oil sump.

Note! **Always handle the pistons with care.**

The piston ring set consists of two chrome-plated compression rings and one spring-loaded oil scraper ring.

Connecting rod parts

1. Connecting rod, upper part
2. Shim
3. Big end, upper half
4. Big end, lower half
5. Big end

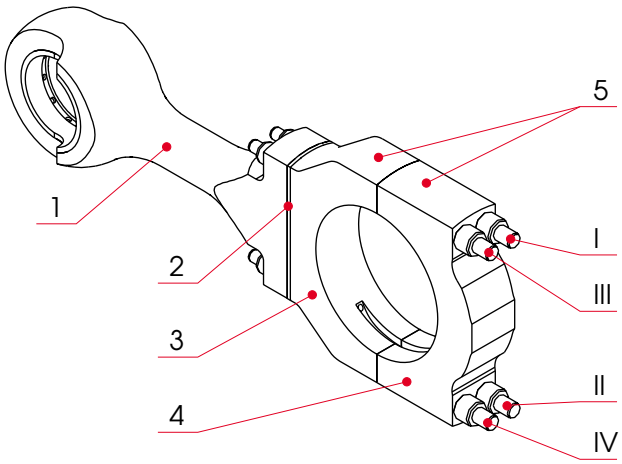


Fig 11-4 3211649544

11.3.2 Removing of piston and upper part of connecting rod for overhaul

1 **Remove the cylinder head,** see chapter 12.

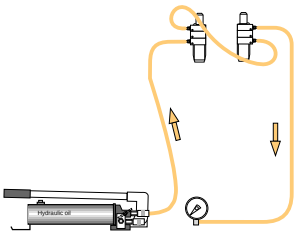
2 **Remove the anti-polishing ring.** Use the tool if necessary. By cranking the engine, the piston pushes out the anti-polishing ring.

3 **Remove both crankcase covers** adjacent to the connecting rod concerned on both side of engine.

4 **Rotate the crankshaft to the BDC** on the cylinder concerned.

5 **Lift the distance sleeves** into position.

Before mounting of the tension screws, check that plastic plugs are mounted inside the tension screws.



DISMANTLING
1. Lift the distance sleeves.
2. Mount the tension screws.
3. Attach hydraulic cylinders and nuts.
4. Connect hoses, open valve.
5. Tighten the tool assembly, until the piston and cylinder are on the same level, open the nuts by 180°.
6. Close the valve, pump to required pressure. Open the nuts about half a turn.
7. Open the valve slowly and remove the tool .

6 **Screw the tension screws** on the connecting rod studs until plastic plugs and studs are in contact.

7 **Lift the hydraulic cylinders** into position and mount the strap nuts, see Fig 11-7.

8 **Connect the hoses** on the hydraulic pump 4V86A33, see adjacent figure.

9 **Open the release valve** and tighten the tool assembly to expel possible oil until the piston and cylinder are on the same level, see Fig 11-7. **This is very important as the effective stroke of the pistons is limited and due to that there is a great risk for insufficient tightening of the nuts, which may cause serious engine damage.** Open the nuts about half a revolution (180°).

10 **Strain the screws by raising the pressure** to the value stated in the chapter 07., and proceed with opening the nuts.

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

11 **Release the pressure slowly and** disconnect the hoses, unscrew the tightening nuts and remove hydraulic tool as one package.

Caution! **Cranking of the engine when studs (M24) are mounted is prohibited, otherwise great risk of damaging the engine block and/or the lower part of connecting rod.**

12 **Remove the nuts** and the studs (M24) by using the tool 4V80D30. The locking screw of the tool has left-hand threads.

Note! **When using the stud remover 4V80D30 only the inner hexagon 27 key grip should be used when the stud is removed or tightened to torque. The outer left hand hexagon 24 screw is only for locking the tool onto the stud and will break if used to loosen the bolt.**

13 **Rotate the crank pin** of the cylinder concerned upwards until the limiter can be mounted.

14 **Mount the limiter 3V83F204** in the lower part of cylinder liner and tighten the screw, see Fig 11-6.

15 **Separate the upper part (1) from** the big end (5) by rotating the crankshaft towards BDC. Support the upper part of the connecting rod to avoid damaging the cylinder liner. **Note! To avoid damaging the guiding pins the separation of the upper part (1) and the big end (5) should be done aligned.**

16 **Remove the shim (2),** see Fig 11-4. **Do not mix the shims (2) with other connecting rod shims.**

17 **Mount the support arm (11)** on the big end by using two (M24) studs and nuts, see Fig 11-5. Tighten by hand.

18 **Mount the glides (9) into the position,** lift the upper part (10) into the position and tighten the nuts.

19 **Rotate the crankshaft towards TDC** until the shaft (12) can be mounted. Secure by the pin (13).

Extension for connecting rod

2. Screw
1V83F190 Extension for conn. rod
9. Glide
10. Upper part
11. Support arm
12. Shaft
13. Pin
2V83F192 Lifting tool for piston

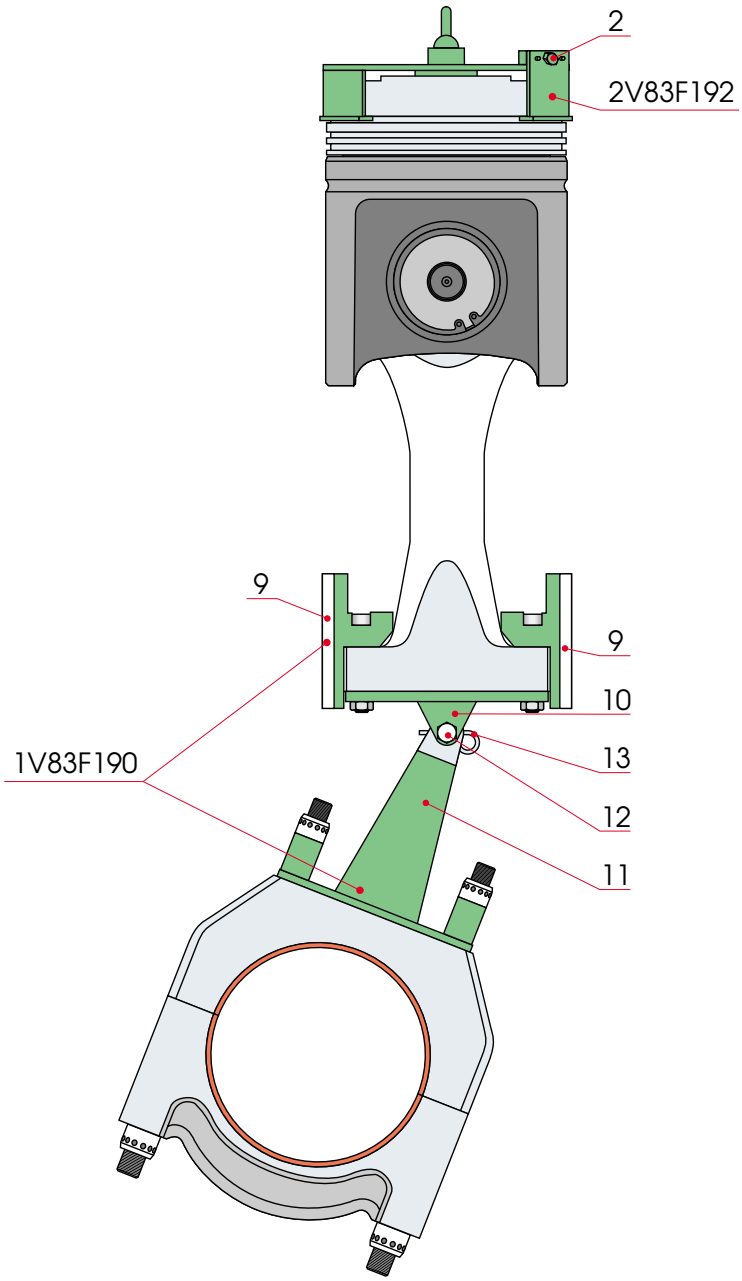


Fig 11-5 3211739701

20 **Rotate the crankshaft** until the piston rings can be removed.

21 **Mount the lifting tool 2V83F192** for the piston in the upper piston ring groove. Tighten the screw (2).

22 **Remove the pin (13)** and the shaft (12).

23 **Lift the piston and the upper part of connecting rod.**

24 **Repeat the steps above in the other** connecting rod on the same crank pin.

11.3.3 Changing of big end bearings

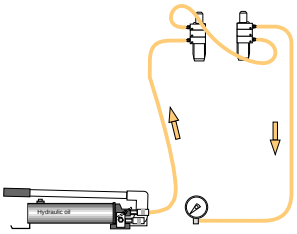
1 **Remove both crankcase covers** adjacent to the connecting rod concerned on both side of engine.

2 **Rotate the crankshaft to the BDC** on the cylinder in concern.

3 **Lift the distance sleeves** into position.

Before mounting of the tension screws, check that plastic plugs are mounted inside the tension screws.

4 **Screw the tension screws** on the connecting rod studs until plastic plugs and studs are in contact.



DISMANTLING
1. Lift the distance sleeves.
2. Mount the tension screws.
3. Attach hydraulic cylinders and nuts.
4. Connect hoses, open valve.
5. Tighten the tool assembly, until the piston and cylinder are on the same level, open the nuts by 180°.
6. Close the valve, pump to required pressure. Open the nuts about half a turn.
7. Open the valve slowly and remove the tool .

5 **Lift the hydraulic cylinders** into position and mount the strap nuts, see Fig 11-7.

6 **Connect the hoses** on the hydraulic pump 4V86A33, see adjacent figure.

7 **Open the release valve** and tighten the tool assembly to expel possible oil until the piston and cylinder are on the same level, see Fig 11-7. **This is very important as the effective stroke of the pistons is limited and due to that there is a great risk for insufficient tightening of the nuts, which may cause serious engine damage.** Open the nuts about half a revolution (180°).

8 **Strain the screws by raising the pressure** to the value stated in the chapter 07., and proceed with opening the nuts.

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

9 **Release the pressure slowly** and disconnect the hoses, unscrew the tightening nuts and remove hydraulic tool as one package.

Caution! **Cranking of the engine when studs (M24) are mounted is prohibited, otherwise great risk of damaging the engine block and/or the lower part of connecting rod.**

10 **Remove the nuts** and the studs (M24) by using the tool 4V80D30. The locking screw of the tool has left-hand threads.

Note! **When using the stud remover 4V80D30 only the inner hexagon 27 key grip should be used when the stud is removed or tightened to torque. The outer left hand hexagon 24 screw is only for locking the tool onto the stud and will break if used to loosen the bolt.**

11 **Rotate the crank pin** of the cylinder concerned upwards until the limiter can be mounted.

12 **Mount the limiter 3V83F204** in the lower part of cylinder liner and tighten the screw, see Fig 11-6.

Tools for connecting rod V34

6. Guiding pins
7. Screw
1V83F171 Assembling tool
3V83F163 Support arm
2V83F165 Sledge
3V83F177 Support arm
3V83F180 Mounting screw
3V83F204 Limiter
4V86B269 Protecting cap

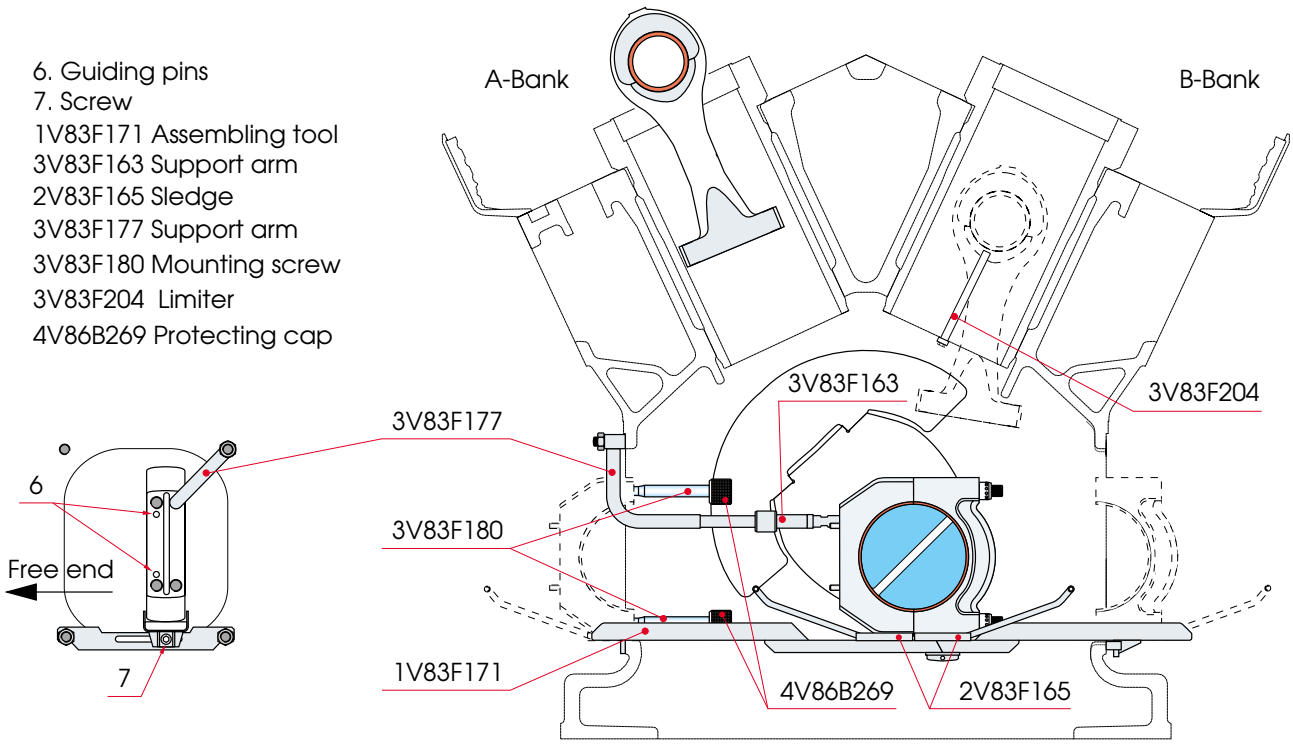


Fig 11-6

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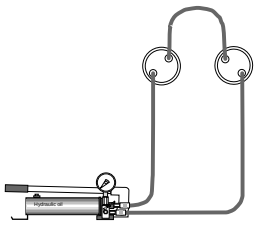
13 **Separate the upper part (1) from** the big end (5) by rotating the crankshaft towards BDC. Support the upper part of the connecting rod to avoid damaging the cylinder liner. **Note! To avoid damaging the guiding pins the separation of the upper part (1) and the big end (5) should be done aligned.**

14 **Remove the shim (2),** see Fig 11-4. **Do not mix the shims (2) with other connecting rod shims.**

DISMANTLING
1. Screw on cylinders by hand
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Screw cylinders 180° counter -clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.

Always when assembling tool or/and the limiter is/are mounted in the crankcase observe extremely cautiousness when using the turning device.

15 **Lift the distance sleeves** and screw on the hydraulic tools 3V86B186 into position on the connecting rod screws, places I and IV, see Fig 11-4. Proceed with opening of the nuts.

Note! **Loosen crosswise.**

16 **Lift the distance sleeves** into position II and III, see Fig 11-4. Proceed with opening of the nuts.

17 **Unscrew two nuts diagonally** and remove the studs by using the tool 4V80D26. The locking screw of the tool has left-hand threads.

Note! **When using the stud remover 4V80D26 only the inner hexagon 27 key grip should be used when the stud is removed or tightened to torque. The outer left hand hexagon 24 screw is only for locking the tool onto the stud and will break if used to loosen the bolt.**

18 **Mount the mounting screws 3V83F180** in the free thread holes and tighten the nuts by hand.

19 **Unscrew the other nuts** and remove the studs as described above.

20 **Mount the assembly rail 2V83F171** through the crank case openings on the lower crank case cover studs and tighten the nuts, see Fig 11-6.

21 **Loosen the screw (7)** and adjust the side position of the rail correct and tighten the screw. Lift the sledges 2V83F165 on the rail.

22 **Rotate the crankshaft** by using the turning device manually until the big end is leaning against the sledge.

23 **Mount the support arm 3V83F163** on the upper threads (M24) of the big end and support arm 3V83F177 on the upper crank case stud, see Fig 11-6. Tighten the nut.

Piston and connecting rod assembly

3. Securing ring
3V83F158 Assembling tool for piston
1V84D43 Compression tool for piston rings
3V86B186 Hydraulic tightening tool for M30 screws
3V86B158 Hydraulic cylinder
2V86B187 Distance sleeve
2V86B201 Hydraulic tightening tool for M24 screws
2V86B204 Distance sleeve

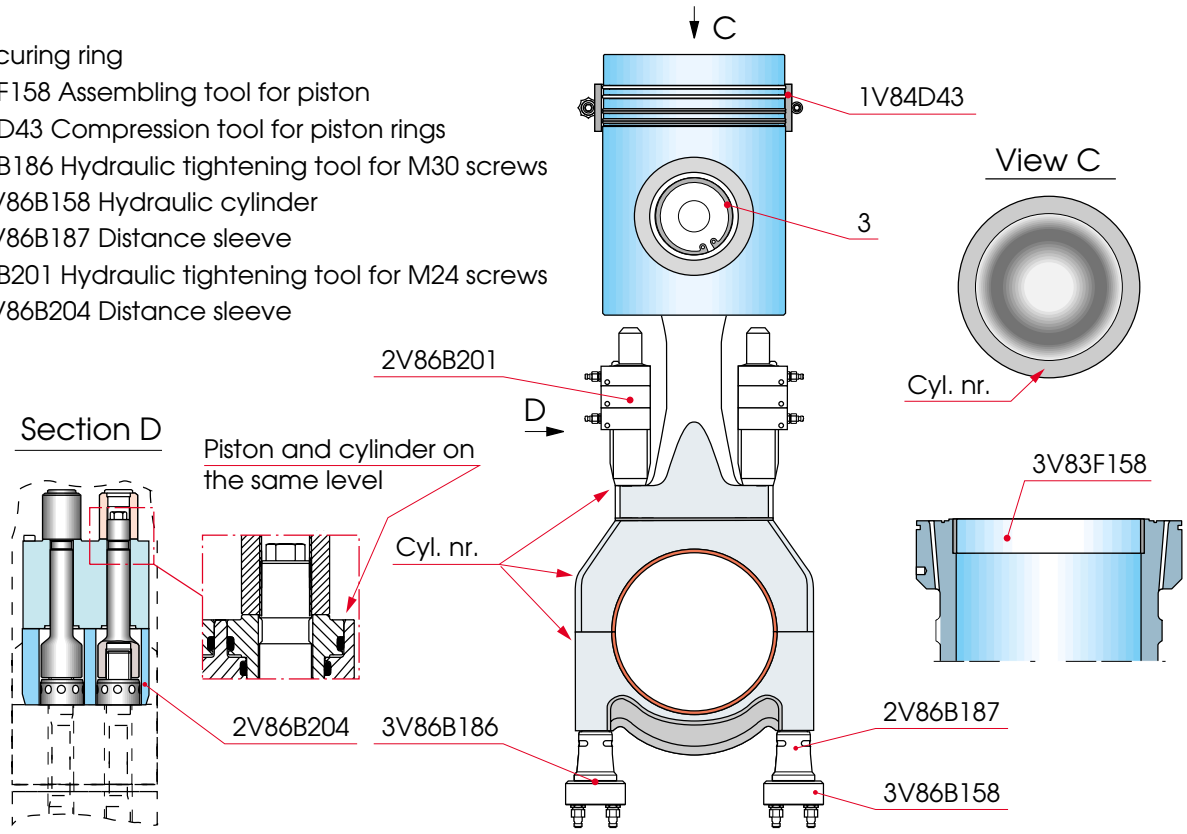


Fig 11-7 321162200045

24 **Tighten the hand nut of the tool.**

25 **Unscrew the nuts** on the mounting screws.

26 **Pull lower part of the big end bearing cap out** of the crankcase, by using the sledge. Take care not to damage the crank pin. Support the lower half sideways and don't drop it.

27 **Apply the protecting caps** 4V86B269 on the screws and remove the support arm.

28 **Pull the upper part out** of the crankcase, by using the sledge. Support the lower half sideways and don't drop it.

Note! **Take care not to damage the crank pin.**

29 **Remove the other big end as described above.**

30 **Cover the crank pin** and oil holes with tape and clean plastic.

11.3.4 Maintenance of piston, rings and connecting rod bearings

1 Remove the securing ring (3) from the gudgeon pin hole in the piston, on the side where the gudgeon pin drawing number is located, by using the pliers J5.

Note! Never compress the securing ring more than necessary to remove it from the groove.

2 Drive out the gudgeon pin from the opposite side. In low temperatures the gudgeon pin may stick but will be easily removed after heating the piston to about 30°C.

3 If the rings and grooves require cleaning, measuring etc., remove the piston rings by using the pliers 320D12/6-S7/8. Before removing, note the positions of the rings to ensure mounting in the same grooves. The design of the pliers prevents overstressing of the rings. Using other means may overstress the rings.

4 Clean all the parts carefully. Remove burned carbon deposits from the piston and piston ring grooves. Special care should be taken not to damage the piston material. Never use emery cloth on the piston skirt.

The cleaning is facilitated if coked parts are soaked in kerosene or fuel oil. An efficient carbon solvent — e.g. ARDROX No. 668 or similar — should preferably be used to facilitate cleaning of the piston crown. When using chemical cleaning agents, take care not to clean piston skirt with such agents because the phosphate/graphite overlay may be damaged.

5 Measure the height of the piston ring grooves and fill in the measuring record.

6 Inspect anti-polishing ring. Turn the ring upside down after first period. Change the ring every second period.

When mounting a new cylinder liner, or honing the old liner, all rings are to be replaced by new ones, acc. to chapter 04.

7 Check the gudgeon pin and big end bearing clearances by measuring the pin diameters and assembled bearing bores separately. When measuring the big end bearing bore all the connecting rod screws (upper and lower) must be tightened to the stated pressure.

Regardless of the condition of the big end bearing it is recommended to replace bearing shells at every piston overhaul.

Mark new bearings with the bearing number.

Note! It is very important that the bearing shells are mounted straight.

11.3.5 Assembling and mounting of piston and connecting rod

1 Lubricate the gudgeon pin, and mount it from the same side from where it was removed, with the end marked with the drawing number in the same direction. The cylinder number is stamped on the piston crown and connecting rod, Fig 11-7. When changing the piston, mark the new piston with the same cylinder number in the same place as on the replaced one.

At low temperatures, the gudgeon pin may stick but will be easily fitted after heating the piston to about 30°C, e.g. in oil.

2 Mount the securing ring (3).

Note! Never compress the securing ring more than necessary to fit into the groove. If the ring is loose in its groove after mounting, it must be replaced by a new one.

3 Mount the assembling tool through the crank case openings on the crankcase cover lower studs and tighten the nuts, see Fig 11-6. Mount the sledges 2V83F165 on the rail.

Caution! Always when assembling tool or/and the limiter is/are mounted in the crankcase observe extremely cautiousness when using the turning device.

4 Rotate the crankshaft, until the big end halves can be placed on the crank pin by using the turning device manually.

Note! The guiding pins between upper part of connecting rod and big end should be towards free end.

5 Clean the big end upper half carefully. Mount the shell, so that the lug guides in its groove.

Note! It is very important that the bearing shells are mounted straight.

6 **Mount the support arm 3V83F163,** the mounting screws 3V83F180 and the protecting caps 4V86B269.

7 **Take off the protecting tape** from the crank pin oil holes and lubricate the crank pin with clean engine oil.

8 **Lift the upper big end half** on the sledge.

9 **Push the upper big end half** carefully against the crank pin, take care not to damage the crank pin.

10 **Mount the support arm 3V83F177** on the upper crank case stud, see Fig 11-6. Tighten the nut.

11 **Tighten the hand nut of the tool.** Remove the protecting caps.

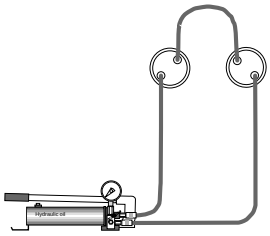
12 **Clean the big end lower half carefully.** Mount the shell, so that the lug guides in its groove.

Note! **It is very important that the bearing shells are mounted straight.**

13 **Lift the big end lower half** on the sledge.

14 **Push the lower big end half carefully** against the crank pin and check that guiding pins are in right position, take care not to damage the crank pin.

REASSEMBLING
1. Screw on nuts, attach distance sleeve. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Close the valve and pump pressure to the stated value.
4. Screw the nuts until close contact to face.
5. Open the valve and remove tool set.

15 **Mount the nuts** and tighten by hand.

16 **Mount the the studs** and tighten to the stated torque by using the tool 4V80D26, see section 07.3. Mount the nuts and tighten by hand.

17 **Replace the mounting screws** by the normal studs and tighten as mentioned above. Mount the nuts and tighten by hand.

18 **Remove the assembling tool.**

19 **Lift the distance sleeves** and screw on the hydraulic tools 3V86B186 into position on the big end studs, places I and IV, see Fig 11-4 and proceed with tightening of the nuts in hydraulic pressure according to section 07.3.

Note! **Tighten crosswise in two steps.**

20 **Lift the distance sleeves** into position II and III, see Fig 11-4 and proceed with tightening of the nuts in hydraulic pressure according to section 07.3.

21 **Release the pressure slowly by opening the valve.** Close the valve and rise the pressure to the fully stated pressure, according to section 07.3.

22 **Release the pressure slowly** by opening the valve.

23 **Lift the distance sleeves** and screw on the hydraulic tools into position on the big end studs, places I and IV. Proceed with tightening of the nuts in fully stated pressure according to section 07.3.

24 **Release the pressure slowly** by opening the valve and remove tool set.

Note! **Check that the big end is movable axially after tightening.**

25 **Mount the lifting tool 2V83F192** for the piston in the upper piston ring groove. Tighten the screw (2), see Fig 11-5.

26 **Lift the piston and upper part of connecting rod.**

27 **Mount the glides (9) into the position,** lift the upper part (10) into the position and tighten the nuts, see Fig 11-5.

28 **Mount the support arm (11)** on the big end by using two (M24) studs and nuts, see Fig 11-5. To secure that the piston is free sliding in the cylinder liner during assembly, the nuts should first be tightened by hand and then loosened so that there is approx. 10 mm clearance between the nuts and the support arm.

29 **Mount the limiter 3V83F204** in the lower part of cylinder liner and tighten the screw, see Fig 11-6.

30 **Place the mounting tool 3V83F158** into the cylinder liner.

31 **Lubricate the piston.**

32 **Lower the piston/connecting rod upper part** carefully into the cylinder liner, until the upper part (10) and support arm (11) can be connected by the shaft (12) and secured by the pin (13). Rotate the crankshaft if necessary.

33 **Remove the lifting tool** for the piston.

34 **Rotate the crankshaft** towards TDC until the piston rings and the clamp device can be mounted.

35 **Mount the piston rings** by using the pliers 320D12/6-S7/8. If rings are reused, take care not to turn them upside down. The rings should be placed with gaps located 120° in relation to each other. Note the mark “TOP” near the ring gap, that should be mounted upwards.

36 **Lubricate the piston** and place the clamp device for piston rings, 1V84D43, around the piston, checking that the piston rings slide into their grooves.

37 **Lower the piston/connecting rod upper part** carefully into the cylinder liner by using turning device. Few strokes with non-recoiling hammer onto the top of piston will help if the piston movement downwards stop. Rotate the crankshaft until piston rests on the limiter.

Note! **Take care that the crankshaft is not rotated too far as this will damage the limiter or/and cylinder liner.**

Note! **The piston should move freely in the liner when the instructions above are followed. If the piston movement downwards stop, the support arm (11) will touch the M24 nuts. In that case, stop rotating the crankshaft immediately as there is a great risk of damaging the piston rings.**

38 **Remove the mounting tool** inside the cylinder liner.

39 **Mount the anti-polishing ring.**

40 **Remove the pin (13) and the shaft (12).** Unscrew nuts and remove the upper part (10) and the glides (9).

41 **Unscrew the nuts** and remove the support arm (11). Unscrew the studs.

42 **Turn the lower part (5)** of the connecting rod straight upwards. Mount the shim (2).

43 **Rotate the crank pin** of the cylinder concerned towards TDC.

Note! **To avoid damaging the guiding pins the connecting of the upper part (1) and the big end (5) should be done aligned.**

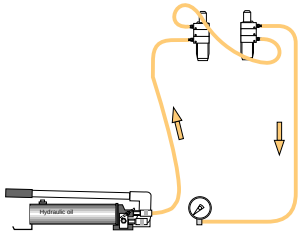
44 **Place the upper part of the connecting rod** and the big end. Remove the limiter.

45 **Rotate the crankshaft counter-clockwise** until the studs (M24) can be mounted. Tighten studs to correct torque by using the tool 4V80D30, see section 07.3.

46 **Mount the nuts** and tighten by hand.

47 **Lift the distance sleeves** into position.

Before mounting of the tension screws, check that plastic plugs are mounted inside the tension screws.



REASSEMBLING
1. Lift the distance sleeve.
2. Mount the tension screws.
3. Attach hydraulic cylinders and nuts.
4. Connect hoses, open valve.
5. Tighten the tool assembly, until the piston and cylinder are on the same level.
6. Close the valve, pump to required pressure. Tighten the nuts. Release the pressure slowly.
7. Repeat steps 5 and 6.
8. Open the valve slowly and remove the tool.

48 **Screw the tension screws** on the connecting rod studs until plastic plugs and studs are in contact.

49 **Lift the hydraulic cylinders** into position and mount the strap nuts, see Fig 11-7.

50 **Connect the hoses** on the hydraulic pump 4V86A33, see adjacent figure.

51 **Open the release valve** and tighten the tool assembly to expel possible oil until the piston and cylinder are on the same level, see Fig 11-7. **This is very important as the effective stroke of the pistons is limited and due to that there is a great risk for insufficient tightening of the nuts, which may cause serious engine damage.**

52 **Strain the screws by raising the pressure** to the value stated in the chapter 07., section 07.3 and tighten the nuts by the pin. Release the pressure slowly.

53 **Repeat the steps 51 and 52.** See adjacent figure.

54 **Release the pressure slowly.** Disconnect the hoses and remove the tools.

Note! Check that all tools are removed from crankcase.

11B. Piston Overhaul

11B.1 General

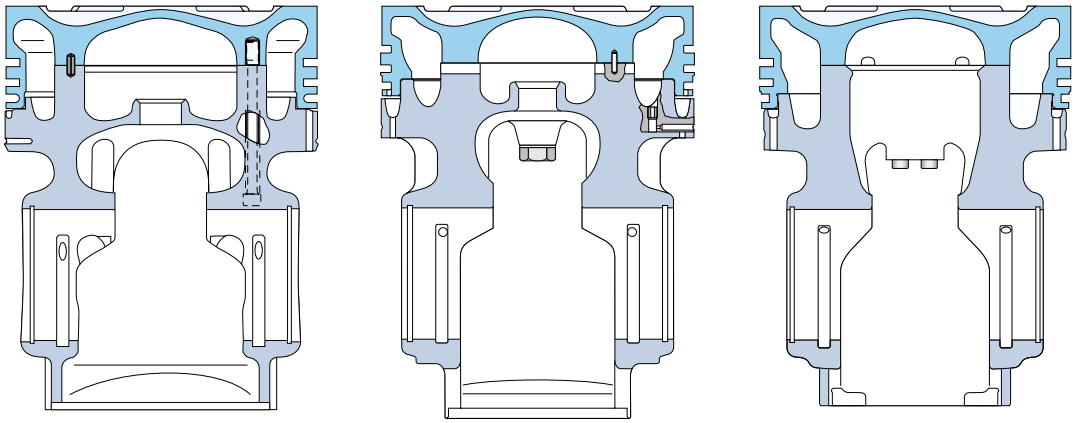
All the engines mentioned in the table below are fitted with composite type pistons.

Manufacturer/ type marked in Instruction Manual	Fastening screws for the crown	W32	32LN	W32DF	W34SG
KS / (type 1)	Four (4) M16 screws	X(1)	X		X
Mahle / (type 2)	Two (2) M22 screws	X	X	X	
Wecometal / (type 3)	Four (4) M14 screws	X	X		

Note! (1) On W32 KS-piston crown, there is only an inner support surface.

For these pistons it is necessary to make more extensive inspections at every piston overhaul.

Pistons



Piston of type 1 Piston of type 2 Piston of type 3

Fig 11B-1 321180200112

11B.2 Pistons

The piston assembly must be dismantled for inspection of mating surfaces between piston skirt and piston crown and for inspection and cleaning of cooling oil spaces.

11B.3 Piston crown

11B.3.1 Visual inspection

The combustion space must be checked for corrosion and/or burning marks.

- If marks deeper than 2 mm are found the piston crown should be replaced.

Deposits in the cooling oil space thicker than 0.5 mm is an indication of contaminated lubricating oil. Such extensive deposit layers can cause overheating of the piston crown.

11B.3.2 Crack detection test

A crack detection test by use of liquid penetrant or, preferably, magnetic particle detection method should be performed, comprising all surfaces.

- No cracks are allowed.

11B.3.3 Measurements

Piston ring grooves to be measured regarding wear in accordance with normal practice.

Measurements of the distance between the inner and outer support surfaces must be made, see piston type specific instructions below. Please note that a special measuring tool has been designed for this measurement.

11B.3.4 Reconditioning

Please contact Wärtsilä for reconditioning of piston crowns.

No repair welding is allowed.

11B.4 Piston skirt

11B.4.1 Visual inspection

The running surface of the skirt is coated with a graphite-phosphate layer. Consequently cleaning with use of emery cloth or other abrasives is not allowed.

- Excessive wear marks and/or scoring/seizure marks on the running surface may require replacement of the skirt.

11B.4.2 Support surfaces

Assessment of wear of the support surfaces to be made by measurement of the distance between the inner and outer support surfaces, see measurement record 3211V025GB.

11B.4.3 Crack detection test

Crack detection test of the entire piston skirt with use of liquid penetrant must be made. Special attention must in this regard be given to the upper part of the piston skirt and to the gudgeon pin bore with its supports to the upper part and to the circumferential part of the skirt, see Fig 11B-2.

Piston skirt

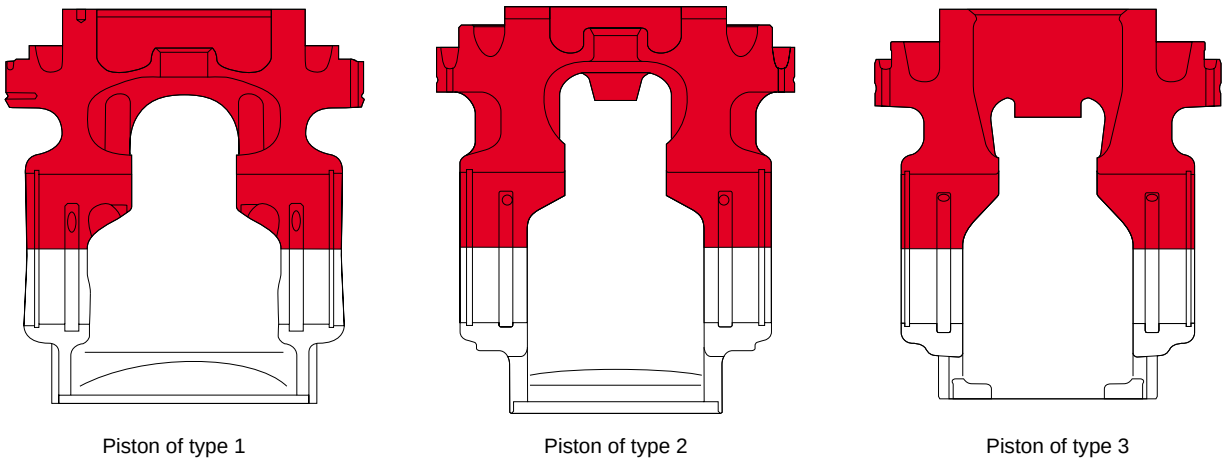


Fig 11B-2 321180200112

- As piston skirts are cast pieces a crack detection test may also give indications for surface “defects” which are normal in castings. Indications exceeding 5 mm in length should be examined more in detail. If a crack is confirmed, the piston skirt must be replaced with a new or reconditioned one.

11B.4.4 Measuring of piston crown and piston skirt

Measurements of the distance between the inner and outer support surfaces must be measured according to the measurement record 3211V025GB.

11B.4.5 Assembling of pistons (All types)

If the inspections are resulting in a conclusion that a piston can be reused **the same pair of crown and skirt must be assembled together again**.

It is not allowed to mix partly worn but reusable crowns and skirts!

When assembling a piston crown to a piston skirt follow tightening procedure mentioned in chapter 07.

12. Cylinder Head with Valves

12.1 Description

The cylinder heads are cast of special quality gray iron. Each head includes two inlet valves, two exhaust valves, a centrally located injection valve and main gas admission valve.

12.2 Removing and mounting of the cylinder head

12.2.1 Removing of the cylinder head

1 **Drain the cooling water.** Remove the cooling water discharge pipe (6).

2 **Remove the cylinder head cover,** the cover over the injection pump and the insulating panel over the exhaust gas connection to the cylinder head.

Cylinder head

5. Cylinder head
6. Discharge pipe
7. Injection valve
8. Bearing bracket for rocker arms
11. Inlet valve seat ring
12. Exhaust valve seat ring
14. Main gas admission valve
19. Hose
20. Distance ring

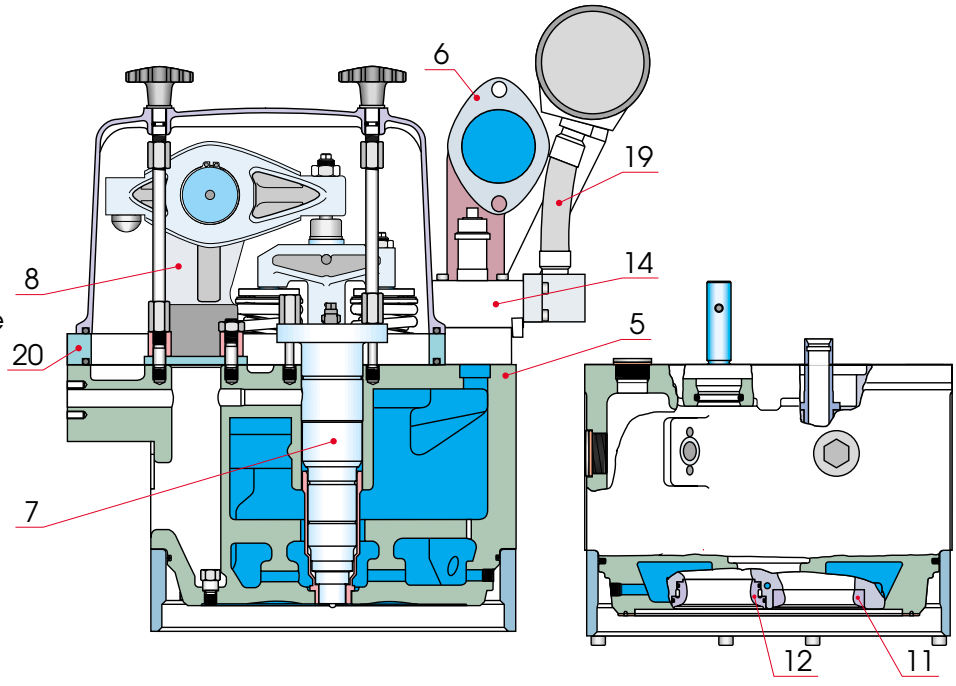
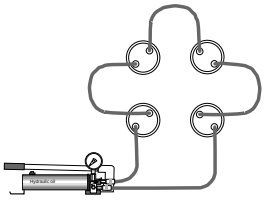


Fig 12-1 3212599801

DISMANTLING
1. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Screw cylinders 180° counter-clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.

3 **Disconnect the cables** to the main gas admission valve (14), injection valve (7) and to the exhaust gas temperature sensors.

4 **Remove the fastening screws of the exhaust pipe clamp** and air pipe. Loosen the oil pipe.

5 **Remove the gas feed pipe** to the main gas admission valve. Remove the injection pipe and the pilot fuel pipe to adjacent cylinders. Protect the connections of the gas feed pipe, fuel pipes, oil pipe and exhaust pipes.

6 **Remove the covers of the cylinder head screws** and the distance ring (20). Put on the distance sleeves and hydraulic cylinders and proceed with opening of cylinder head nuts.

7 **Remove the cylinder head nuts.**

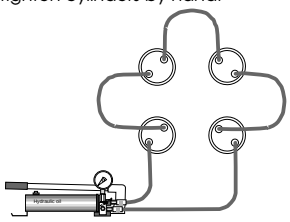
8 **Apply the lifting tool.**

9 **Lift off the cylinder head.**

10 **Cover the cylinder opening** with a piece of plywood or something similar and apply the caps to protect the screw threads.

12.2.2 Mounting of the cylinder head

REASSEMBLING
1. Screw on nuts, attach distance sleeve. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Close the valve and pump pressure to the stated value.
4. Screw the nuts until close contact to face.
5. Open the valve and remove tool set.

1 **Clean the sealing surfaces** and put a new cylinder head gasket and new O-rings for the circulating water jacket, charge air and push rod protecting pipe.

2 **Lubricate the O-ring sealing surfaces with grease or oil.**

3 **Apply the lifting tool** to the cylinder head.

4 **Lift on the cylinder head.** When lowering the head, take care that the push rod protecting pipes slide into the seal rings without force.

5 **Screw on the cylinder head nuts.**

6 **Put on the distance sleeves,** screw on the hydraulic cylinders and proceed with tightening of cylinder head nuts.

7 **Apply the protecting caps** to the cylinder head screws and the distance ring (20).

8 **Connect the exhaust pipe,** charge air pipe, oil pipe, gas feed pipe, pilot fuel pipe and injection pipe. Fit the discharge pipe. Put on the exhaust pipe insulating piece.

9 **Connect the cables** to the gas valve, injection valve and exhaust temperature box.

10 **Adjust the valve clearance.**

11 **Put on the distance ring,** cylinder head cover and side cover.

12 **Before starting, fill the engine circulating water system.**

12.2.3 General maintenance of the cylinder head

The injection valves are dealt with in chapter 16.

When refitting, the injection valves should only be lubricated with engine oil.

The main gas admission valves are dealt with in chapter 17.

12.2.4 Adjusting valve clearance and yoke

1 **Turn the crankshaft to TDC at ignition** for the cylinder concerned.

2 **Loosen the counter nuts** (2) of the adjusting screws on the rocker arm as well as on the yoke (4), and turn the adjusting screws in counter-clockwise direction to provide ample clearance.

3 **Press the fixed end of the yoke against the valve stem** by pressing down the adjustable end. Screw down the adjusting screw (3) until it touches the valve end and note the position of the spanner (pos. a). Now press down the fixed end. Keep on screwing down while the yoke tilts, until the guide clearance is on the other side and the fixed end of the yoke starts lifting from the valve stem. Note the position of the spanner (b).

4 **Turn the adjusting screw** counter-clockwise to the middle position between “a” and “b”, i.e. “c”, and lock the counter nut of the adjusting screw.

Adjusting valve clearance

1. Adjusting screw
2. Counternut
3. Adjusting screw
4. Counternut

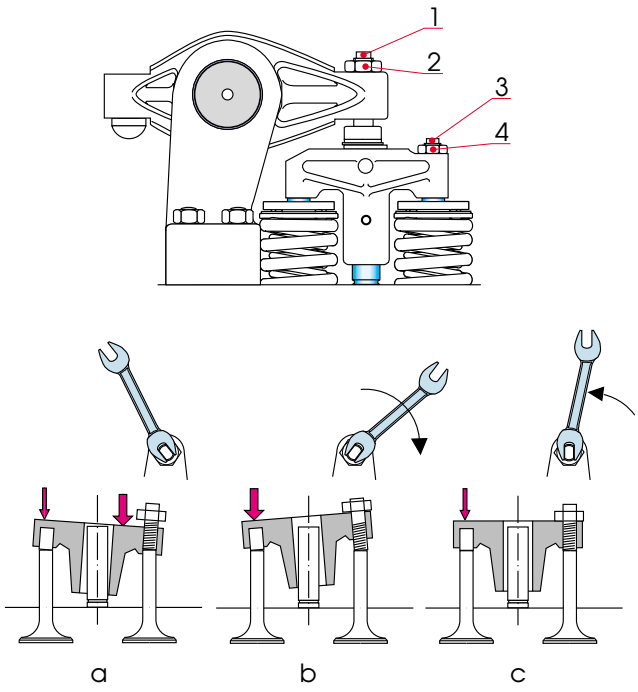


Fig 12-2 3212539501

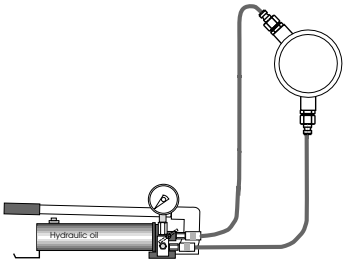
5 Put a feeler gauge corresponding to the valve clearance between the surface of the yoke and the shoe at the rocker arm. Tighten the adjusting screw (1) until the feeler gauge can be moved to and fro only with slight force. Hold the adjusting screw and tighten the counter nut. Check that the clearance has not changed while tightening.

12.3 Maintenance of exhaust and inlet valves

12.3.1 Dismantling valves

1 Fit the tool assembly according to Fig 12-3.

Caution! For safety reasons it should be made sure that the nut (A) is properly installed prior to applying the hydraulic pressure!



DISMANTLING
1. Connect hoses, open valve.
2. Tighten the tool assembly.
3. Close the valve and pump to required pressure.
4. Open the valve and remove the tool.

2 Connect the hydraulic pump and compress the valve springs 15 - 20 mm.

3 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.

4 Open the release valve of the pump slightly so that the valve springs are unloaded slowly.

5 Spring holders and springs can now be removed.

Tool assembly for dismantling valves

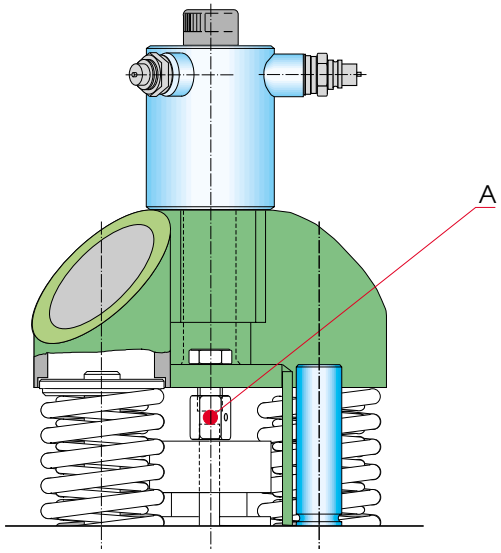


Fig 12-3 3212548932

6 **Note the marks of the valves** or mark them so they can be re-installed into the same guide if they are in good condition.

12.3.2 Checking and reconditioning valves and seats

1 **Clean the valves,** seats, ducts and guides as well as the underside of the head.

2 **Control the burning-off on the valve disc** according to Fig 12-4. The measure "Y" should be more than 8 mm (nominal 9 mm) and measure "Z" should be less than 2 mm. If the measures exceed these limits the valve must be replaced.

Control of burning-off on valve

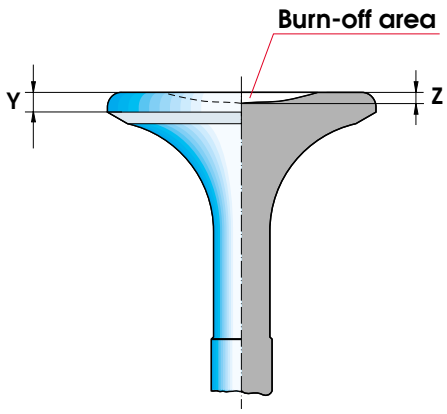


Fig 12-4 3212568932

3 **Reconditioning of inlet valve and valve seat ring** is recommended to be done by grinding or by machining. If there is only slight pitting, lapping is adequate. Valve and seat ring grinding, see section 12.3.4.

4 **Reconditioning of exhaust valve and valve seat ring** has to be done by grinding or by machining. If the sealing faces are bright or if there is a coherent sealing face, grinding is not necessary. Valve and seat ring grinding, see section 12.3.4.

Note! **If blow-by has occurred, the O-ring for the corresponding valve seat ring must be changed. Blow-by increases the temperature and the O-ring is "burned", which will result in water leakage into the cylinder.**

5 **Before grinding, check the valve stem clearance.** If the clearance is too large, measure the stem and guide, and change the worn part; the valve guide can be pressed out. Check the bore in the cylinder head. When refitting, cooling in with liquid air is recommended, but pressing in with oil lubrication can also be accepted. After fitting in, check the guide bore and calibrate, if necessary.

12.3.3 Lapping of inlet valves

If there are slight pits on the sealing faces they can be lapped by hand:

1 **Fit the turning tool 4V84B108** to the valve.

2 **Apply a thin layer of lapping compound** to the sealing surface of the valve; No.1 for coarse lapping, No.3 for fine lapping.

3 **Rotate the valve to and fro** towards the seat with the nut speeder. Lift the valve from the seat at intervals while lapping.

4 **Remove the smallest possible amount of material** because the sealing faces have hardened during operation and are valuable. It is not necessary to grind off all pits.

5 **Clean the valve and seat** carefully after lapping.

Note! **Lapping is not allowed for exhaust valves.**

12.3.4 Machine grindind of exhaust and inlet valves

Note! **The valve should be cooled by water during the grinding.**

1 **Seat face of the inlet valve:** The seat angle of the inlet valve is 20° with a tolerance of +0.25° - +0.50° to achieve contact to the seat ring at the inner edge of the valve. Minimum allowable edge thickness is 8.5 mm; after that, the valve must be replaced by a new one.

2 **Seat face of the exhaust valve:** The seat angle of the exhaust valve is 30° with a tolerance of 0° - -0.25° to achieve contact to the seat ring at the periphery of the valve. Minimum allowable edge thickness is 8 mm; after that, the valve must be replaced by a new one.

3 **Seat ring for the inlet valve:** The seat angle of the inlet valve seat ring is 20° with a tolerance of 0° - +0.25°. The seat can be ground until the outer seat diameter is 109 mm; after that, the ring must be replaced by a new one.

4 **Seat ring for the exhaust valve:** The seat angle of the exhaust valve seat ring is 30° with a tolerance of 0 - +0.25°. The seat can be ground until the outer diameter is 108 mm; after that, the ring must be replaced by a new one.

Note! **After grinding it is recommended to check contact between valve and seat with marking colour.**

12.4 Change of seat ring

12.4.1 Removal of the old ring

1 **Fit a scrapped valve to the seat** and weld it to the seat by means of electric beam welding. Preferably the valve disc should be machined to a diameter 95 mm to get a better welding.

2 **Press or knock out the ring** but be careful not to damage the valve guide.

Note! **The exhaust seat ring can most conveniently be removed hydraulically by using tool 846050, which can be ordered from the engine manufacturer.**

12.4.2 Fitting a new inlet valve seat ring

1 **Check the bore diameter** in the cylinder head, see section 06.2.

2 **The ring can be assembled** by freezing in with liquid nitrogen of -190°C, the cylinder head temperature being min. 20°C, or by pressing in with a guided arbor.

3 **Check the eccentricity** of the sealing face in relation to the valve guide, and if it exceeds 0.1 mm, the seat surface must be ground in a seat grinding machine.

12.4.3 Fitting a new exhaust valve seat ring

1 **Clean the bore carefully** with a grit 400 or finer emery cloth.

2 **Check the bore diameter in the cylinder head,** see section 06.2 in the instruction manual.

3 **Heat up the cylinder head** to 100°C by means of either steam heating, e.g. put the cylinder head into a closed box, or a gas burner.

Note! **It is important that the whole cylinder head is heated up, not only the seat bore.**

4 Cool the seat ring to -10 - -15°C prior to fitting. Note that a temperature lower than -15°C may damage the O-rings at mounting.

5 Apply a water-soap solution on the O-rings and in the cylinder head bores. The water-soap solution should be neutral (pH about 7) and a mixture ratio of 1:2.

6 Mount the sealing rings on the cooled valve seat.

7 Mount the exhaust valve seat by using one of following methods:

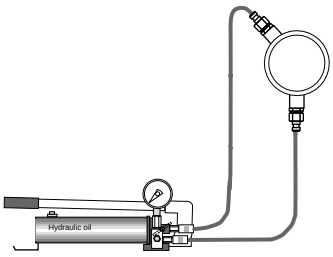
- Put the seat rings into a guiding bush and press in the seat with a guided arbor. A special tool (846050) is also available. This tool can be ordered from the engine manufacturer.
- Insert the seat ring by using an exhaust valve. Knock on the valve until the seat ring is correctly seated.

Note! Mounting of a exhaust valve seat ring should be done carefully so that the seat ring is correctly seated.

8 Check the eccentricity of the sealing face in relation to the valve guide, and if it exceeds 0.1 mm, the seat surface should be ground in a seat grinding machine.

9 Pressure test the cylinder head before mounting with a test pressure 8 - 10 bar if possible.

12.4.4 Reassembling of the engine valves



REASSEMBLING
1. Connect hoses, open the valve.
2. Tighten the tool assembly.
3. Close the valve and pump to required pressure.
4. Open the valve and remove the tool.

1 Check the valve springs for cracks, corrosion or wear marks, and if any, replace the springs by new ones.

2 Put new seal rings in the valve guides.

3 Lubricate the valve stems with engine oil.

4 Put in the valves and check for free movement.

5 Put on the springs and spring discs or rotators. Compress the springs with the tool set . Put in the valve cotters and unload the springs. Check that the valve cotters fit properly.

12.A. Testing of cylinder tightness

12.A.1 Testing

A tool can be used for control of cylinder and valve tightness.
Note! Should be done immediately after engine stop.

1 **Turn the piston to TDC** (all valves closed) for the cylinder concerned.

12.A.1.1 Connecting of the tool for Wärtsilä 20/32 and Vasa 32

1 **Connect the tool** (848020, Wärtsilä 20), (800064, Wärtsilä 32), (848020, Vasa 32) to the open indicator valve. Continue with section 12.A.1.4.

12.A.1.2 Connecting of the tool for Wärtsilä 34SG

1 **Remove the cover plate ,** ignition coil and the spark plug extension and other necessary components. See section 12.2.

2 **Remove the spark plug,** mount the distance sleeve 3V84H85 (848052) with seal ring and tighten to the stated torque.

3 **Connect the pressure gauge and valve assembly** to the distance sleeve.

4 **Install the tool** (848020) to the cylinder head. Continue with section 12.A.1.4.

12.A.1.3 Connecting of the tool for Wärtsilä 32DF

1 **Remove injection valve** with neccessary pipes. See section 12.2.

2 **Assembly the distance sleeves** 3V84H85 (848052) and 2V84H97 (848061) with necessary seals.

3 **Connect the pressure gauge and valve assembly** to the distance sleeves.

4 **Install the tool** (848020) to the cylinder head. Continue with section 12.A.1.4.

Testing tool of cylinder tightness

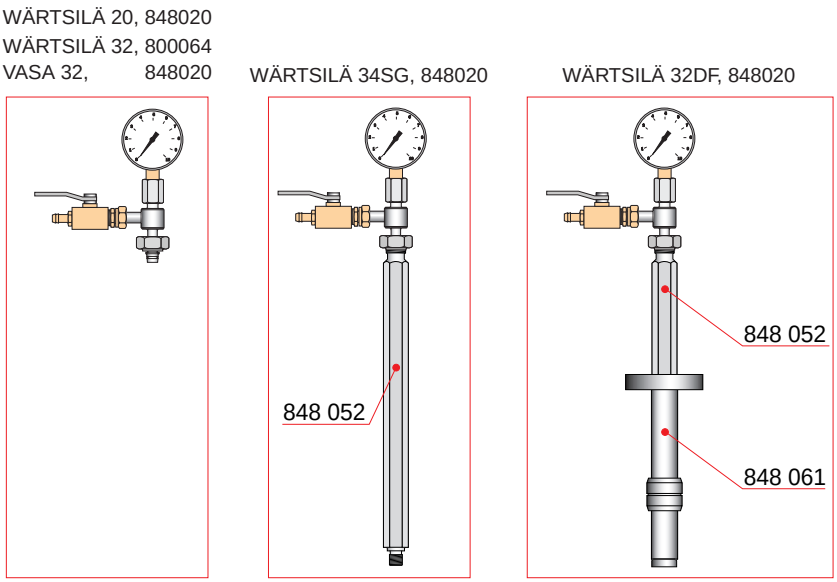


Fig A-1 321260200142

12.A.1.4 Measurement

1 Connect air to the tool with a pressure of 6-7 bar (= normal working air pressure). Open the valve on the tool and record the pressure.

2 Close the valve. Measure the time in seconds it takes for the pressure dropping to 0.5 bar.

- If the pressure from the beginning was 6 bar and it takes more than 10 sec. for the pressure to drop to 0.5 bar, the result is acceptable.
- If the pressure drops directly to 0 bar, it is possible that one or more valves are sticking or the valve(s) are burnt.
  A sticking valve can be found from the immobility of the valve when the engine is turned.
  A burnt valve can normally be seen from the exhaust temperature. If the valve clearance is zero that would also cause an direct pressure drop.
- Carbon particles trapped between the valve and the seat when the engine is stopped could also prevent the valve to close properly thus causing a direct pressure drop. If that is suspected, the engine should be run for a few minutes and after that a new check of the same cylinder.
- If a blow-by between the cylinder liner and piston is suspected e.g. from fast fouling of filters or high crankcase pressure, it is best to take readings of the complete engine and make a comparison.
  For example: From a six cyl. engine you get a serial: 12, 17, 15,

4, 19 and 18 seconds.
This shows that cyl.no.4 is the one to be suspected for a blow-by.
The test can be verified by listening for leaking sounds inside crankcase during testing.

- If the time is limited to overhaul only one piston, it is recommended to dismantle the worst measured blow-by piston for inspection. The result of inspection gives a hint of general engine condition.
- When re-testing the cylinder after an overhaul a rapid pressure drop can be observed. The reason for this is because the running in of piston rings is not yet performed.

Note! **Keep pre-lubricating pump running during test.**

Note! **The turning gear should be engaged during test.**

- In general, the location of leakage can be found by listening when the air valve is open.

Attention! **A general condition of engine is indicated with the test device, but more important is the operation data records.**
The overhauls must be made according to recommended overhaul intervals and not only when the pressure test shows a big blow-by.

13. Camshaft Driving Gear

13.1 Description

The camshaft is driven by the crankshaft through a gearing. The gear wheel (1) is split and fixed to a flange on the crankshaft by the axial screws (2). These screws as well as the fastening screws (25) are locked with Loctite 262.

The bearing shafts (26) and the intermediate wheels (3), (10) and (11) are journalled in the engine block. The camshaft driving wheel (12) is fixed to the camshaft end (24) by a guiding pin (20) and fastened by means of a flange connection between the end and the camshaft extension (14). The camshaft driving wheel supports a helical gear wheel (22) for the speed governor drive, and the camshaft extension is equipped with an overspeed trip (15). Lube oil nozzles provide for lubrication and cooling of the gearing.

13.2 Intermediate gears

13.2.1 Removing of camshaft gearing

1 **Remove the gearing covers** and the adjacent camshaft covers. Remove half of the camshaft bolts (13), see Fig 13-1. Turn the crankshaft to TDC at firing for cylinder No.1.

2 **Remove concerned oil distributing pipes,** oil sprays and the governor drive.

3 **Unscrew the fastening screws (18)** for the housing of the overspeed tripping device (15) and remove the cover (17).

4 **Unscrew the fastening screws (16),** and remove the overspeed tripping device (15) and the housing (19).

5 **Remove the cover (6), Fig 14-2,** from the starting air distributor at the free end of the camshaft (in-line engine and V-engine, A-bank).

6 **Unscrew the remaining flange connection screws (13)** and remove the camshaft extension (14).

7 **Unscrew the fastening nuts (1), Fig 14-1,** of all rocker arm brackets, only on the A-bank for a V-engine. Move the camshaft in the direction of the free end (max. 25 mm) by using a suitable lever or the hydraulic jack, and lift the camshaft driving wheel out.

8 **Unscrew the cover fastening screws (7).** Remove the cover (32). Unscrew the shaft plate fastening screws (8) and remove the shaft plate (31).

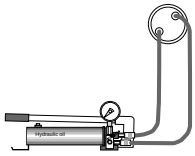
9 **Remove the outer thrust bearing ring (30).**

10 **Unscrew the housing fastening screws (9)** and remove the housing (5).

11 **Remove the inner thrust bearing ring (29).**

12 **Unscrew the extension shaft fastening screws (27)** and remove the extension shaft (28). Secure the intermediate wheels (10) and (11) in a nylon strap.

DISMANTLING
1. Screw on cylinders by hand
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Screw cylinders 180° counter -clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.

13 **Apply distance sleeve 3V86B135** and hydraulic cylinder 3V86B150 to the fastening bolt (6) and remove the nut (33).

14 **Remove the shaft (35).** The shaft can be pulled out by using suitable screws, i.e. M8 screws.

15 **Unscrew the bolt (6)** by using the tool 3V84G189.

16 **Remove the intermediate gear wheel (11)**

17 **Remove the intermediate wheel (10).** Using lifting tools will make the gear wheel handling easier.

18 **Remove the intermediate wheel (3)** by proceeding as with the intermediate wheels (10) and (11).

Note! **Even though the design of both intermediate gear shafts is similar, the parts must not be mixed with each other.**

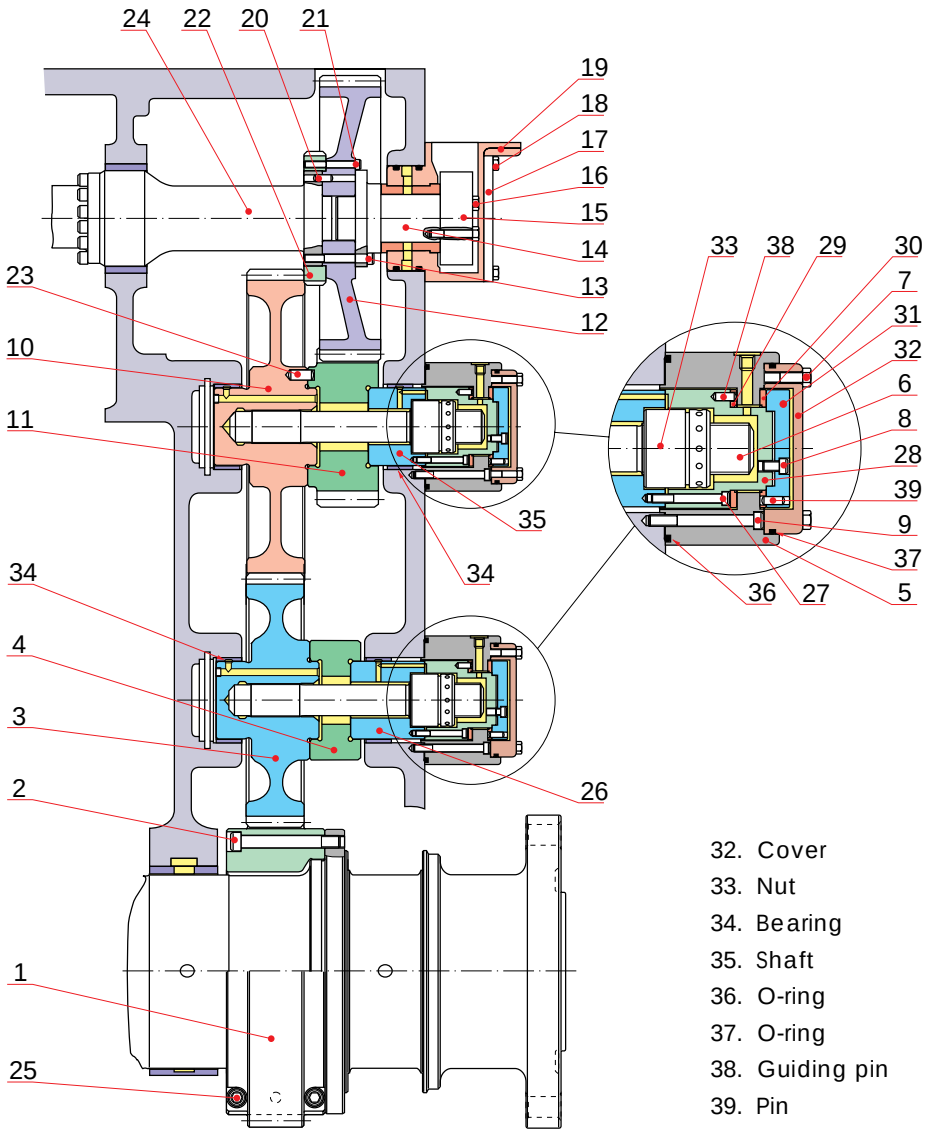
13.2.2 Mounting of the camshaft gearing

1 **Turn the crankshaft as follows:**
a) In-line engine: Turn crankshaft to TDC for cylinder No.1.
b) V-engine; camshaft gearing of both cylinder banks removed: Turn crankshaft to TDC for cylinder No.A1.
c) V-engine; gearing of A-bank mounted, gearing of B-bank removed: Turn crankshaft to TDC at ignition for cylinder No.A1. Then turn 50° in direction of TDC for cylinder No.B1.
d) V-engine; gearing of B-bank mounted, gearing of A-bank removed: Turn crankshaft to TDC at ignition for cylinder No.B1. Then turn 50° in direction of TDC for cylinder No.A1.

Note! **Make sure that the crankshaft is in TDC at ignition for cylinder No.1 in an in-line engine and for respective bank in a V-engine before proceeding with the job.**

Camshaft driving gear

1. Gear wheel
2. Screw
3. Intermediate wheel
4. Distance sleeve
5. Housing
6. Cover
7. Screw
8. Screw
9. Screw
10. Intermediate wheel
11. Intermediate wheel
12. Driving wheel
13. Camshaft screw
14. Camshaft extension
15. Overspeed trip
16. Screw
17. Cover
18. Screw
19. Housing
20. Guiding pin
21. Screw
22. Gear wheel
23. Pin
24. Camshaft end
25. Screw
26. Bearing shaft
27. Screw
28. Extension shaft
29. Bearing ring
30. Bearing ring
31. Shaft plate



32. Cover
33. Nut
34. Bearing
35. Shaft
36. O-ring
37. O-ring
38. Guiding pin
39. Pin

Fig 13-1 3213559045

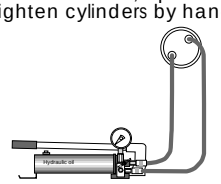
2 **Lift the intermediate wheel (3)** into position. The wheel must be tilted, when inserted, to get free from the rib in the engine block.

Note! **Insert the intermediate gear wheels and bearing bushes according to the marking of the wheels, see Fig 13-2 and Fig 13-3.**

3 **Insert the distance sleeve (4).**

4 **Screw in the bolt (6)** and tighten to the torque stated in chapter 07.

REASSEMBLING
1. Screw on nuts, attach distance sleeve. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Close the valve and pump pressure to the stated value.
4. Screw the nuts until close contact to face.
5. Open the valve and remove tool set.

5 **Insert the shaft (26).**

6 **Tighten the nut (33)** by hydraulic cylinder 3V86B150 to stated pressure. Release the pressure and pump to stated pressure again. Tighten the nut finally and release the pressure.

7 **Mount the guiding pin (38)** and insert the extension shaft (28). Tighten the screws (27) to the stated torque.

8 **Insert the inner thrust bearing ring (29).**

9 **Mount the O-ring (36)** in the housing (5) and insert the housing. Tighten the screws (9) to the stated torque.

10 **Insert the outer thrust bearing ring (30).** The gear wheels should be in the outer most position to achieve the correct axial bearing clearance.

11 **Mount the pin (39) to the shaft plate (31),** and insert it. Apply Loctite 242 to the screws (8) and tighten to the stated torque. Insert the cover (32) and the O-ring (37) and tighten the screws (7) to the stated torque.

12 **Check the axial bearing clearance** for the gear wheel (3) and the backlash between the wheels (1) and (3).

13 **To get the intermediate wheels (10) and (3) into the correct position,** mark the meshing teeth of both wheels (10) and (3) with a pencil acc. to Fig 13-2 and Fig 13-3. (The wheel (10) can be marked before mounting by marking the third tooth downwards from a line drawn from the centre point of gear wheel (10), through the dowel pin in the wheel (10)).

V-engines: Do not install the intermediate wheel (10) before camshaft end (24) is installed. Place the intermediate wheel (10) as low as possible in gear train.

14 **Mount the gear wheel (10)** to the engine block according to meshing marks.

15 **Mount the gear wheel (11) to the wheel (10).** The dowel pin of the wheel (10) should be in the middle of the groove in the wheel (11) to get enough timing adjustment allowance

16 **Screw in the bolt (6).**

17 **Insert the shaft (35).**

18 **Tighten the nut (33)** by hand.

19 **Check the backlash** between the wheels (10) and (3).

20 **Lift the camshaft driving wheel (12) into position.** The marks on the wheels should be aligned with the edge of the engine block according to Fig 13-2 and Fig 13-3.

21 **Fit the camshaft extension (14),** push the camshaft into position, guided by the pin (20), and tighten the flange connection screws (13).

Marking of the intermediate gear wheels, in-line engines

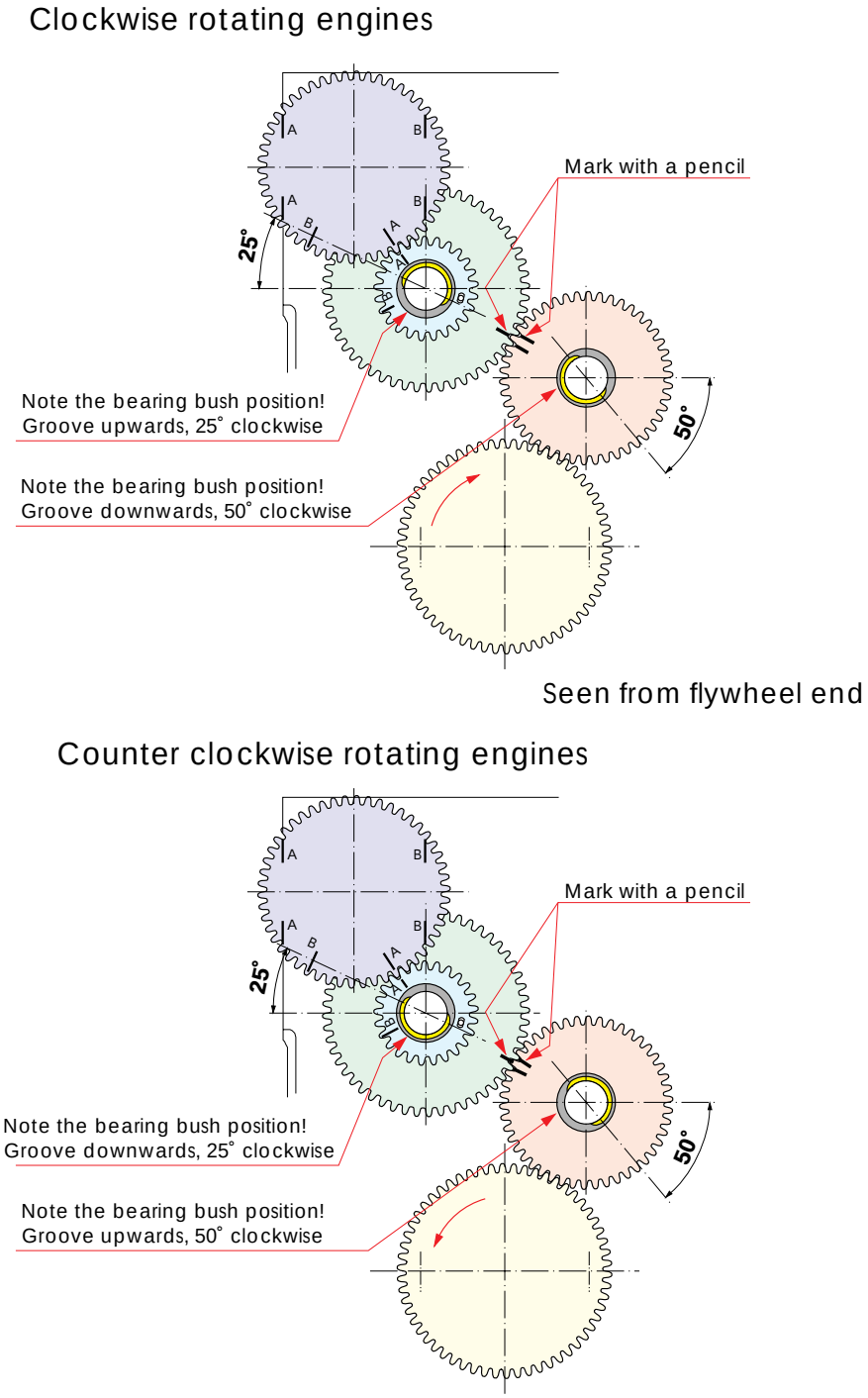


Fig 13-2 3213549501

22 **Mount the overspeed trip housing (19)** and the overspeed trip device (15) and tighten the screws (16). On the V-engine B-bank, the overspeed trip housing and overspeed trip device are substituted by a bearing housing and an end flange.

Marking of the intermediate gear wheels, V-engines

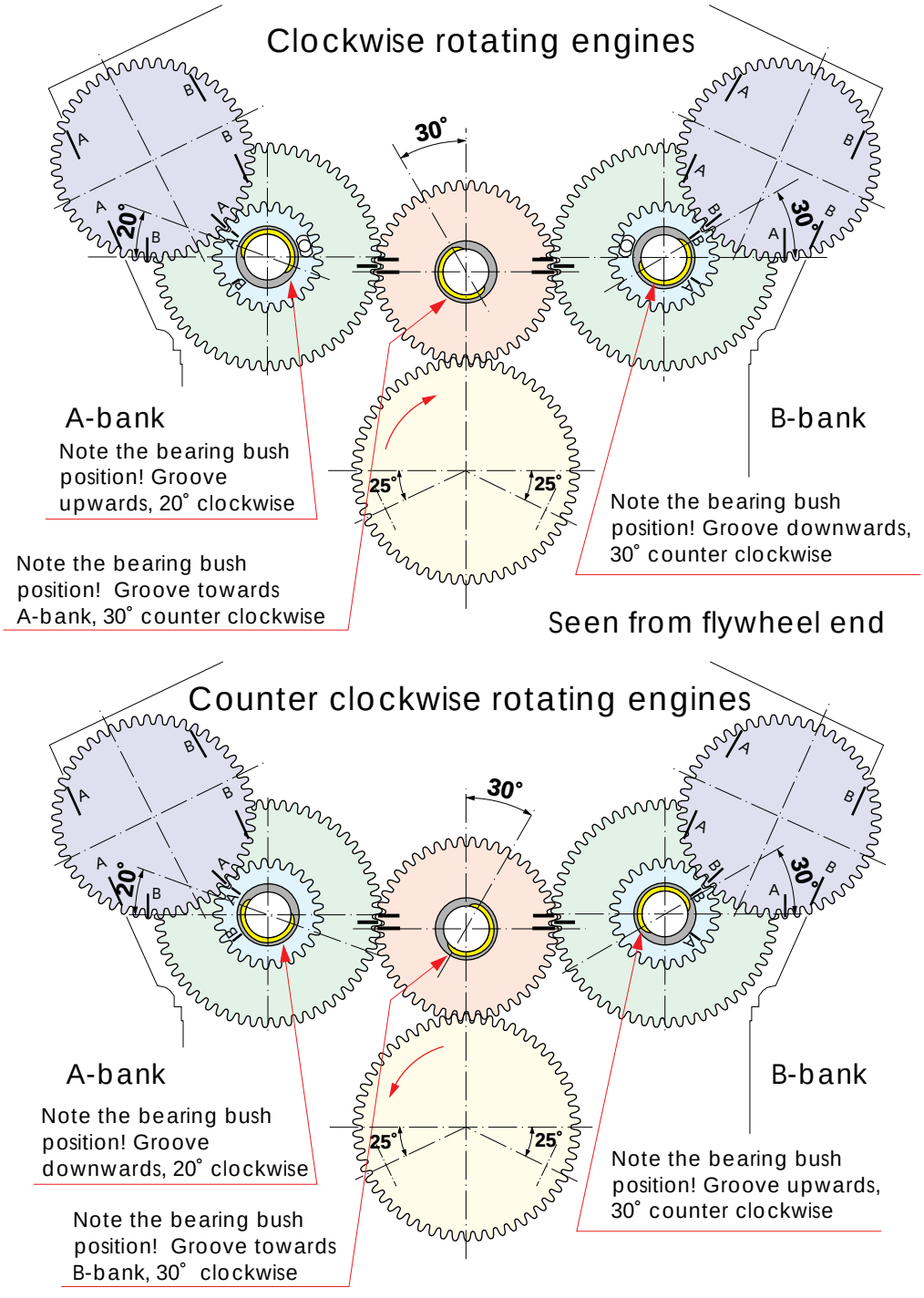


Fig 13-3 3213629501

23 **Lock the screws (16)** with locking wire or alternative design with Loctite and mount the cover (17).

24 **Check the axial bearing clearance** for the camshaft and the backlash between the wheels (11) and (12).

25 **Mount the oil sprays.**

26 **Check the valve timing** of one cylinder and the fuel timing. On the V-engine, check the firing sequence of the cylinder banks. If necessary, the timing can be adjusted by loosening nut (33) slightly so that the gears (10) and (11) can be moved in relation to each other. Tighten the nut (33) according to step 6 above after adjustment and recheck timing.

27 **Proceed with tightening** of screws and nuts according to step 7 - 11 above.

28 **Mount the oil distributing pipes and the covers** for the gearing, camshaft and starting air distributor.

29 **Check the axial bearing clearance** and the tooth clearance between the wheels (10) and (3).

Axial positions of bearings

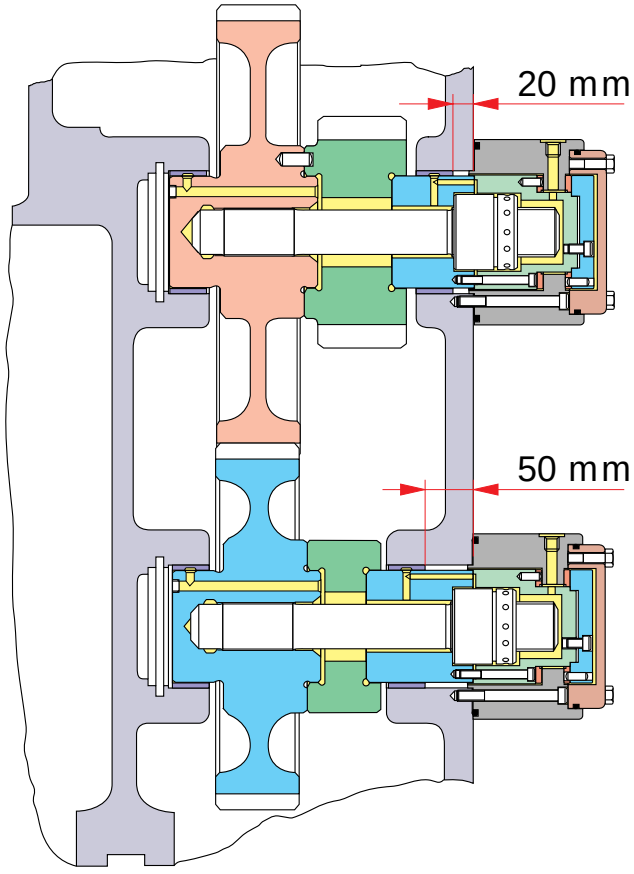


Fig 13-4 3213689917

13.3 Split gear

If only the split gear wheel has to be changed, one half of the wheel can be removed/mounted at a time. Hereby the valve timing will be unchanged and it will not be necessary to adjust it.

13.3.1 Removing of the split gear wheel

After the gearing is removed according to section 13.2.1, the split gear wheel (1) can be removed from the crankshaft.

1 **Lower the bearing cap** for main bearing No.1, see chapter 10., section 10.2.1.

2 **Loosen the fastening screws (25).**

3 **Unscrew the axial screws (2).**

4 **Unscrew the fastening screws (25)** and remove the gear wheel halves.

13.3.2 Mounting of the split gear wheel

1 **Clean the parting surfaces of the wheel halves** and the contact faces of the gear wheel and the crankshaft.

2 **Lower the bearing cap for main bearing No.1,** see chapter 10, section 10.2.1.

3 **Apply Loctite 262 on the threads of the screws (2) and (25).**

4 **Mount the gear wheel halves on the crankshaft** with the parting face at right angles with the crank of cylinder No.1 and fasten the screws (2) and (25) by hand.

5 **Tighten the axial screws (2)** to a torque of 10 Nm and check that contact is established between the gear wheel and the crankshaft flange.

6 **Tighten the fastening screws (25)** to a torque of 40 Nm. The screws closer to the crankshaft flange are to be tightened at first.

7 **Tighten the fastening screws (25)** to stated torque. The tightening order is the same as in the previous point.

8 **Tighten the axial screws (2)** to the stated torque.

9 **Check the gear wheel roundness.** Place a cylindrical pin (ø16 mm) in the toothgap as shown in Fig 13-5. Turn the engine and use a dial indicator to get an indication for the diameters. The maximum permissible difference between the measured values is 0.05 mm.

10 **Lift the bearing cap for main bearing No.1,** see chapter 10 section 10.2.1.

Measuring split gear wheel

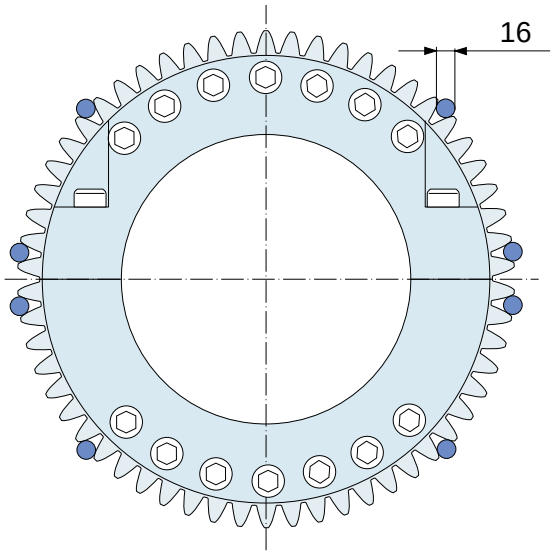


Fig 13-5 3213519045

14. Valve Mechanism and Camshaft

14.1 Valve mechanism

14.1.1 Description of valve mechanism

The valve mechanism consists of valve tappets (11) of the piston type moving in separate guide blocks (7) of cast iron, tubular push rods (4) with ball joints, nodular cast iron rocker arms (3) journalled on a rocker arm bearing bracket (13), and a yoke (14) guided by a yoke pin.

Valve mechanism

1. Nut
2. Retainer ring
3. Rocker arm
4. Push rod
5. Protecting sleeve
6. Nut
7. Guide block
8. Cover
10. Guiding pin
11. Valve tappet
12. Bearing journal
13. Bearing bracket
14. Yoke
15. Cylindrical pin
16. Spring

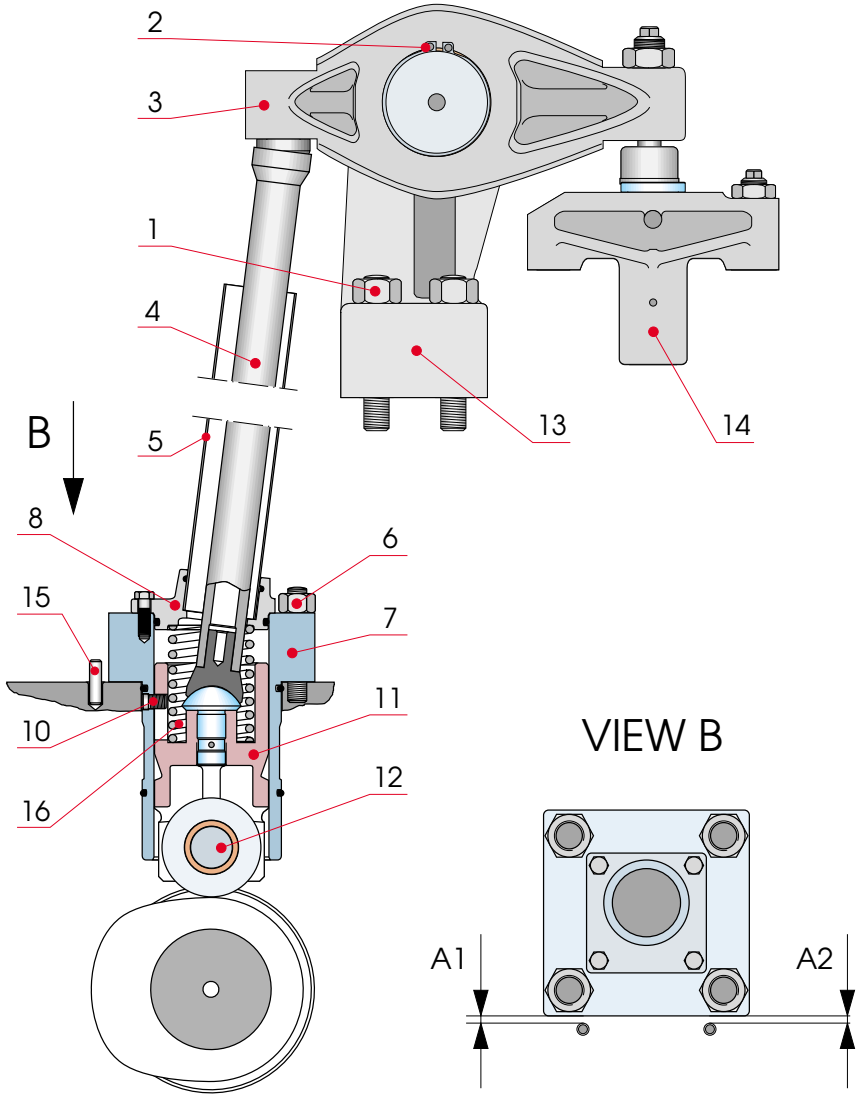


Fig 14-1 321478501

14.1.2 Dismantling of valve mechanism

1 **Remove the covers** of the valve mechanism and camshaft from the cylinder concerned.

2 **Turn the crankshaft** to a position where the valve tappet rollers of the valves are on the base circle of the cam.

3 **Unscrew the nuts (1)** and remove the rocker arm bearing bracket (13) from the cylinder head.

4 **Remove the retainer rings (2)** and rocker arms (3). To remove the retainer rings, use pliers A40 DIN 5254.

5 **Remove necessary pipes.**

6 **Remove the push rods (4)** and the protecting sleeves (5).

7 **Unscrew the nuts (6)** and remove the guide block (7).

8 **Remove the cover (8)** and the guiding pin (10). An M6 screw can be used to remove the pin.

9 **Remove the valve tappet (11)** and dismantle by removing the bearing journal (12). Before dismantling, mark the parts for mounting into the original positions.

14.1.3 Inspection of valve mechanism parts

1 **Clean the rocker arm bearing bush** and the journal and measure for wear. When cleaning, pay special attention to the oil holes.

2 **Clean and inspect all parts of the valve tappet and guide block.** When cleaning, pay special attention to the angled oil holes.

3 **Measure the valve tappet bearing bush** and the journal as well as the cam roller for wear.

4 **Change the O-rings of the cover (8)** if they are damaged or hard.

14.1.4 Assembling of valve mechanism

1 **Lubricate the parts of the valve tappet** with clean engine oil and assemble. Observe the marks for correct positions.

2 **Insert the valve tappet (11)** into the guide block (7) and apply the guiding pin (10).

3 **Mount the cover (8).**

4 **Mount the guide block** to the engine block and tighten the nuts (6).

5 **Check the parallelism** of the roller axis to the camshaft by measuring the distance to the cylindrical pins on both sides of the guide blocks with a feeler gauge, i.e. measures $A_1 = A_2$ according to Fig 14-1. Tighten the nuts (6) to the right torque, acc. to section 07.1.

6 **Grease the O-rings,** insert the push rods (4) and protecting sleeves (5) into the guide block.

7 **Mount the yoke.** For adjusting the yokes, see section 12.2.4.

8 **Lubricate the rocker arm bearing bushes** and mount the rocker arms (3) on the bracket.

9 **Apply the retainer rings** (2) by using pliers A40 DIN 5254 and check the axial bearing clearance and free rotation of rocker arms.

10 **Mount the rocker arm bracket** on the cylinder head and tighten the nuts (1) to the torque, see section 07.1.

11 **Check the valve clearance** acc. to section 06.1 and mount the covers.

14.2 Camshaft

14.2.1 Description of camshaft

The camshaft is built up of one-cylinder camshaft pieces (1) and separate bearing journals (2). The drop forged camshaft pieces have integrated cams, the sliding surfaces of which are case hardened. The bearing surfaces of the journals are induction hardened. The camshaft is driven by the crankshaft through a gearing at the driving end of the engine. At this end the camshaft is equipped with an axial bearing (5), an pressure plate (7) and a helical gear (8) for driving of the speed governor.

On V-engine, B-bank the camshaft has only an axial bearing situated at the driving end.

Camshaft

1. Camshaft piece
2. Bearing journal
3. Screw
4. Fixing pin
5. Axial bearing
6. Cover
7. Pressure plate
8. Gear

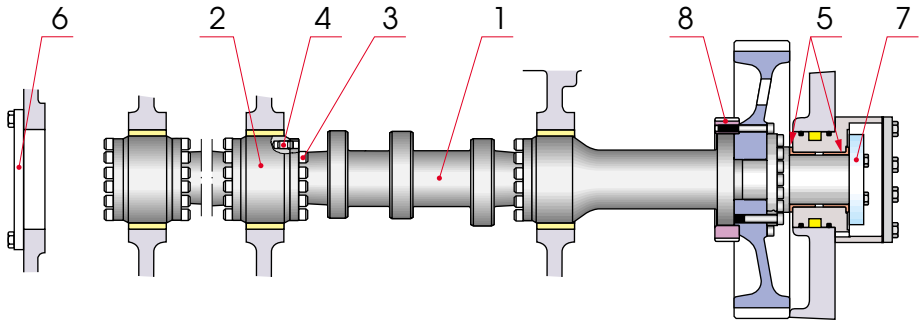


Fig 14-2 3214529648

14.2.2 Removing of camshaft piece

1 **Remove the camshaft cover,** injection pump and guide blocks from the cylinder concerned.

2 **Unscrew the flange connection screws (3)** from both ends of the camshaft piece by using the tool 4V80G17. The flange connection screws are treated with a locking compound and can be used only once.

3 **Remove the end cover** (6) and unscrew the rocker arm bracket fastening nuts of the cylinders in which the camshaft is to be axially displaced. Move the part of the camshaft locating towards the free end of the engine 15 - 20 mm in direction of the free end by using a suitable lever.

4 **Disengage the camshaft piece** from the centerings and fixing pins (4) and remove it sideways.

Note! The rocker arm bearing brackets towards the free end side has to be removed if the crankshaft is turned, otherwise there will be contact between the valve and piston.

14.2.3 Mounting of camshaft piece

1 **Clean and degrease the flange connection surfaces** and threaded holes.

2 **Insert the fixing pins** (4) with retainer rings, the longer part of the pin in the bearing journal.

3 **Mount the camshaft piece** (1) on the fixing pin and centering at either end, then press the camshaft together. Use two or three mounting screws, not the fastening screws, because they are applied with locking glue.

4 **Insert the flange connection screws,** dry and tighten by using the tool 4V80G17. The flange connection screws are treated with a locking compound and can be used only once.

Note! Tighten the screws immediately to correct torque since the screws are treated with a locking compound.

5 **Check the valve tappets and rollers** carefully. Even slightly damaged tappet rollers have to be changed.

6 **Mount the end cover (6),** guide blocks, injection pump etc.

7 **Check the valve clearances** and delivery clearances of the injection pumps on all cylinders towards the free end.

15.C. Exhaust Gas Wastegate

15.C.0.1 Description

A reliable and safe performance of the W34SG engine requires a correct air-fuel ratio during all kind of site conditions. If the air-gas mixture becomes too lean misfire will occur and if the air-gas mixture becomes too rich knocking will occur.

To maintain a correct air-fuel ratio, the engine is equipped with an exhaust gas wastegate valve that keeps the air pressure in the receiver at an optimal level all over the power output range. The exhaust gas wastegate valve is by-passing the exhaust gases past the turbocharger. The wastegate valve is working as a regulator and adjusts the air-fuel ratio to the correct value regardless of varying site conditions (ambient temperature, humidity, etc).

The exhaust gas wastegate system is built on the engine and consist of an actuator (1) connected to the butterfly valve (2) which controls the exhaust gas by-pass flow via pipes (4) and (5) to the distance piece (3) as much as required to get the correct air-fuel ratio according to the preprogrammed values.

Exhaust gas wastegate system

1. Actuator
2. Butterfly valve
3. Distance piece
4. Exhaust pipe
5. Exhaust pipe

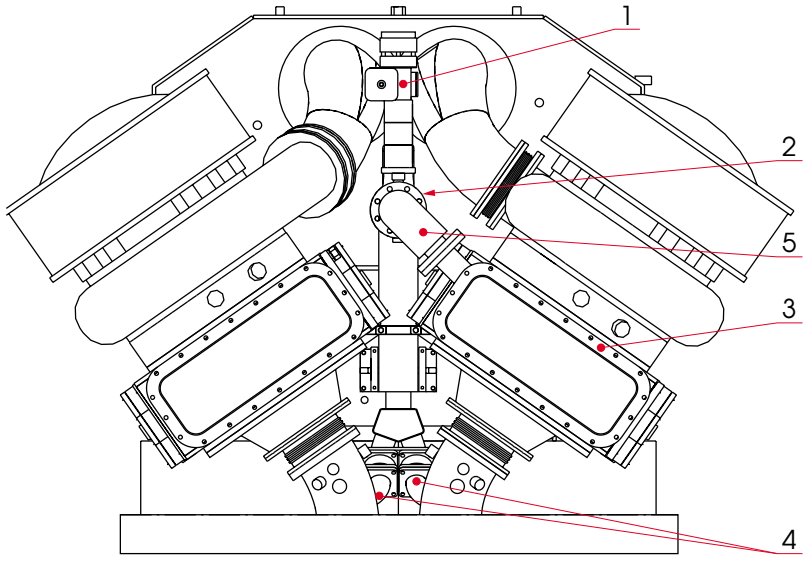


Fig 15C-1 3215909715

15.C.0.2 Function

The wastegate control system gets compressed air from the instrument air system. The pressure is appr. 6 - 7 bar. The instrument air needs to be clean, dry and oil free to secure the function of the components. See also chapter 21.

The wastegate system works as follows:
When the engine is running, the valve (6) is open and supplies air to the I/P converter (8) and to the positioner (9) in the actuator unit (1). The I/P converter maintain a 0.2 - 1.0 bar control air pressure to the positioner according to the incoming 4 - 20mA control signal.
The positioners pilot valve (11), see Fig 15C-3, maintains the actuator (10) with air pressure according to the control air pressure from the I/P converter.

The engine control system (WECS) is monitoring the average exhaust gas temperature after the cylinders. If the average exhaust gas temperature is higher than the set-point, the engine control system will close the wastegate gradually, until the correct value is reached.

The main purpose of the solenoid valve (6) is to prevent air leakage through the I/P-converter to the actuator when the engine is stopped.

The control logic is carried out in the engine control system and no external regulators are required.

15.C.0.3 Maintenance

The system requires usually no other maintenance than a regular check of the function.

The pilot valve (11) in the positioner should be replaced with a new one according to chapter 04 or in case of malfunction.

15.C.0.3.1 Change of positioner pilot valve

1 **Remove the positioners cover** and the pilot valve screws (12), see Fig 15C-3.

2 **Pay attention to the pilot valve stem** and the lever (13) and remove the pilot valve carefully.

3 **Replace the pilot valve (11)** with a new one and re-assemble the positioner casing in the opposite order.

4 **Check the function** of the valve by following the positioners movement when the engine is re-started and runs on load.

Wastegate control system

1. Actuator
2. Butterfly valve
6. Solenoid valve
8. I/P converter
9. Positioner

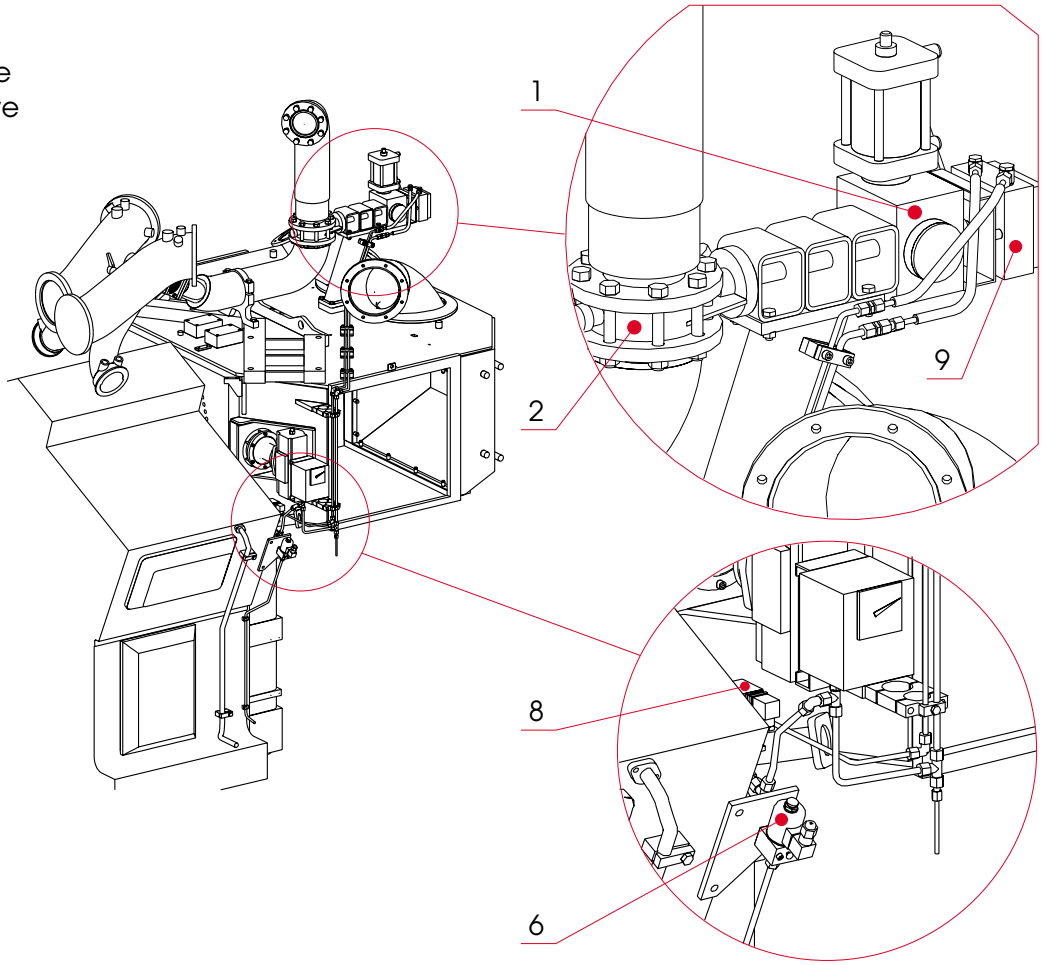


Fig 15C-2

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Wastegate positioner

11. Positioner pilot valve
12. Screw
13. Lever

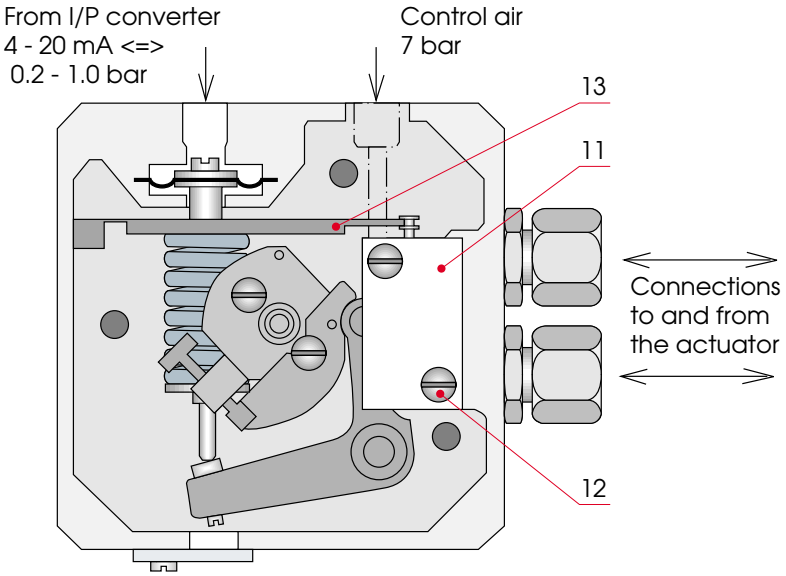

Fig 15C-3

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15. Turbocharging and Air Cooling

15.1 Description

The turbochargers are of the axial turbine type. The insert type charge air cooler is mounted in a welded housing, which, at the same time, serves as a bracket for the turbocharger. The housing is fastened to the engine block by screws, normally at the free end of the engine. V-engines have two identical cooler inserts in a common housing.

The turbocharger is connected to the engine lubricating oil system.

The outlet is connected to the air duct (2) through a piece of metal bellows (1). The exhaust pipes from the engine are also connected to the charger through metal bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions.

The turbocharger is equipped with cleaning devices for cleaning both the compressor and the turbine by water injection.

Materials of the tubes and water boxes of the air cooler depend on the cooling medium used.

Turbocharger and air cooler

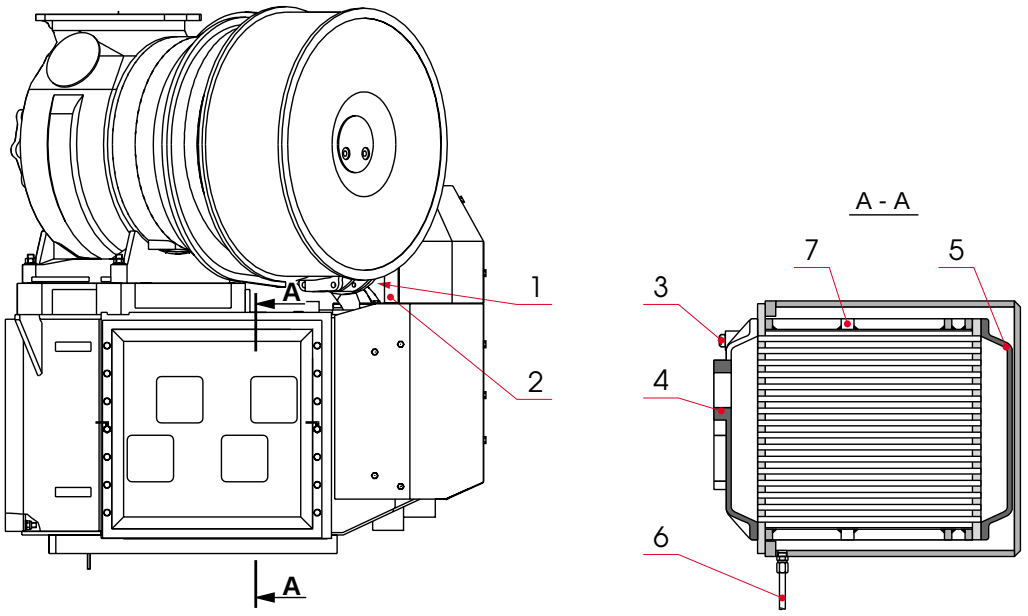

Fig 15-1 3215989915

15.2 Turbocharger maintenance

Normal overhauls can be carried out without removing the turbocharger from the engine. When dismantling, remove the protecting covers. Loosen the exhaust inlet and outlet pipes.

When reassembling change the seals. High temperature resistant lubricants are used for exhaust pipe screws.

Maintenance of the turbocharger is carried out according to section 15.3 and to the instructions of the turbocharger manufacturer. It is recommended to use the service organisation of the engine manufacturer or the turbocharger manufacturer.

15.3 Water cleaning of turbocharger during operation

15.3.1 Water cleaning of turbine

As practical experiences show, the dirt deposits on the turbine side can be reduced by periodic cleaning (washing) during operation. The overhaul periods can be extended. Dirty turbines cause higher temperatures of the exhaust gas and higher stresses of the bearings due to imbalances. Usually, though, washing of the turbine side is necessary only when running on heavy fuel.

During long periods of operation, periodic water cleaning prevents the build-up of significant deposits on the turbine blades and nozzle blades. This cleaning method does not work on very dirty turbines which have not been washed regularly.

If the normal water cleaning of the turbine does not effect much on the exhaust gas temperature level, hard deposits have probably built up on the nozzle ring and the turbine blades in the turbocharger, and they have to be cleaned mechanically. For that purpose, the rotor and the nozzle ring have to be removed from the turbocharger.

The water must be injected into the exhaust system with the engine running at reduced output (see 15.3.2, step 2). The disadvantages of reducing the output occasionally is not significant compared with the advantages of cleaning.

The necessary water flow is basically dependent upon the volume of gas and its temperature. The flow should be adjusted so that the major part of the water is evaporated and escapes through the exhaust. Additives or solvents must not be used in the cleaning water. The use of salt water is prohibited.

Housings with several gas inlets are provided with an inlet valve (1) for each exhaust pipe. The valves are connected to a quick-coupling (2).

The water washing of the turbine should be done as described in section 15.3.2. The water flow is controlled by flow meter (4) to a recommended value, see table below.

Water cleaning of turbine	
Pressure difference Δp (1)	0.5...1.0 bar
Turbocharger size	**Water flow (l/min)**
TPL 65	16 - 19 (2)

(1) Pressure difference between water injection pressure and gas pressure before turbine.
(2) Depends on the water injection pressure and gas pressure before turbine (engine load).

Cleaning should take place regularly according to chapter 04., Maintenance Schedule. Depending on the results obtained, the interval between two washings can be increased or reduced.

Water cleaning of turbine

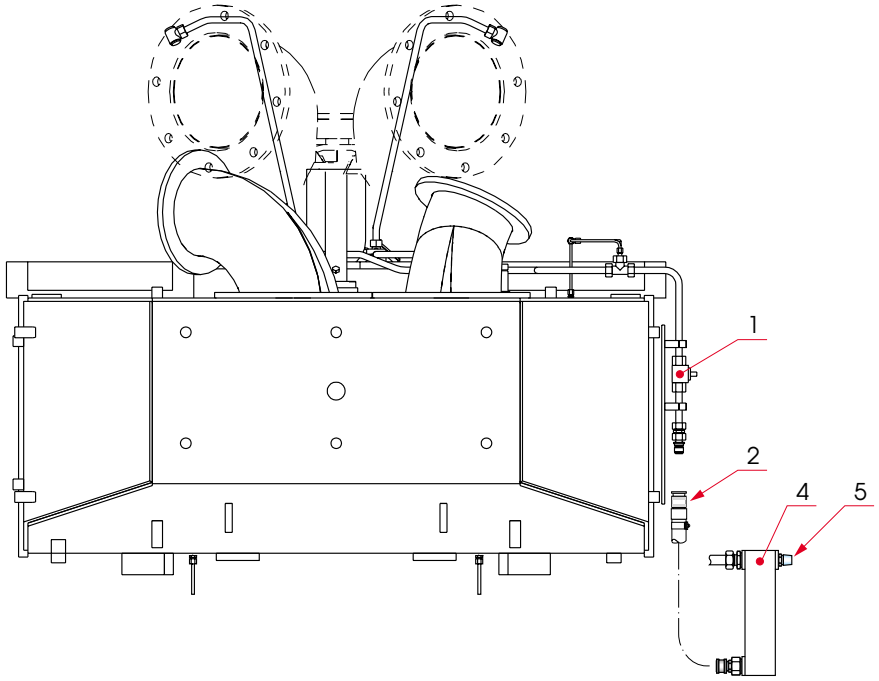

Fig 15-2 3215999915

15.3.2 Cleaning procedure

1 **Record blower charge air pressure,** cylinder exhaust gas temperatures, charger speed, for later use to assess efficiency of the cleaning.

2 **Reduce engine load** corresponding to a receiver pressure of 0.5...0.6 bar at nominal speed or reduce speed to between 400 and 600 RPM with a fixed propeller. Run the engine for five minutes on this load before the washing is started. **Maximum exhaust gas temperature after cylinder is 380°C!**

3 **Open valves** (1), and check that they are not clogged.

4 **Connect water hose.**

5 **Open valve** (5) slowly within 10 s and increase the water flow until the correct flow is reached according to the table shown above.

6 **Close the valve (1) after 60 seconds.** Interval between injections is 60 sec.

Note! It is not allowed to inject water for 5...10 minutes without breaks because the gas outlet casing do not have drain.

7 **Repeat the injection procedure five times** with the same gas inlet according the step 6. above.

8 **Repeat the cleaning procedure** with other gas inlets.

9 **After termination of water injection** the engine must run for three minutes at an unchanged load until all parts are dry.

10 **Shut all valves** and disconnect the hose to ensure that no water can possibly enter exhaust pipes except during the cleaning periods.

11 **Resume normal engine operation** at higher output and, as soon as possible, repeat the readings taken in step 1 above for comparative purposes.

12 **Run the engine for 10 to 20 min. more** after the turbocharger has been cleaned by water. Doing so it is ensured that all the parts in the exhaust system are completely dry.

Note! Clean the turbine (exhaust side) of the turbocharger at low loads (30 - 50 % of full rated load).

15.3.3 Water cleaning of compressor

For water washing of the compressor side during operation, see turbocharger instruction manual, section 3.4.

Note! Clean the compressor (air side) of the turbocharger at as high a load as possible (full rated load).

15.4 Allowable operation with damaged turbocharger

In case of a serious breakdown of the turbocharger, a blanking device or a rotor locking device can be fitted according to the instructions in the turbocharger manual, section 3.1.

When the Vasa engines are in an emergency situation like this, they are able to operate temporarily at 20% output. The thermal overload is a limiting factor on the diesel engine. Therefore, the exhaust gas temperatures must be carefully watched during operation with a locked rotor.

The exhaust gas temperature after the cylinder cover must not exceed 500°C.

Note! **Both of the turbochargers on a V-engine must be locked or blanked if one of them fails.**

15.5 Maintenance of charge air cooler

15.5.1 General maintenance

1 Condensate from the air is drained through a small hole/ pipe (6), Fig 15-1, at the bottom of the cooler housing, after the insert, and at the opposite end plate of the air manifold. Examine regularly that the pipe is open by checking the air flow when running.

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 that the water level in the system goes down when the engine is stopped, drain the cooler completely. Open the air vent screw (3), Fig 15-1, 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.

15.5.2 Cleaning of air cooler

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. Loosen the cooler flange screws and, on an in-line engine, withdraw the cooler until the thread or the hole (7) for the lifting tool is visible. On the V-engine, withdraw the cooler about 300 mm and fit the tool 32.84G02. Screw on the tool by using four of the air cooler fastening screws. Then, withdraw the cooler completely towards the tool stop. If necessary, use screws in the two threaded extractor holes in the flange to loosen the cooler.

2 Apply the lifting tool and lift off the cooler.

3 Clean the air side of the cooler by immersing it in a chemical cleaning bath for at least 24 hours. Recommend cleaning detergents, see section 02.4. We recommend that cleaning tank should be equipped with perforated pipes on the bottom for the best cleaning effect, see Fig 15-3. During cleaning steam or pressurised air should be connected to the pipes to get a good circulation.

When cleaning is completed, the cooler should be flushed thoroughly by water.

Note! **The use of a high pressure water jet for flushing, should be avoided because:**
- it will pack the dirt into the middle of the cooler.
- the risk of damaging the cooler fins is great.
Both of above will result in an increased pressure drop over the cooler.

4 Clean the water side by detaching the headers (4) and (5) from the cooler bundle and immersing the tube bundle into a chemical cleaning bath for at least 24 hours. Upon completion, follow the direction given for the air side.

5 Change the gaskets before reassembling the headers.

6 It is also recommended to pressure test the cooler before mounting it on the engine.

7 Mount the cooler on the engine.

8 Vent the cooler and check the tightness when starting up.

Air cooler cleaning tank

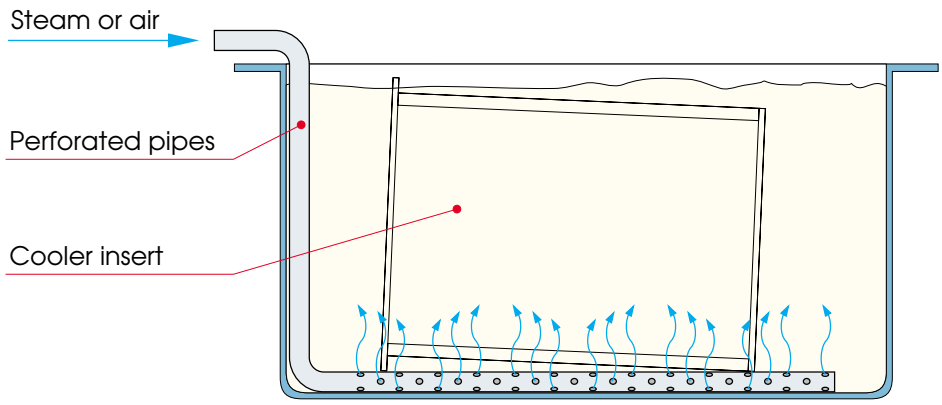

Fig 15-3 3215869701

16. Injection system

16.1 General

The Wärtsilä 32DF is a pilot fuel ignited lean-burn gas engine with instant switch-over capability to back-up fuel. There are two operating modes, gas mode and diesel mode. In gas mode low pressure gas is mixed with the combustion air in the air inlet channel in the cylinder head, the mixture is compressed in the cylinder during compression stroke and ignition is initiated with a small amount of pilot fuel injected into the combustion chamber. In diesel mode the diesel fuel is injected into the cylinder at the end of the compression stroke by means of the injection pump. In diesel mode there is no gas mixed with the air, but pilot fuel is injected as well as main diesel fuel to prevent pilot nozzle orifices to clog.

Only LFO is allowed as pilot fuel as well as back-up fuel. If HFO is to be used, the injection valves must be replaced with one-needle type injection valves made for this purpose, and the pilot fuel pump must be switched off and disconnected from the fuel lines. Also if the intention is to run a longer time (more than 100 h) in diesel mode, it is recommended to replace the injection valves with one-needle type diesel injection valves.

16.2 Description

This chapter deals with the high pressure side of the fuel system including injection pump, high pressure pipe, injection valve as well as the pilot fuel system.

The injection pumps are one-cylinder pumps with built-in roller tappets. The element, of mono type, is pressure lubricated and the drain fuel is led to a pipe system with atmospheric pressure outside the pump, or back to the low pressure circuit of the injection pump. Each injection pump is equipped with an emergency stop cylinder, which is coupled to an electro-pneumatic overspeed protecting system.

The injection line from the injection pump consists of an injection pipe and a connection piece attached sideways into the nozzle holder at a conical inlet port.

The pilot fuel system is a common rail system fed by an electric driven pump. A connection piece is mounted to each cylinder head connecting the one per cylinder rail pipes. From the connection piece the fuel is fed through a connection pipe to the injection valve.

The injection valve is a two-needle type combined pilot and main diesel fuel injection valve, where the pilot injection is electronically controlled. The nozzle holder consists of a top body and a lower body, which contain the rods, springs, control valve and solenoid.

16.3 Injection pump

16.3.1 Removal of injection pump

It is recommended that the engine runs 5 min with light fuel before it is stopped for overhaul of the injection pump.

1 **Shut off fuel supply** to the engine and stop the prelubricating pump.

2 **Remove the elbows** of the fuel feed pipes and the pneumatic air pipe. Loosen the oil pipes to the pump.

3 **Remove the pneumatic shut-down cylinder.**

4 **Remove the injection line.** Immediately cover all openings with tape or plugs to prevent dirt from entering the system.

5 **Turn the crankshaft** so that the injection pump tappet is in the bottom position, the roller resting on the base circle of the cam.

6 **Loosen the flange nuts and** lift off the pump.

7 **Cover the bore** in the engine block.

16.3.2 Mounting of injection pump

1 **Test and clean the pump.** Also clean the plane and the bore of the engine block.

2 **Check the O-ring** of the insert part and lubricate with vaseline or engine oil. Check that the fuel cam is not in the lifting position.

3 **Fit the pump.** Slide the fuel rack connection into place during this operation.

4 **Check with a feeler gauge** that the pump housing is aligned with the camshaft, i.e. measures $B_1 = B_2$ according to Fig 16-1.

5 **Tighten the flange nuts** to torque, remove protecting tapes and/or plugs and connect the oil pipes.

6 **Rotate the control shaft** and check that all pumps follow the shaft movement. Check the fuel rack positions of all pumps, see chapter 22.

7 **Remove the protecting tapes** or plugs and connect the fuel feed pipes and the injection line. Tighten the nuts to torque.

8 **Open fuel supply** to the engine and vent the fuel system according to the instructions in chapter 17. The injection pump is provided with a venting plug (42).

16.3.3 Control of fuel delivery commencement

The beginning of the effective pump stroke is determined by an indirect method, i. e. by watching when the passage between the low pressure side and the high pressure side of the injection pump is shut by the edge of the element plunger, A in Fig 16-1, the so-called “flowing position”.

Control of fuel delivery commencement is necessary only if major components have been changed, e. g. injection pump, injection pump element or camshaft piece.

1 **Shut off fuel supply** to the engine.

2 **Remove the injection pipe.**

3 **Open the screws (39)** crosswise in steps of 30°, remove the head piece (35) and the fuel delivery valve cone and spring (33).

4 **Replace the head piece (35)** and tighten the screws (39) to torque.

5 **Connect the funnel 3V86C29** to the injection pump to obtain fuel supply.

6 **Set the injection pump rack** at its maximum end position.

7 **Turn the crankshaft** to a position 22° before TDC at ignition.

8 **Fill the funnel** with distillate fuel. Fuel is now flowing out from the head piece (35).

9 **Keep the level in the funnel constant** by refilling and turn the crankshaft slowly in the engine rotating direction. Watch when fuel stops emerging. Read the position of the crankshaft.

10 **Repeat steps 7, 8 and 9** for all the cylinders to be checked.

11 **Compare the crankshaft positions** with the correct values, see test records. The deviation between the different cylinders in one engine should not exceed 1° crank angle. If larger deviations are noted, the injection pumps must be changed and/or overhauled and checked.

12 **Reassemble the fuel delivery valve,** pressure relief valve and the head piece. Tighten the screws (39) to torque given in chapter 07.

Injection pump

11. Fuel rack
14. Control sleeve
16. Spring disc
17. Spring
18. Spring disc
21. Fixing screw
28. Calibrating disc
32. Screw
33. Spring
35. Head piece
42. Vent screw

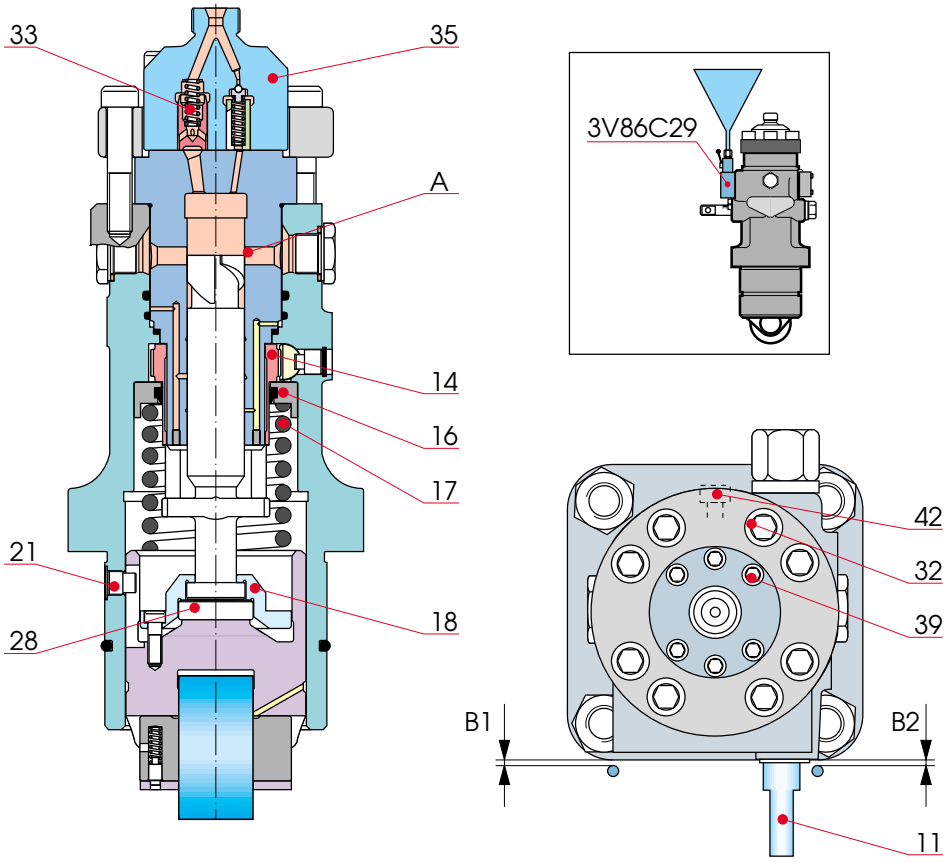

Fig 16-1 3216609648

16.3.4 Injection pump overhaul

It is presupposed that the injection pump is removed from the engine and the outside of the pump is carefully cleaned.

Note! **The element cylinder, plunger and delivery valve are matched, and they must be kept together during the overhaul.**

1 **It is recommendable** to put the pump in a screw vice, in positions convenient for the different operations.

2 **Support the roller tappet** and open the fixing screw (21).

3 **The roller tappet** and the element plunger can now be taken out. Take care when handling the plunger because it may come loose from the tappet.

4 **Remove the spring** and the control sleeve.

5 **Turn the pump** into vertical position.

6 **Open the screws (39)** crosswise in steps of 30°, remove the head piece and remove the fuel discharge valve with spring and pressure relief valve with spring.

7 **Open the screws (32)** of the element in steps of 30°.

8 **Take out the element cylinder** by using a soft tool.

9 **Wash the element plunger** and the cylinder in clean fuel or special oil and always keep them together, the plunger being inserted in the cylinder. Pay special attention to the grooves and bores for leak fuel and lubrication oil.

10 **Normally, further dismantling** is not necessary. It is recommendable to keep the components of different pumps apart from each other, or to mark the details so they can be fitted into the same pump. The details must be protected against rust, and the running surface of the element plunger especially should not be unnecessarily handled with bare fingers.

11 **Wash the details** in absolutely clean diesel oil and lubricate the internal parts with engine oil. When handling details of the injection equipment, keep hands absolutely clean and grease them with grease or oil.

12 **Renew the seal rings and supporting rings** in the pump house and on the element cylinder and lubricate the rings with vaseline or lubricating oil.

13 **Re-install the element cylinder** into the position where the fixing groove corresponds to the guiding pin.

14 **Tighten the screws (32)** crosswise in steps acc. to section 07.1, to ensure equal tightening of every screw.

15 **Re-install the main delivery valve** with spring and the pressure relief valve with its spring.

16 **Mount the head piece (35)** and tighten the screws (39) crosswise in steps, acc. to section 07.1, to ensure equal tightening of every screw.

Caution! **Incorrect mounting may cause the engine to overspeed!**

---

17 **Turn the pump** and fit the control sleeve (14). Move the fuel rack (11) to a position where two marks can be seen. **One of the control sleeve teeth is chamfered, and this tooth must slide into the tooth space between the marks of the rack.**

18 **Re-install the spring disc (16)** and spring (17).

19 **Assemble the element plunger** and tappet with the spring disc (18) and pressure plate (28).

20 **Note the mark on one of the plunger vanes.** The marked plunger vane must slide into the fuel rack side of the control sleeve, i.e. correspond to the marks on the fuel rack and the chamfered tooth of the control sleeve. The guiding groove of the tappet must correspond to the fixing screw, i.e. be turned to the slide opposite the marked plunger vane.

21 **Re-install the plunger tappet assembly.**

22 **Screw in and tighten the fixing screw (21).**

23 **Check that the fuel rack (11)** can be easily moved.

24 **Unless the pump is immediately mounted** on the engine, it must be well oiled and protected by a plastic cover or similar. The fuel ports and injection line connection must always be protected by plugs or tape.

16.4 Injection line

The main fuel injection line consists of two parts, the connection piece and the injection pipe from the injection pump. The spherical end of the connection piece is pressed against the conical inlet port of the nozzle holder by means of a flange. Always check the sealing surface before mounting, and tighten the flange screws to correct torque. The injection pipe is shielded with an annular pipe and equipped with a drain hose. It seals against the pump and the connection piece with conical metallic surfaces.

The pilot fuel line consists of cylinder specific shielded pipes, connection pieces on the cylinder heads and connection pipes between the connection piece and the injection valve. The rail pipes, delivered complete with connection nuts assembled, seals with conical metallic surfaces. The connection pipe have spherical metallic sealing surfaces pressed against cones in the connection piece and the injection valve. Always check the sealing surfaces before mounting and always tighten to correct torque.

Note! **Cleanliness is of utmost importance to obtain functionality and reliability of the injection system.**

16.5 Pilot fuel pump unit

The pilot fuel pump is an 8- or 4-cylinder radial piston pump driven by an electric motor and a coupling. The built-in pressure regulating unit is electrically controlled by the engine control system. On the feed line a valve group with a filter regulates the inlet pressure to the pump. A safety valve is mounted on the high pressure line.

The pump shaft is equipped with two roller bearings. The pump elements slide on ceramic slide rings, one ring per two elements. The

fuel oil functions as lubricating media. The pump is equipped with an indication hole for shaft sealing leakage.

Note! Do not run the pump without sufficient feed pressure nor with zero consumption! Do not run the pump in wrong rotation direction!

Already three pilot injection valves causes leakage enough to consume the pump delivery with fully throttled pressure regulating unit.

16.5.1 Overhaul of pilot fuel pump

Before dismantling the pilot fuel pump, turn the switch gear for pump motor to off position, close the fuel feed shut-off valve and the high pressure shut-off valve.

1 Disconnect the electrical cable connector (1) to the pressure regulating unit, unscrew the pipe fittings for feed pipe, high pressure pipe and drain pipe.

2 Loosen nuts (48) and remove screws (49), see Fig 16-3.

3 Make a wooden support under the pump. Unscrew the pump fixing screws on the pump flange and pull out the pump. Half of the coupling is fixed on the shaft.

4 To remove the coupling, connect tool and high pressure hydraulic hand pump 3217T01 to the pump shaft and pump to 2000 bar.

Removing and mountig of the coupling half

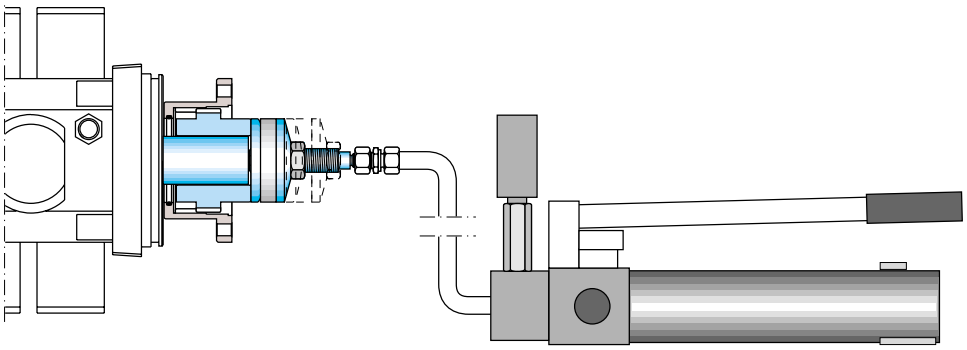

Fig 16-1 3216049938

5 Mark the pump elements (5) with numbers for later positioning. Unscrew the element fixing screws (24) and lift off the element. Be careful not to drop the plunger.

Note! **The element cylinder and plunger are matched and must be kept together during overhaul.**

6 **Remove the feed check valve (26)** and delivery check valve (27), be aware of the positioning. Wash the details in clean fuel oil or special oil. Check the plunger surface and foot. If any part is in bad condition, the whole element should be replaced with a new one. **Do not scratch the metal sealing surfaces!**

Pilot fuel pump

1. Connector
2. Valve stem
3. Flange screw
4. Flange screw
5. Pump element
6. Roller bearing
7. Roller bearing
11. Distance plate
13. Sliding ring
22. Distance piece
24. Fixing screw
26. Feed check valve
27. Feed check valve
32. Throttle valve
35. Spring
39. Shaft lubricating bush
41. Solenoid
47. Shaft sealing

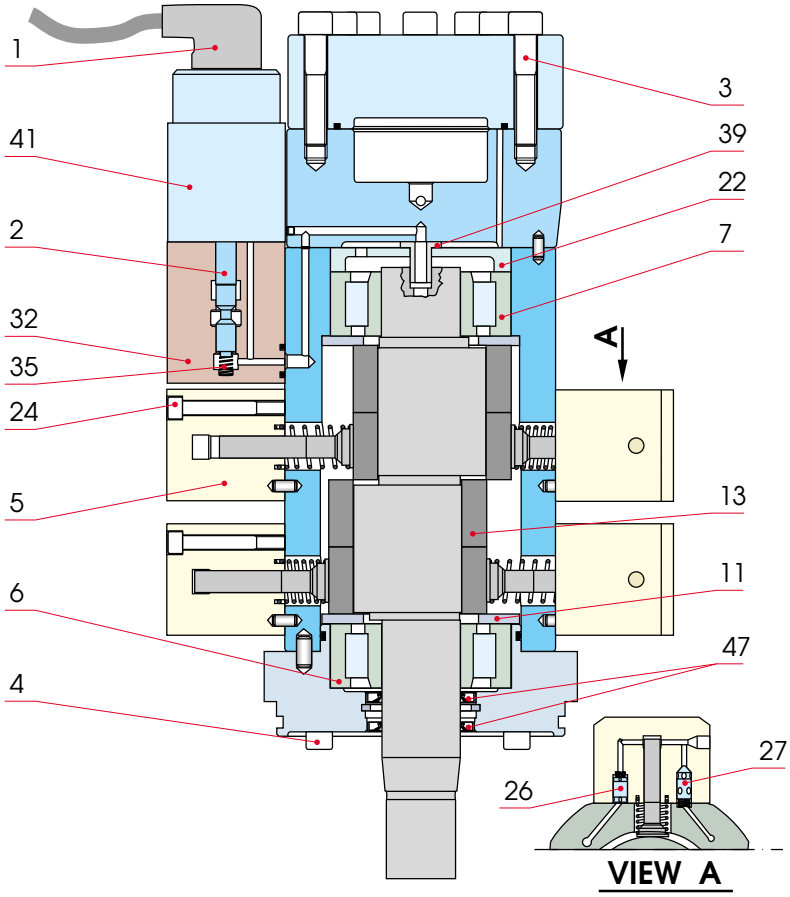

Fig 16-2 3216029801

7 **Remove the solenoid (41)** and the throttle valve (32). Pull out the valve stem (2) and spring (35), and check the sliding surfaces and the throttling edge. Clean the details in clean fuel oil.

8 **Unscrew the accumulator end flange screws (3)** and disassemble the accumulator, the shaft lubricating bush (39) and the distance piece (22). Clean the details and check for wear. Check the sealing surfaces. **Do not scratch the high pressure metal to metal sealing surface!**

9 **Unscrew the shaft end flange screws (4)** and extract the flange with the roller bearing (6) and the shaft sealings(47). Clean and check the roller bearing for wear, and replace if necessary.

10 **Remove the distance plate (11)** and pull out the shaft with the ceramic sliding rings (13). Clean the details and check for wear. Renew sliding rings if necessary. Check the accumulator end roller bearing.

11 **Renew all sealings.** Immerse all parts in clean fuel oil before reassembling the pump. Tighten the pump element screws to 80 Nm, the shaft end flange screws to 35 Nm, the accumulator end screws in two steps, first to 100 Nm and second to 120 Nm, the throttle valve screws and the solenoid screws according to chapter 07.

12 **Change the O-rings (50)** in the coupling.

13 **Mount the coupling half** onto the pump shaft first by hand. Mark the position on the shaft. Then apply hydraulic pressure max. 2000 bar to the shaft end and screw the nut a distance of 4..5 mm from the original position. Drain the hydraulic pressure.

Coupling for pilot pump

48. Nut
49. Screw
50. O-ring
51. Grease chamber
52. Set screw

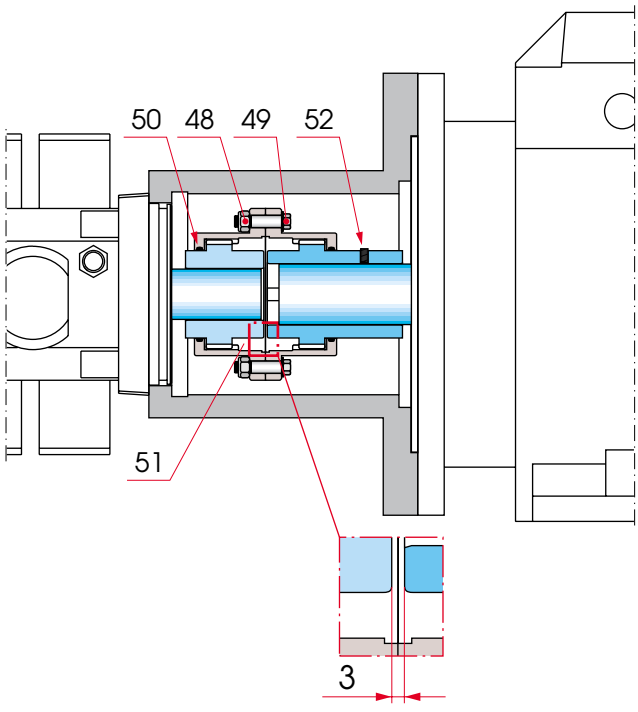

Fig 16-3 3217709938

14 **Mount the pilot pump** to the connection flange for the electric motor. Adjust the clearance (3±0.5 mm) between coupling halves by opening the set screw (52) and moving the coupling half on the shaft, see Fig 16-3.

15 **Tighten the set screw (52)** and fill the grease chamber (51) with EP-quality grease, see section 16.5.2.

16 **Slide the sleeves into contact,** mount the screws and nuts and proceed with tightening in crosswise.

17 **Connect the pipes** and open the fuel feed valve and the high pressure shut-off valve. Run the fuel feed pump for some minutes to fill up the pilot pump casing before starting the pilot pump. Connect the cable to the regulating unit.

16.5.2 Maintenance of coupling

The coupling should maintain according to chapter 04. The coupling is equipped with nipple for regreasing.

When changing grease, the coupling should be opened and cleaned. Check for possible wear and replace parts if necessary. Add new grease and check the clearance, see section 16.5.1.

The grease should be Lithium-based “high pressure” type (EP) with an ASTM of 300 to 350 when the operating temperature of the coupling is between 30°C to 70°C. The NLGI grade at the above mentioned operating temperature should be 1. Recommended greases are listed below.

- AGIP: GR/MU/EP
- CHEVRON: DURA LIGHT GREASE-EP
- ESSO: BEACON EP
- IP: ATHESIA-EP
- MOBIL: MOBIL TEMP 78
- SHELL: ALVANIA EP

16.6 Injection valve

16.6.1 Description

The injection valve is a combined pilot and main fuel oil injection valve centrally located in the cylinder head. The valve consists of a two-part nozzle holder and the nozzle. A solenoid valve for pilot injection control is located in the upper part of the nozzle holder. The fuel enters the nozzle holder sideways through two connection pipes with spherical ends pressed against the conical ports in the holder.

The pilot fuel pressure acts on both the pilot needle pressure step (opening force) and through an orifice on the pilot piston (closing force). The solenoid valve opens a drain port from the pilot cylinder and thus eliminates the pressure acting on the piston, and the fuel pressure acting on the needle forces the needle upwards. The drained fuel is led through borings to the normal clean fuel leakage system of the engine. A spring acting on the push rod keeps the pilot needle closed in event of loss of pilot fuel pressure.

There are very small clearances in the nozzle and in the solenoid valve, and therefore cleanliness and prevention of particles and dirt from entering the valve nor pipes are of utmost importance.

16.6.2 Removing the injection valve

1 **Remove the cylinder head cover** and the hot box cover.

2 **Remove the pilot fuel pipes** to neighbour cylinders and protect the ends.

3 **Remove the pilot fuel connection piece** and pull out the connection pipe from cylinder head.

4 **Remove the main fuel injection pipe.**

5 **Remove the flange** for main fuel connection piece and pull out the connection piece.

6 **Disconnect the cables from injection valve.**

7 **Remove the fastening nuts** of the injection valve.

8 **Lift out the injection valve.** If necessary, use the tool 3V83H0163.

9 **Protect the bore in the cylinder head.**

Injection valve

1. Cover
2. Upper body
3. Nozzle
4. Screw
5. Cap nut
6. Push rod
7. Connector
8. Spring
9. Adjusting screw
10. Counter nut
11. O-ring
12. Bushing
13. Extension piece
14. Screw
15. Piston
16. Spring
17. Valve plate
18. Cylinder
19. Control part
20. Spring
21. Shim
22. Spring retainer
23. push disc
24. Spring retainer
25. Solenoid
26. Push rod
27. Conductor fixing screw

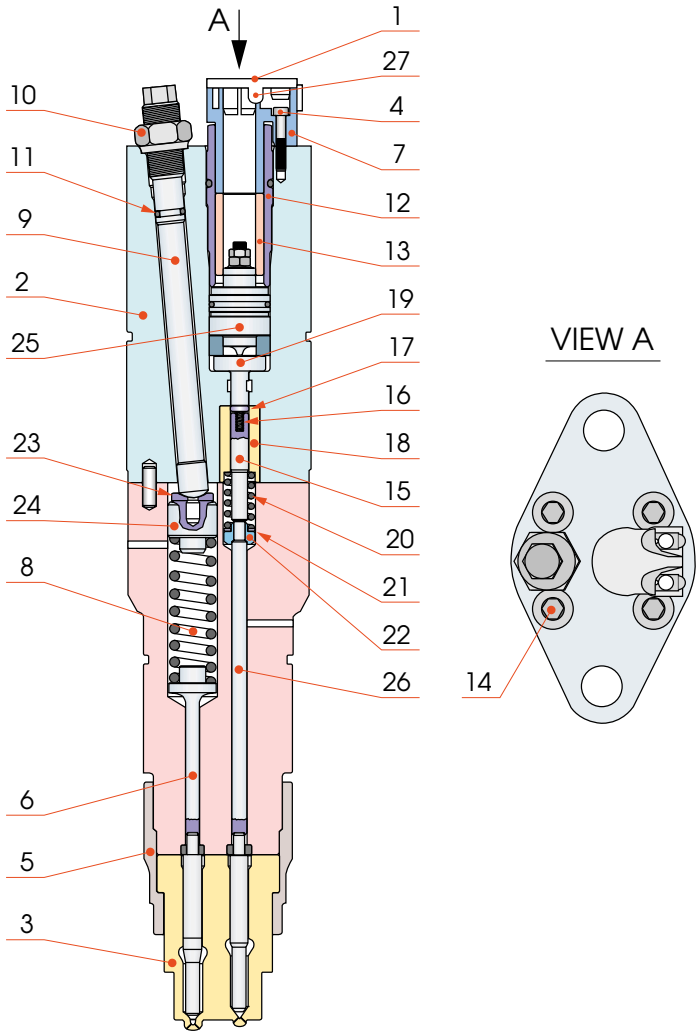

Fig 16-4 3216999801

16.6.3 Mounting of the injection valve

1 **Check the bottom of the stainless sleeve** in the cylinder head. Clean if necessary. The injection valve seals directly to the bottom of the sleeve.

2 **Put new O-rings** on the injection valve. Lubricate the O-rings with engine oil or grease. Fit the injection valve into the cylinder head bore and tighten the valve fastening nuts only by hand.

3 **Put a new O-ring** on the liquid fuel connection piece. Mount the connection piece and flange. Tighten screws to torque stated in chapter 07.

4 **Put a new O-ring** on the pilot fuel connection pipe. Mount the pipe and the connection piece. Tighten screw to torque stated in chapter 07.

5 **Put a new a ring** on the nozzle cooling connection piece. Lubricate the O-ring with engine oil or grease. The connection piece has to be assembled carefully to avoid damages on connection piece end sealing surface. Tighten the screw to torque.

6 **Tighten the fastening nuts** of the injection valve to torque stated in chapter 07.

7 **Mount the nozzle cooling pipe** and pilot fuel rail pipes. Tighten connection nuts to torque stated in chapter 07.

8 **Connect the cables to the injection valve.**

9 **Mount the covers.**

16.6.4 Overhauling the injection nozzle

The injection valve is a precision made valve with small borings and moving parts with small clearances. Therefore cleanliness is of utmost importance. Overhaul of injection valve should be done in a dust free place. All parts of the injection valve should be kept together and not mixed with parts from other injection valves.

1 **Inspect the nozzle immediately after removing** the injection valve from the engine. Carbon deposits (trumpets) may indicate that the nozzle is in poor condition, or the spring is broken. Clean the outside of the nozzle with a brass wire brush. **Do not use steel wire brush.**

2 **Insert the valve in the test bench** and connect the high pressure supply to the main diesel inlet port. Check the opening pressure for the main diesel needle. If the opening pressure is more than 20 bar below the stated value, it indicates a broken spring or badly worn parts. Check the main diesel sprays.

Then connect the high pressure supply to the pilot fuel inlet port. Apply high pressure fuel (900 bar). Check for pilot nozzle leakage. If the nozzle sprays, the pilot needle or the pilot valve is stuck open. Shoot some single injections to check the spray pattern.

3 **Fix the injection valve** in the fixing tool 2V84G0263. Release the main needle spring tension by opening the counter nut (10) and screwing up the adjusting screw (9).

4 **Remove the nozzle from the holder** by opening the cap nut (5). Press the nozzle towards the holder, the guiding pins will then prevent the nozzle from rotating and thereby damage the needles. If there is coke between the nozzle and the nut, the guiding pins may break and damage the nozzle. To avoid this, knock with soft hammer on the nozzle bottom. **Never knock on the nozzle tips.** Be careful not to drop the nozzle.

5 Check the nozzle needle movement. If a needle is sticking it may result in complete jamming if removed by force. Unless it can be easily removed, immerse the nozzle in lubricating oil and heat oil to 150 - 200°C. Normally a needle can be removed from a hot nozzle. Note that the needles from different nozzle bodies may not be mixed.

Max. lift of nozzle

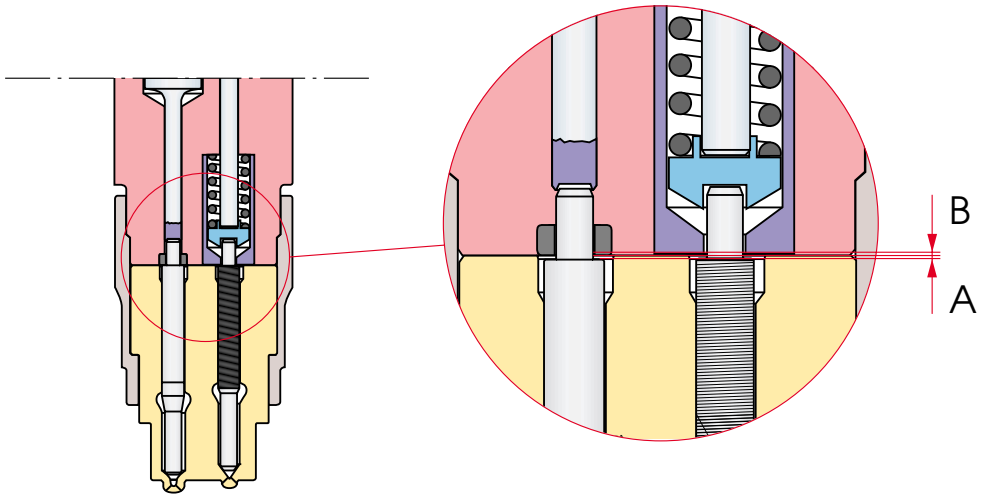

Fig 16-5 3216019801

6 Clean the details. If possible, use a chemical carbon dissolving solution. If there is no such available, immerse the details in clean fuel oil, white spirit or similar to soak carbon. Then clean the details carefully by tools included in the tool set. **Do not use steel wire brushes or hard tools.** Clean the nozzle orifices with needles provided for this purpose. After cleaning, rinse the details to remove carbon residues and dirt particles.

Before inserting the needles in the nozzle body, immerse the details in clean fuel oil or special oil for injection systems.

Seat surfaces, sliding surfaces (needle shaft) and sealing faces against the nozzle holder should be carefully checked.

7 Check the max. lift of the needles, i.e. sum of measures A and B in Fig Fig 16-5. If wear B exceeds 0.05 mm the nozzle holder can be sent to the engine manufacturer for reconditioning. If the total lift is out of the value stated in chapter 06, section 06.2, the nozzle should be replaced by a new one.

8 Clean the nozzle holder and cap nut. Pay special attention to the sealing surface of the nozzle holder, i.e. the contact face to nozzle, and the inlet port cones.

9 Reassemble the nozzle. Grease the cap nut thread and the nozzle shoulder with Molykote. Tighten the cap nut to 600 Nm.

10 Insert the valve in the test bench and connect the high pressure supply to the main diesel inlet port. Apply fuel pressure and adjust the opening pressure to stated value (350 bar). **Note the fuel spray uniformity.**

11 Check the needle seat tightness:

- Decrease the supply pressure to a value 20 bar below the opening pressure
- Keep the pressure constant for 10 s and check that no fuel drops appear at the nozzle tip. A slight dampness may be acceptable.

12 Connect the high pressure supply to the pilot fuel inlet port. Apply fuel pressure (900 bar). Check the needle seat tightness, no fuel drops may occur, a slight dampness may be acceptable.

Shoot some single injections to check the spray pattern. Then shoot a serie of injections for measurement of injected amount of fuel:

- Check that the fuel pressure is 900 bar, and that the duration is set to 1.1 ms
- Put a graduated glass onto the nozzle and shoot a serie. A serie of 10 s should give an amount of 76±4 cm^3.

13 If leakage occurs on the high pressure sealing surfaces, the damaged detail should be replaced by a new one ore reconditioned.

14 If nozzles or injection valves are to be stored they should be treated with corrosion protecting oil.

16.6.5 Overhauling the injection nozzle holder

The nozzle holder should be reassembled only if necessary, i.e. the injection valve has poor function even if the nozzle is in good condition.

16.6.5.1 Pilot solenoid

1 Remove the cap (1) of the connector (7). Loosen the conductor fixing screws (27) on the side of the connector. Unscrew the connector fixing screw (4), and pull out the connector carefully.

2 Unscrew the bushing (12) and pull out the solenoid with the extension piece (13). Be careful not to drop the valve stem or the ring. Note, the solenoid, the valve stem and the ring are calibrated together and may not be changed individually. **Do not unscrew the solenoid adjusting screw.**

3 Clean the details in clean fuel oil, white spirit or similar. Replace the O-ring on the solenoid and on the bushing. If the solenoid has a malfunction, the solenoid, valve stem and ring should be replaced with new ones.

4 Rinse the details with clean fuel oil. Insert the ring into the top body. Apply the bushing and the solenoid to tool 4V84G0511. Insert the valve stem into solenoid. Mount the solenoid with the valve stem into the top body and screw in the bushing. Fix the orientation of the solenoid with the pin 4V84G0512 through the tool 4V84G0511 into the thread hole in the top body. Tighten the bushing to 50 Nm.

5 Pull out the tool and the pin, and mount the extension piece and the connector. Tighten the connector fixing screw and the conductor fixing screws. Put on the cap.

6 After overhaul or replacement of the solenoid, the function should be checked in the test bench. See chapter 16.6.4 step 12.

16.6.5.2 Springs, pilot piston and push rods

1 Release the main needle spring tension by opening the counter nut (10) and screwing up the adjusting screw (9).

2 Unscrew the fixing screws (14) on the top of the nozzle holder. Remove the top body. Be careful not to drop the pilot piston (15), spring (16) and valve plate (17). Be careful not to scratch the high pressure sealing surface between the top body and the lower body.

Note! The pilot piston is lapped together with the cylinder (18) and may not be mixed with other pistons. Check the piston for seizure marks.

The cylinder and the control part (19) are pressed into the top body and should not be dismantled.

3 Remove the pilot needle return spring (20), push rod (26) with shim (21) and spring retainer (22). Check the spring wire for damages and the push rod sliding surface for seizure marks.

4 Remove the push disc (23), the spring retainer (24), the main fuel return spring (8) and the push rod (6). Check the spring.

5 Clean all details. Assemble in opposite order.

6 Adjust the main fuel needle opening pressure and check the valve function in the test bench. See chapter 16.6.4 point 10.

17. Fuel System

17.1 General description for gas system

Before the gas is supplied to the engine it passes a gas regulating unit. The unit includes filter, pressure regulators, shut-off valves and ventilating valves. The outlet gas pressure is controlled by the control system (WECS) according to engine load and site ambient conditions. As the gas regulating unit can vary from one installation to another, this unit is not described in detail in this manual. See separate instructions.

Gas fuel system

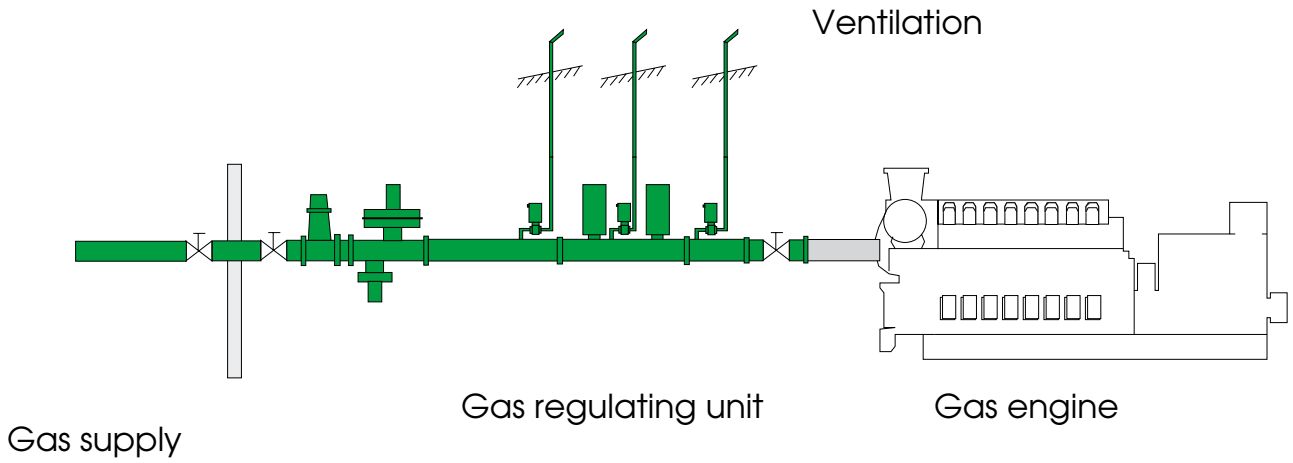

Fig 17-1 3217689801

On the engine the gas is supplied via a common pipe running along the engine, continuing with individual feed pipes to each cylinder.

The gas admission is controlled with “Main Gas Admission Valves” for the main charge. Valve is direct actuated solenoid valve and controlled by the control system (WECS).

Main gas pressure at the engine can be checked from the local display unit. Alarms are set for low pressure difference between charge air pressure and the gas pressures.

17.2 Maintenance for gas system

When working with the fuel system, always observe utmost cleanliness. Pipes, gas valves, check valves, components in the gas regulating unit, etc. should be carefully cleaned before taken into use.

Note! **Before doing any maintenance work, check that gas supply valves are closed, vent valves are in open position and gas pressure is drained out from the gas lines.**

17.3 Gas pipes

Both A- and B-bank has own distributing pipes which feeding the gas along the engine for the main gas admission valves. The gas pipe connections are sealed by O-rings. Always renew the O-rings if a pipe has been removed.

17.3.1 Gas system leak test

1 **Connect compressed air pressure,** 8 bar to the inlet flange of the gas system.

2 **Check all connections** with soap water or leakage spray, beginning from the inlet flange and continue through the gas line. The last connection on the main gas line is connections between flexible hoses and the main gas admission valves.

3 **Growing bubbles on the connection** indicates leakage.

Note! **Release the air pressure in the system before disassembling.**

4 **Disassemble the leaking connection,** examine the O-rings and sealing faces. Replace worn parts.

5 **Repeat the leak test** for the repaired connection(s).

17.4 Main gas admission valve

17.4.1 Description

The main gas admission valve is controlling the amount of gas fed to each cylinder of the engine. The valve is located on the cylinder head and the gas is fed into the inlet channel of the cylinder head. The main gas valve is a direct actuated solenoid valve.

With the control system (WECS) it is possible to adjust the amount

of gas fed to individual cylinders, even when the engine is running. For further information about engine control, see chapter 22.

Main gas admission valves

1. Main gas admission valve
8. Hose
9. Screw
10. Screw
11. Cable connector
12. O-ring
13. O-ring

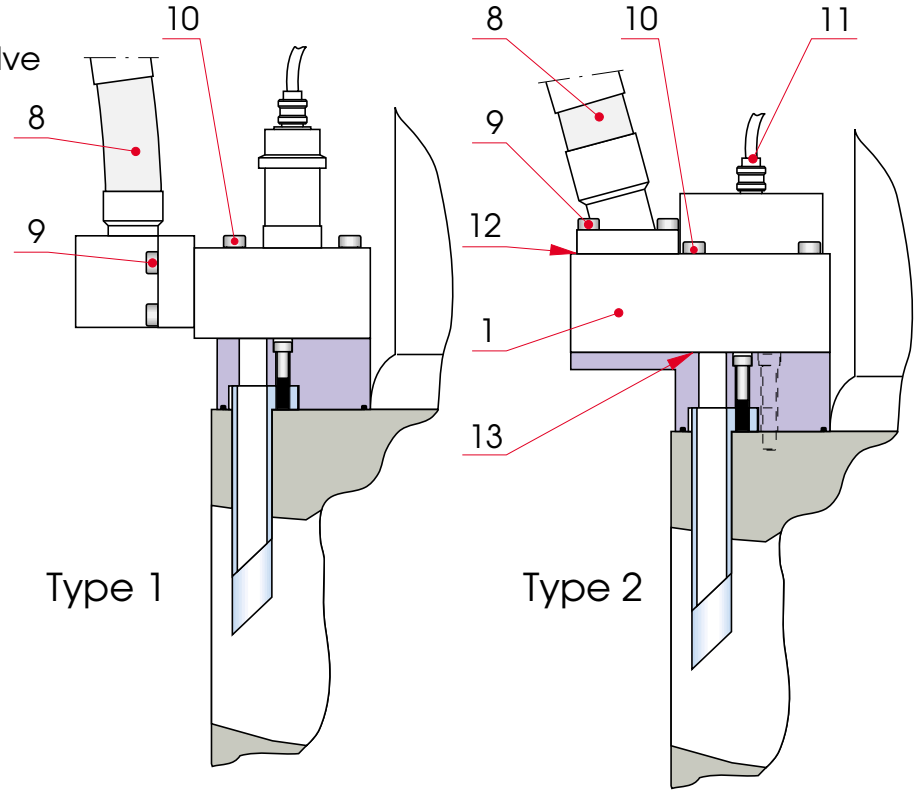

Fig 17-2 3217679720

17.4.2 Removing of the gas admission valve

1 **Check that the gas supply valves are closed,** gas vent valve is in open position and gas pressure is drained out from the gas lines.

2 **Unscrew the fastening screws (9)** of the flexible hose connection piece.

3 **Disconnect the electrical connector (11).**

4 **Unscrew the fastening screws (10)** of the gas admission valve and remove the gas admission valve.

5 **Protect the bore** in the cylinder head and the gas pipe end.

17.4.3 Overhaul of the gas admission valve

The main gas admission valve requires no maintenance. The gas admission valve should be replaced by a new valve in the event of malfunction.

17.4.4 Mounting of the gas admission valve

1 **Remove the protecting covers** and check that the surface of the cylinder head is clean.

2 **Renew O-rings** (12) and (13) on the gas admission valve.

3 **Mount the gas valve** and tighten the fastening screws (10) to correct torque acc. to chapter 07.

4 **Mount the gas distributing hose** and tighten all fastenings screws for pipe connections (9).

5 **Connect the electrical connector (11).**

17.5 General description for liquid fuel system

As the fuel treatment system before the engine can vary widely from one installation to another, this system is not described in detail in this manual. See separate instructions.

In multi-engine installations the engine is equipped with an electrically driven fuel feed pump and a duplex filter to provide correct flow, pressure and filtration irrespective of the number of engines connected to a common external treatment system.

The fuel feed pump (9) delivers the correct flow to the engine through the duplex filter (8). The pressure control valve (11) maintains the correct pressure in the engine system. To prevent damage of the injection equipment by a broken filter insert, there is a pressure control valve (12) on the filter's primary side which by-passes the filter when the pressure drop over the filter is too high. To make operation with a by-passed filter possible in an emergency situation, the by-pass duct has been connected to the engine side of the pressure control valve (11). Take care that the pressure difference alarm (13) has started to operate before the by-pass duct opens.

A pressure gauge (5) on the instrument panel indicates the fuel inlet pressure and a local thermometer (6) indicates the inlet temperature. A pressure switch (7) for low fuel pressure is connected to the automatic alarm system.

Fuel leaking from injection pumps and injection valves is collected in a separate enclosed system. Thus this fuel can be reused. A special module for automatic handling of this fuel back to the system can be delivered on request.

A separate pipe system leading from the top level of the engine block collects waste oil, fuel and water arising, for example, when overhauling cylinder heads.

The high pressure system, with injection pump and injection valve, is described in chapter 16.

Fuel system

5. Pressure gauge
6. Thermometer
7. Pressure switch
8. Fuel filter
9. Fuel pump
10. Control valve
11. Pressure control valve
12. Pressure control valve
13. Pressure difference indicator
14. Valve
15. Pilot fuel filter
16. Pilot fuel pump

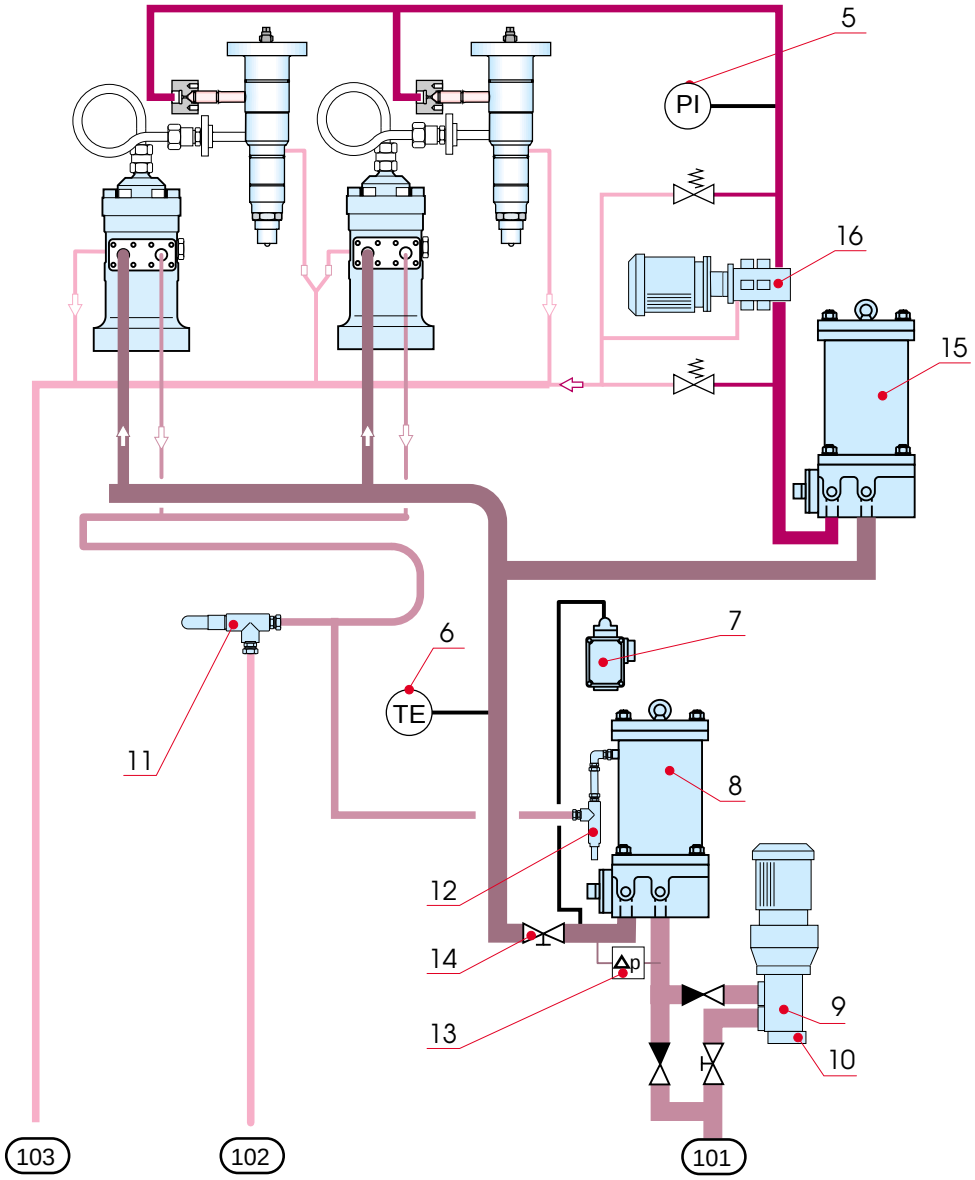

Fig 17-3

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17.6 Maintenance for liquid fuel system

When working with the fuel system, always observe utmost cleanliness. Pipes, tanks and the fuel treatment equipment, such as pumps, filters, heaters and viscosimeters, included in the engine delivery or not, should be carefully cleaned before taken into use.

Change the filter cartridges regularly. The fuel filter is provided with a combined visual indicator/electrical switch, connected to the automatic alarm system, which indicates too high pressure drop over the filter.

Note! The paper cartridges should be changed as soon as possible when too high a pressure drop is indicated.

The intervals between changes of cartridges depend largely on the quality and dirt content of the fuel as well as on fuel treatment before the engine. Guidance values are stated in chapter 04.

The fuel should always be separate and it is recommendable to fit an automatic filter in the fuel treatment system.

Always when the system has been opened, it should be vented after reassembly, see section 17.7

For maintenance of the fuel treatment equipment not mounted on the engine, see separate instructions.

17.7 Venting

Open the air vent screws on the injection pumps (see chapter 16, Fig 16-60 pos. 42.). Start the fuel feed pump if the static pressure from the day tank is not sufficient.

Always vent the filter after changing cartridges in the filter.

If the engine has been stopped and the feed pump is not running, the three-way valve can be changed directly over to the position where both sides are in operation. The air can be vented through the respective air vent screw. If the engine is running, the change-over of the three-way valve should be carried out very carefully to give only a small flow of fuel to the filter side to be vented. The best way is to use the slow filling valve on the three-way valve. Set the valve in “slow filling” position (see Fig 17-4), and the filter side will be slowly filled. Vent the filter side. Set the three-way valve and slow-filling valve in normal position (both filter sides in use).

A sudden change-over of the three-way valve to an empty filter side will cause a temporary pressure drop in the engine system, and the alarm switch will give a signal for too low a fuel pressure. This may also involve the risk of air escaping from the filter to the injection pumps, which may also cause the engine to stop.

To avoid air escaping to the injection pump, fill up the filter with clean fuel before changing over.

Three-way valve positions

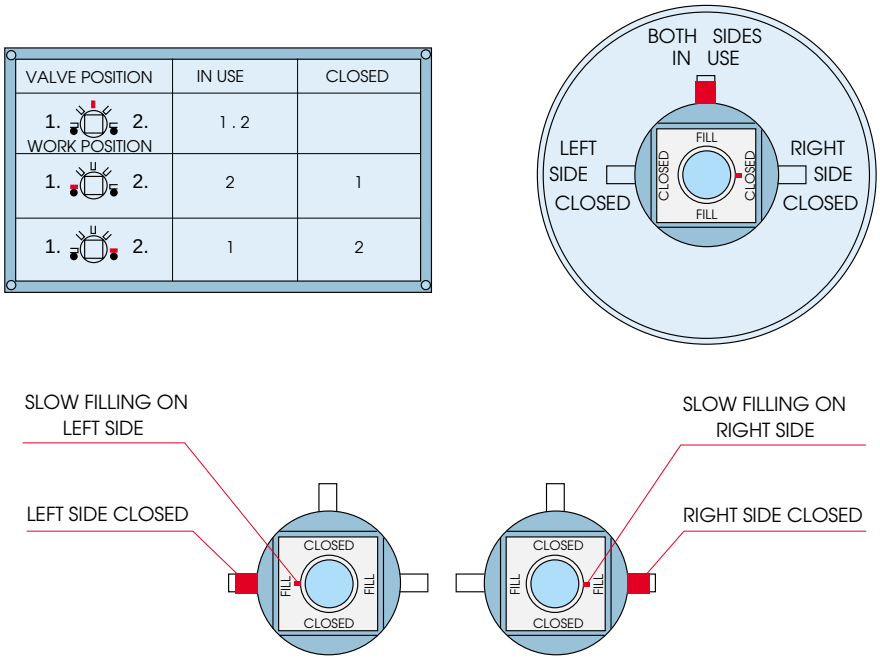


Fig 17-4 3217558935

17.8 Adjustment of pressure control valves

Check the adjustment at intervals recommended in chapter 04. Adjust the valves at normal temperatures with an idling engine, i.e. the booster pump (9, Fig 17-3) running.

All pressures mentioned in the instructions apply to the readings of the pressure gauge (5) in the instrument panel of the engine.

Turn the adjusting screws of the pressure control valves clockwise to achieve higher pressure, counter-clockwise to achieve lower pressure.

1 Adjustment of the valve (10) on the pump: Raise the pressure in the system slowly by closing the valve (11). Adjust the valve (10) to 12 bar. Open the valve (11) completely.

This adjustment should be carried out rapidly as the pump (9) may run hot if the system is closed for a lengthy time.

2 Adjustment of pressure control valve (11): Adjust the valve (11) to 6 bar.

3 Adjustment of pressure control valves (12): Close the valve (14). With both sides of the filter (8) in operation (normal operation condition) the pressure should be 8.5 bar. Adjust both the valves (12) to give the correct pressure. Check that both the valves (12) are equally adjusted by closing one side of the filter, one after the other. Adjust on the open filter side, if necessary. The pressure of the valves (12) can be somewhat higher with only one side of the filter in operation than with both sides in operation. Do not forget to open the valve (14) after the adjustment.

17.9 Fuel feed pump

The electrically driven fuel feed pump is of the same type as the prelubricating pump. For description and maintenance, see chapter 18, section 18. 9.

Set the pressure according to section 17.8

17.10 Fuel filter

17.10.1 Description

The filter is a duplex filter. By means of the three-way valve (8) the fuel flow can be guided to one side or the other, or to both sides in parallel. The direction of the flow appears from the mark on the cock (7). **At normal operation, both sides of the filter are used in parallel to provide maximum filtration**. Fig 17-5A shows the valve in this position. When changing cartridges during operation one side can be closed. Fig 17-5B shows the position of the valve when the right side of the filter is closed.

The arrows in the figure show the flow through the filter. The fuel flows first through a cartridge (3) made of special paper, filtering off particles larger than 10 to 15 µm, then through an insert (4) of pleated wire gauze around a firm perforated case. The wire gauze insert, with a mesh size of 40 µm, serves as a safety filter in case of failure of the paper element.

Fuel filter

1. Vent screw
2. Cover
3. Cartridge
4. Insert
5. Guide ring
6. Drain plug
7. Mark
8. Three-way valve

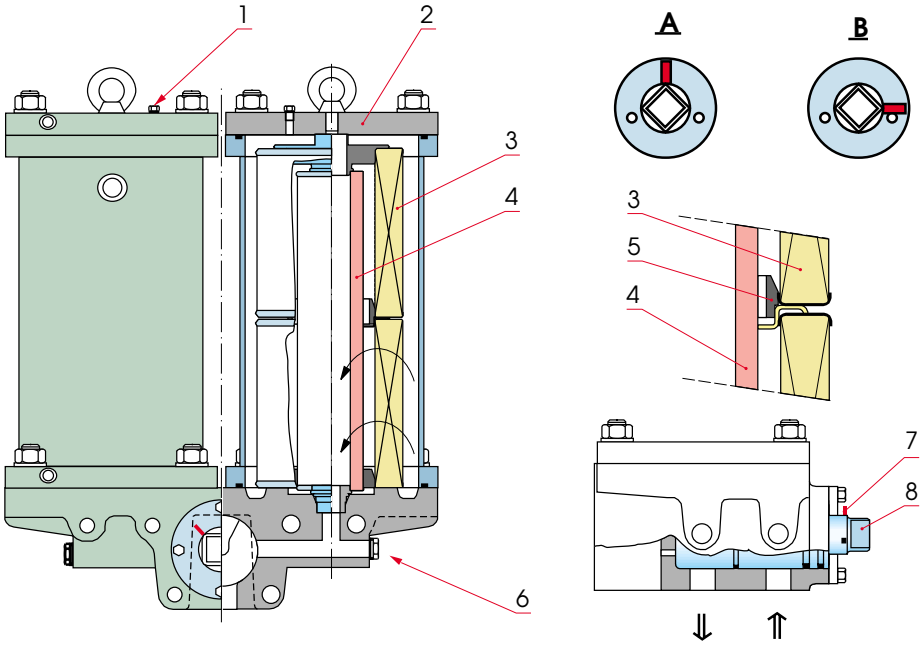


Fig 17-5 3217538934

17.10.2 Changing of filter cartridges and cleaning of filter

Change cartridges regularly (see chapter 04) and, if the pressure drop indicator gives alarm, as soon as possible. As the useful life of the cartridges is largely dependent on fuel quality, centrifuging and filtering before the engine, experience from the installation concerned will give the most suitable intervals between changes of cartridges.

Change of cartridges and cleaning is most conveniently done during stoppage. By closing one side of the filter the cartridges can, however, be changed during operation as follows:

Take care not to open the side of the filter in operation.

1 **Shut off the filter side to be serviced.**

2 **Open the air vent screw (1)** and, afterwards, the drain plug (6). Drain the fuel.

3 **Open the filter cover (2).**

4 **Remove the wire gauze insert (4).** Wash in gas oil. Check that it is intact.

5 **Remove the paper cartridge(s) and throw away.** Paper cartridges cannot be cleaned. Always keep a sufficient quantity of cartridges in stock.

6 **Clean and rinse filter housing** carefully with gas oil.

7 **Fit new paper cartridges** and the cleaned wire gauze insert. Check that all seals are intact and in position.

8 **When the filter has two or three inserts per side,** check that the guide ring (5) is mounted.

9 **Mount the drain plug and cover.**

10 **If possible, fill the filter with clean fuel** before changing over to the working position (both sides of filter in operation). If the filter cannot be filled, change over very slowly, see section 17.7

11 **Vent the filter** if not completely filled according to pos. 10. See section 17.7

18. Lubricating Oil System

18.1 General design

Normally, a wet sump system is used, but also dry sump systems can be used.

The engine is provided with a lubricating oil pump (10) directly driven by the pump gear at the free end of the crankshaft. In some installations there is a separately driven stand-by pump in parallel. The pump sucks oil from the engine oil sump and forces it through the lubricating oil cooler (1) equipped with a thermostat valve (3) regulating the oil temperature, through the lubricating oil main filters (4) to the main distributing pipe (5) in the oil sump, through the hydraulic jacks (in this respect acting as ordinary pipes) to the main bearings and through bores in the connecting rods to the gudgeon pins (6) and piston cooling spaces. Oil is led through separate pipes to other lubricating points like camshaft bearings (7), injection pump tappets and valves, rocker arm bearings (8) and valve mechanism gear wheel bearings and to oil nozzles for lubricating and cooling. Part of the oil flows through a centrifugal filter back to the oil sump. The oil sump is provided with a level switch connected to the automatic alarm system.

The V-engine is not equipped with a built-on oil cooler nor a filter.

The dry sump system differs from the wet sump system only in that the oil flows freely from the oil sump to a separate tank, and the pump sucks the oil from this tank. (There is also the possibility to mount a second oil pump directly driven by the engine for draining the oil sump to a separate oil tank.)

The electrically driven prelubricating pump is a screw type pump equipped with an overflow valve. The pump is used for:

- filling of the diesel engine lubricating oil system before starting, e.g. when the engine has been out of operation for a long time,
- continuous prelubrication of a stopped diesel engine through which heavy fuel is circulating,
- continuous prelubrication of stopped diesel engine(s) in a multi-engine installation always when one of the engines is running,
- providing additional capacity to the direct driven lubricating oil pump in certain installations where the diesel engine speed drops below a certain value (the pump should start and stop automatically on signals from the speed measuring system).

In V-engines which have no built-on lubricating oil pump, the prelubrication should be arranged by means of an external pump.

The pressure in the distributing pipe (5) is regulated by a pressure control valve (11) on the pump. The pressure can be adjusted by means of a set screw (Fig 18-2, pos. 17) on the control valve. It is very important to keep the correct pressure in order to provide efficient lubrication of bearings and cooling of pistons. Normally, the pressure stays constant after having been adjusted to the correct value.

The pressure can rise above the nominal value when starting with cold oil but will return to the normal value when the oil is heated. A pressure gauge (9) on the instrument panel indicates the lubricating oil pressure before the engine (in the engine distributing pipe). The system includes three pressure switches for low lubricating oil pressure (2), two connected to the automatic alarm system and one for lower pressure to the automatic stop system (see chapter 23.).

The temperature can be checked from thermometers (14) before and after the oil cooler (chapter 01., section 01.2). A temperature switch for high lubricating oil temperature is connected to the automatic alarm system (see chapter 23).

The speed governor have its own oil system. Depending on the turbocharger type, it can be lubricated by an own oil system or by the engine oil system. See separate instruction books.

The oil filling opening (12) is located at the free end, and an oil dipstick (13) is located at the middle of the engine.

Connections for a separator are provided on the oil sump at the free end of the engine.

For taking oil sample a valve (15) is available after oil filter.

18.2 General maintenance

Use only high quality oils approved by the engine manufacturer according to chapter 02., section 02.2.

Always keep 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 near the max. mark and never allow the level to go below the min. mark. The limits apply to the oil level in a running engine. Add max. 10 % new oil at a time (see chapter 02., section 02.2). One side of the dipstick is graduated in centimeters. This scale can be used when checking the lubricating oil consumption.

Change oil regularly at intervals determined by experience from the installation concerned, see chapter 04. and 02., section 02.2.3.While the oil is still warm, drain the oil system, also the oil cooler and filter. Clean the crankcase and the oil sump with proper rags (not cotton waste). Clean the main filter and the centrifugal filter. Change cartridges in the main filter unless they have been changed recently.

Centrifuging of the oil is recommended, especially when using heavy fuels, see chapter 02., section 02.2.3.

Utmost cleanliness should be observed when treating the lubricating oil system. Dirt, metal particles and similar may cause serious bearing damage. When dismantling pipes or details from the system, cover all openings with blank gaskets, tape or clean rags. When storing and transporting oil, take care to prevent dirt and foreign matters from entering the oil. When refilling oil, use a screen.

Lube oil system

1. Lubricating oil cooler
2. Pressure switch
3. Thermostat valve
4. Lubricating oil filter
5. Main distributing pipe
6. Gudgeon pin
7. Camshaft bearing
8. Rocker arm bearing
9. Pressure gauge
10. Lubricating oil pump
11. Pressure control valve
12. Filling opening
13. Dipstick
14. Thermometer
15. Oil sample valve

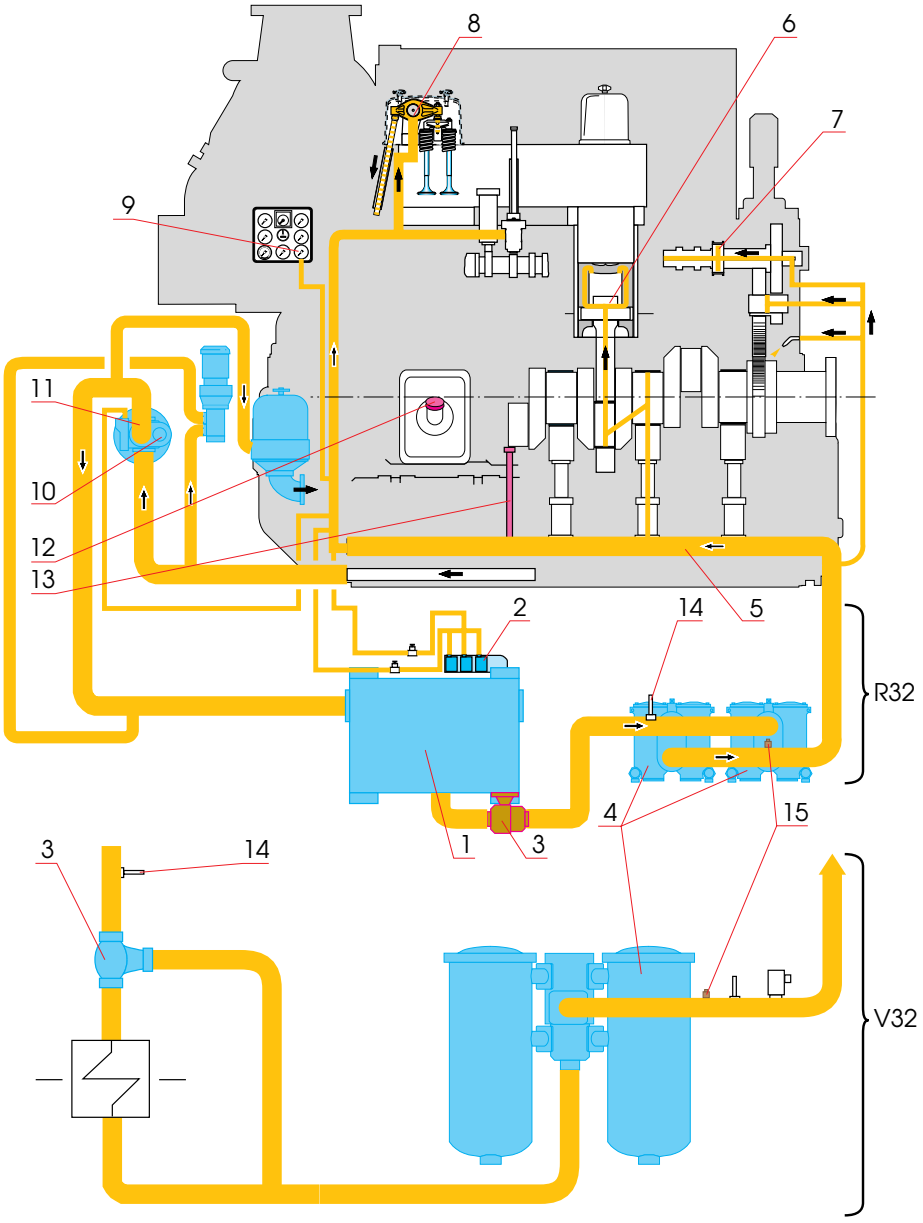


Fig 18-1 3218629701

18.3 Lubricating oil pump

18.3.1 Description

The pump is of the gear type, equipped with a built-on, combined pressure regulating/safety valve. Four and six cylinder engines have

pumps with two pump gears each, according to Fig 18-2. The pumps of 8- to 18-cylinder engines have three pump gears each, and the two-fold pressure and suction spaces are connected by ducts in the pump cover, where the pressure control/safety valve is also located. Identical bronze bearings are used. No outside lubrication is required. The cover is sealed by an O-ring.

Lube oil pump

1. Screw
2. Gear wheel
3. Pressure plate
4. Screw
5. Grooves
6. Pin
7. Cylinder
8. Sealing ring
9. Piston
10. Pipe
11. Sealing ring
12. Ball
13. Drain bore
14. Regulating piston
15. Spring retainer
16. Spring
17. Screw
20. Conical ring elements

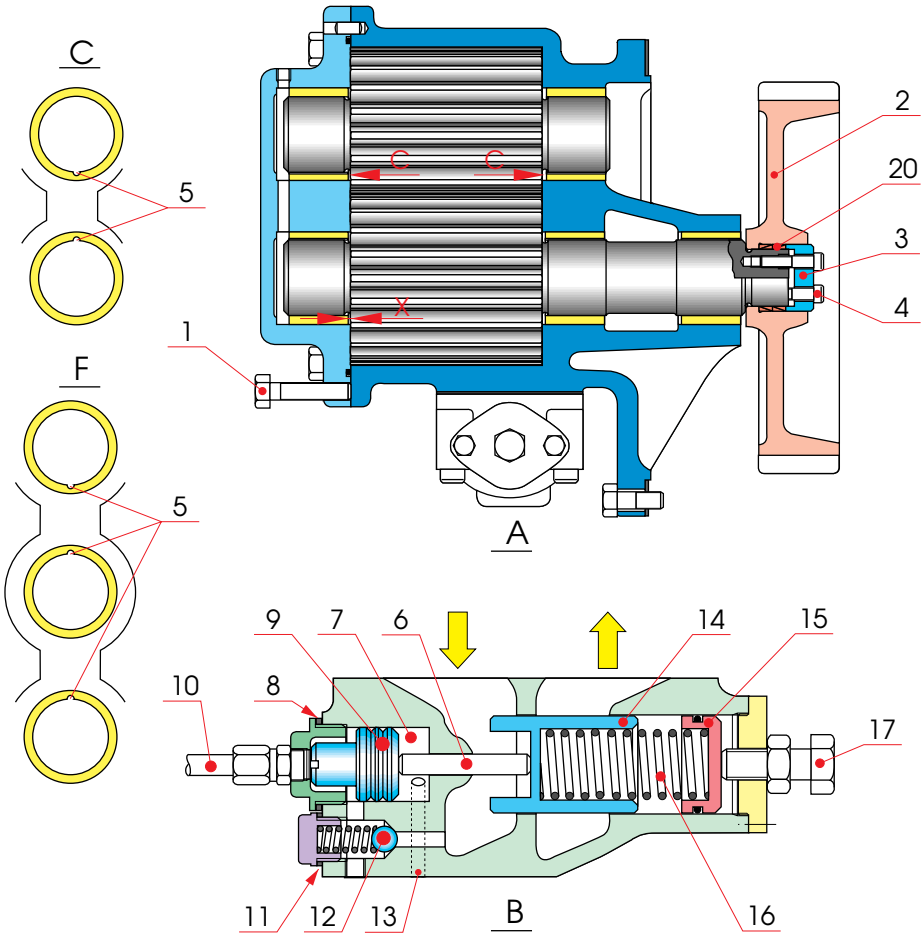


Fig 18-2 3218529045

18.3.2 Dismantling

1 Remove and inspect the regulating valve according to section 18.4.

2 Loosen the screws (4) and remove the pressure plate (3), according to Fig 18-2.

3 **Pull off the gear wheel (2)** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The conical ring elements come loose together with the gear wheel.)

Using an extractor will only damage the shaft (axial scratches).

4 **Withdraw the pump cover** by using two of the fastening screws (1) in the two threaded holes located in the cover.

18.3.3 Inspection

1 **Check all parts for wear** (chapter 06., section 06.2) and replace worn parts.

2 **Remove worn bearings** from the housing by driving them out with a suitable mandrel, from the cover by machining.

3 **Mount new bearings** (freezing is recommended) so that the bearings are three (3) mm below the cover and housing level (measure X = 3 mm), Fig 18-2 A. Be careful so that bearing lubrication grooves (5) slide into the right position according to Fig 18-2 C.

4 **Check the bearing diameter** after mounting. Check the gear wheel axial clearance (see chapter 06., section 06.2).

18.3.4 Assembling

1 **Clean all details carefully before assembling.** Check that the O-ring in the cover is intact and in position.

2 **Before re-installing the gear wheel,** all contact surfaces should be cleaned and oiled.

3 **Re-install the conical ring elements** (20).

Re-install the conical ring elements exactly as situated in Fig 18-3. The conical ring elements should fall easily in place and must not jam.

4 **Re-install the pressure plate.**

5 **Tighten the screws a little** and check that the gear wheel is in the right position.

6 **Tighten the screws to torque** according to chapter 07.

7 **If the gear wheel (2) has been changed,** check the backlash after mounting the pump on the engine.

Mounting of gear wheel to oil pump

3. Pressure plate
4. Screw
20. Conical ring elements

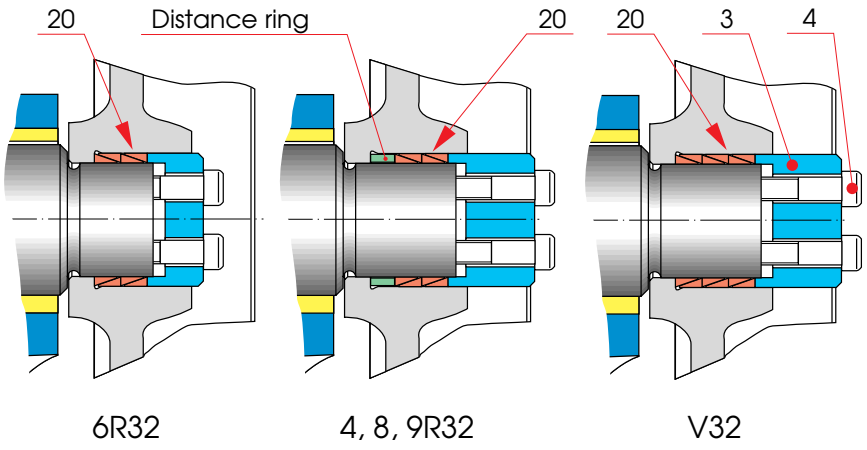


Fig 18-3 3218589045

18.4 Lubricating oil pressure regulating valve and safety valve

18.4.1 Description

The pressure regulating valve is mounted on the lubricating oil pump and regulates the oil pressure before the engine by returning the surplus oil direct from the pressure side of the pump to the suction side.

The pipe (10), Fig 18-2, is connected to the engine distributing pipe, where the pressure is kept constant in engines running at constant speed. This pressure actuates the servo piston (9) and the force is transferred to the regulating piston (14) through the pin (6). The spring (16) is tensioned to balance this force at the required pressure. Thus the pressure is kept constant in the distributing pipe, irrespective of the pressure in the pressure side of the pump and of the pressure drop in the system. By tensioning the spring (16) a higher oil pressure is obtained.

In engines which are running at varying speeds, the valve is arranged to give a pressure depending on the speed, according to operating pressures recommended at various speeds (chapter 01).

If, for some reason, the pressure should increase strongly in the pressure pipe, e.g. due to clogged system, the ball (12) will open and allow oil to pass to the servo piston (9), which will open the regulating piston (14) by means of the pin (6).

The valve serves as a safety valve.

18.4.2 Maintenance

1 Dismantle all moving parts. Check them for wear and replace worn or damaged parts by new ones.

2 Clean the valve carefully. Check that the draining bore (13) is open.

3 Check that no details are jamming.

Do not forget copper sealing rings (8) and (11) when reassembling. (Part 8 is used for 4- and 6-cylinder engines, only.) If the sealings are changed, check that the thickness is correct, (8) = 2 mm, (11) = 1.5 mm, as the thickness of these sealings influences the valve function.

4 After reassembling, check that the piston (14) closes (especially if some details have been replaced by new ones).

18.5 Plate cooler for lubricating oil

18.5.1 Description

The plate cooler consists of a number of heat transfer plates, arranged so that every other passage between the plates is accessible for one of the two liquids. A double gasket has a channel to the atmosphere between the gasket parts and prevents leakage between the media.

Each plate cooler is marked with the compression measure “A” and the specification number of the plate pack.

A damaged plate can easily be replaced by an identical spare plate. Two adjoining plates can be removed without being replaced. The capacity of the cooler will usually be slightly reduced. The plate pack length (A) will be reduced by the assembly length of two plates (2 × 2.6 mm).

18.5.2 General maintenance

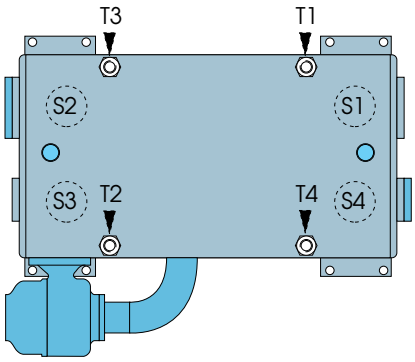
1 Clean and test the cooler at intervals according to chapter 04. or if the lubricating oil temperature tends to rise abnormally.

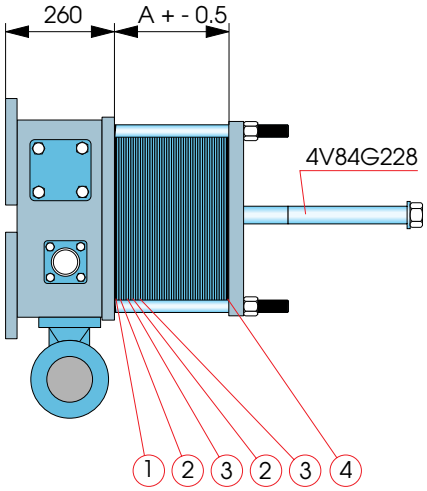
2 Always when cleaning, check for corrosion and test by hydraulic pressure.

It is preferable to change plates in bad condition too early, rather than too late. Water leakage to lubricating oil has serious consequences

3 When replacing plates, make sure that all plates are assembled in correct order. Change gaskets when necessary.

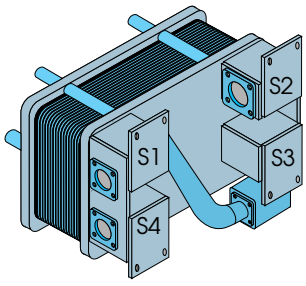
Plate oil cooler





S1 = Oil inlet
S2 = Water inlet
S3 = Oil outlet
S4 = Water outlet

1 = End plate II
2 = Channel plate
3 = Channel plate
4 = End plate I



Measure A = Q x 2.6 mm
where Q = number of plates

Example :

135 plates gives
A = 135 x 2.6 mm = 351 mm

Fig 18-4 3218639045

18.5.3 Opening

1 **Release the pressure from the cooler.**

2 **If the plate cooler is hot** wait until it has cooled to about 40°C.

3 **Drain the cooler.**

4 **Mount the tool 4V84G228** according to Fig 18-4.

5 **Slacken the nuts** in turn diagonally as shown in Fig 18-4.

Note! During opening, the slant of the pressure plate must not exceed 10 mm (2 turns/nut).

6 **Dismantle the plate pack.**

18.5.4 Cleaning

Normally the plates can be cleaned by a soft brush and water.
Solid deposits can be cleaned with a soft brush and 4 % nitrite acid. Max. temperature 60°C.

Note! Rinse well.

18.5.5 Closing

1 **Check that all sealing surfaces** (surfaces in contact with media) of the heat exchanger are clean.

2 **Check the threads of the tightening nuts.** See that they are undamaged, cleaned and smeared with a thin film of lubricating paste.

3 **Check that all plates** are in good condition.

4 **Bring the plates together** and mount the nuts.

5 **Tighten the nuts** in turn, diagonally as shown in Fig 18-4.

Note! The slant of the pressure plate must not exceed 10 mm (2 turns/nut) during compressing.

6 **Compress to measure A.** Measure A should be checked near the bolts. Max deviation: 2 mm. **Max tightening torque: 900 Nm**.

7 **The final tightening** must be even so that the measure A is kept within +0.5 mm. Should the cooler tend to leak, the compression may be A - 0.5 mm.

8 **Procedure if measure A has not been attained** with max. tightening torque:

- check the number of the plates and measure A
- check that the nuts run easily. If not, clean, lubricate or change them.

18.6 Thermostat valve

18.6.1 Description

The figure shows the valve in a closed position (left). When the temperature exceeds the nominal value, the contents of the elements (9) expand and force the valve unit (10) towards the seat (11), thus passing part of the oil through the cooler. This movement continues until the right temperature of the mixed oil is obtained. As the cooler becomes dirtier, the temperature will rise a few degrees, which is quite normal, because the valve needs a certain temperature rise for a certain opening to increase the oil flow through the cooler.

Thermostatic valve for oil system

9. Element
10. Valve unit
11. Seat

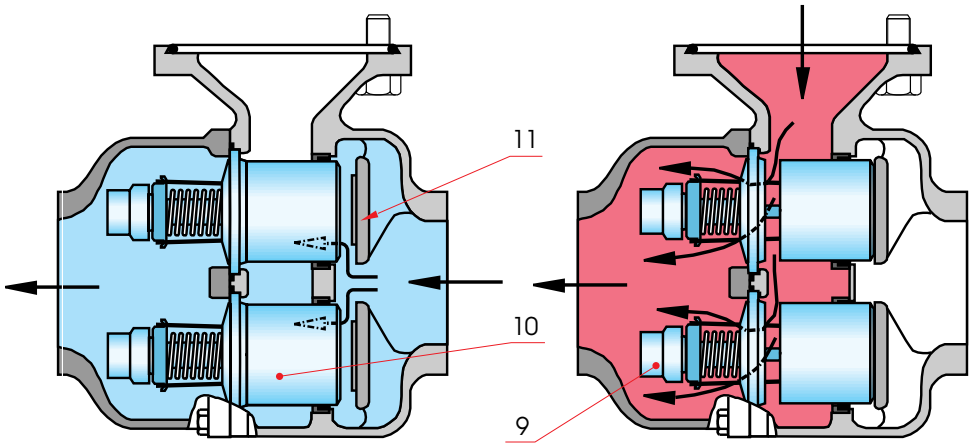


Fig 18-5 3218648932

18.6.2 Maintenance

Normally, no service is required. Too low an oil temperature depends on a defective thermostat. Too high a temperature may depend on defective thermostat, although, in most cases, it depends on dirty cooler.

Remove the elements by unscrewing the pipe after the valve and opening the cover.

Check the element by heating it slowly in water. Check at which temperatures the element starts opening and is fully open. The correct values can be found in chapter 01.; the lower value for lube oil temperature is the opening temperature, the higher for the fully open valve.

Change the defective element. Check O-rings and change, if necessary.

18.7 Lubricating oil main filter

18.7.1 Description

The in-line engines are provided with built-on filters (Fig 18-6) as follows:

- 4R32 1 pc of filter with 3 cartridges on each side
- 6R32 2 pcs of filters with 2 cartridges on each side
- 8R32 2 pcs of filters with 2 respectively 3 cartridges on each side
- 9R32 2 pcs of filters with 3 cartridges on each side

The V-engines can be provided with filters according to Fig 18-7. In that case, 12V32 has a filter consisting of three filter units connected together. 16V32 and 18V32 have four filter units connected together.

The filters are full-flow filters, i.e. the whole oil flow passes through the filter(s). Normally, all filter units should be in operation to provide maximal filtration. When changing a cartridge during operation, one filter half can occasionally be closed.

For the in-line engine, the flow direction appears from the mark on the three-way valve cock (9). In Fig 18-6 C the valve is shown in normal operating position (each side in operation).

When changing cartridges during operation one side can occasionally be closed, e.g. by closing the right side according to Fig 18-6 D.

For the V-engine, the pin (12) on the cock (9) shows the direction of the filter unit which is closed according to the table in Fig 18-7.

The position of the valve (“position”), which filter units are in operation (“open”) and which one is closed (“closed”) are stated in the table. The black field states the position of the pin (12). Position B indicates normal operation with all filter units in service. Note that for 12V32 the filter unit 4 is missing.

The arrows in the figures show the flow through the filters. At first, the oil flows through a cartridge (2), made of special paper, with a

nominal fineness of 15 µm, then through a cartridge (3) consisting of a plated wire gauze around a perforated case. The wire gauze insert, with a mesh of 63 µm, serves as a safety filter in case of failure or by-passing of the paper insert.

The filters are provided with by-pass valves (7) over the paper cartridges. The valves open when the pressure drop exceeds 2 - 3 bar.

The filter is provided with a combined visual indicator/electrical switch connected to the automatic alarm system, which indicates high pressure drop over the filter.

The paper cartridges should be changed as soon as possible if a high pressure drop over the filter is indicated.

Lube oil filter for in-line engine

1. Vent screw
2. Paper cartridge
3. Cartridge
4. Guide
6. Cartridge end
7. By-pass valve
8. Drain plug
9. Cock

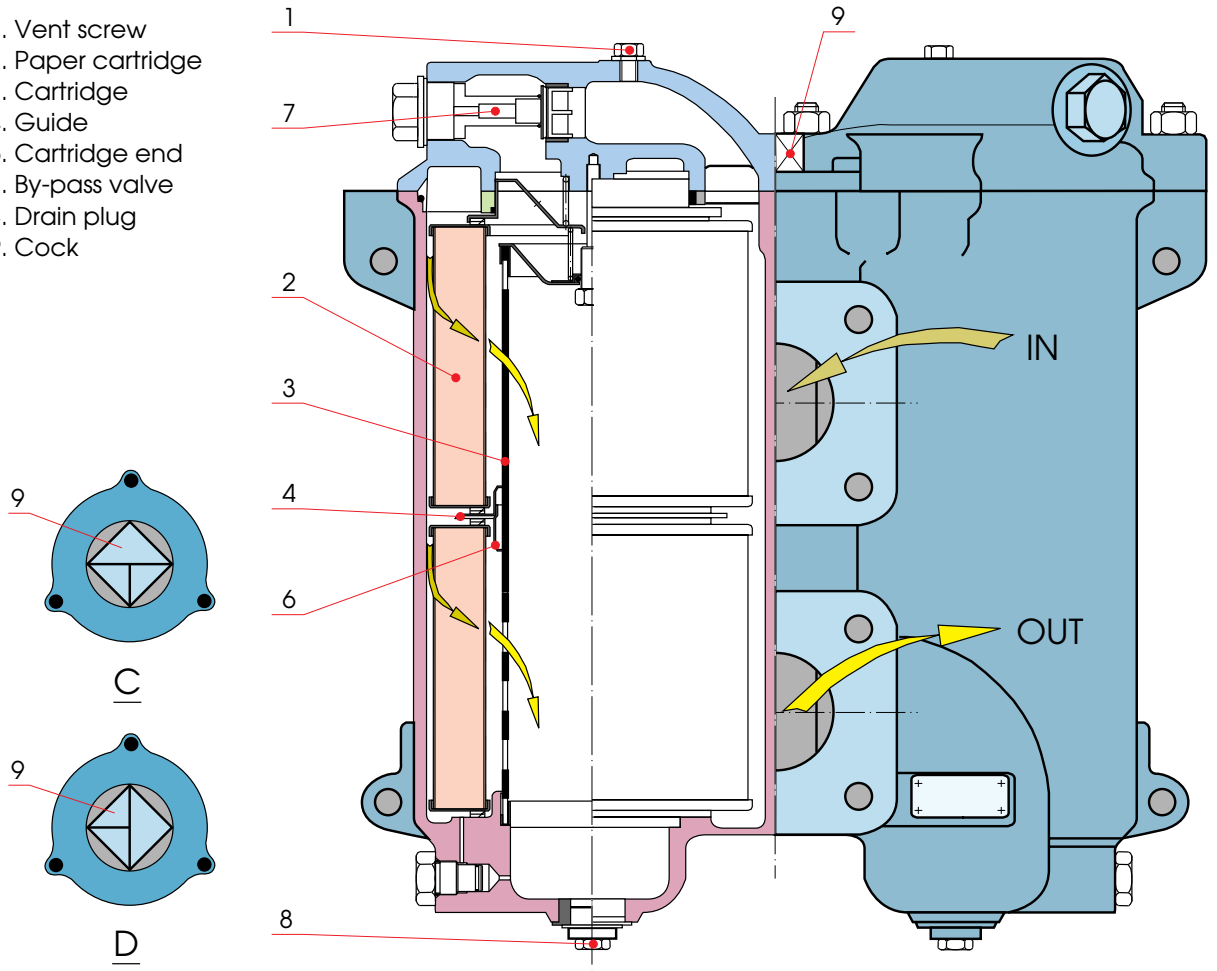
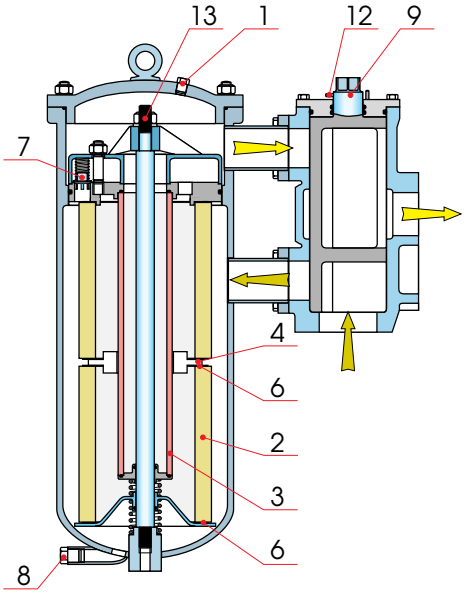
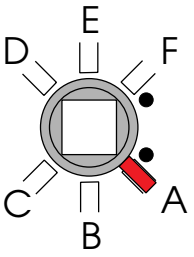


Fig 18-6 3218549045

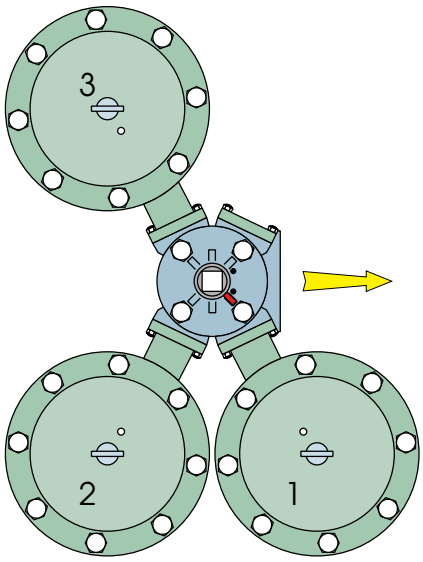
Lube oil filter for V-engine

1. Air screw
2. Paper cartridge
3. Cartridge
4. Guide
6. Cartridge end
7. By-pass valve
8. Drain plug
9. Cock
12. Pin
13. Nut

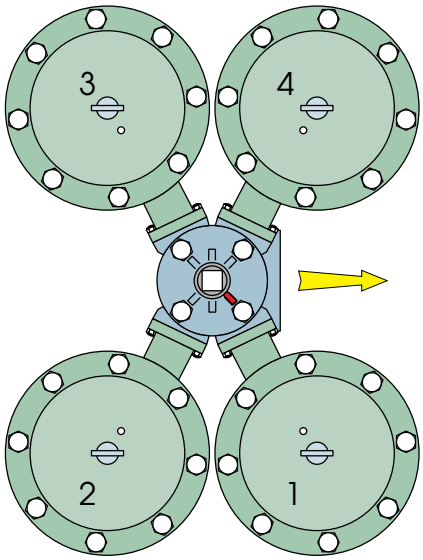




Position	Open	Closed
A	2, 3, 4	1
B	1, 2, 3, 4	
C	1, 3, 4	2
D	1, 2, 4	3
E	1, 2, 3, 4	
F	1, 2, 3	4



12-cylinder engines



16- and 18-cylinder engines

Fig 18-7 3218559045

18.7.2 Changing of filter cartridges and cleaning of filter

Careful maintenance of the filter reduces engine wear. Change cartridges regularly (see chapter 04.) and, if the pressure drop indicator gives alarm, as soon as possible.

As the useful life of the cartridge is, to a great extent, dependent on the fuel quality, load, lubricating oil quality, centrifuging and care of

centrifugal filter, experience from the installation concerned will give the most suitable intervals between changes of cartridges.

Change of cartridges and cleaning should, if possible, be done during stoppages. By closing one of the filter halves, the cartridge can, however, be changed during operation. As the load on the other cartridges (especially in 4R32) will increase, the change of cartridges should be carried out as fast as possible.

Note! Release the pressure by opening the air vent screw (1) before the drain plug (8) is opened.

1 **Drain the filter.** Open the air vent screw (1) and afterwards the drain plug (8), and discharge oil through the plug (8). **Do not refill the system with drained oil because it is very dirty.**

2 **Open the complete cover.**

3 **Remove the paper cartridges (2)** and wire gauze inserts (3). On V-engine filters, open the nut (13).

4 **Wash the wire gauze inserts** in gas oil and check that they are intact.

5 **Clean and rinse the filter housing** carefully with gas oil.

6 **Change the paper cartridges. Paper cartridges cannot be cleaned**. Always keep a sufficient quantity of cartridges in stock.

7 **Check that all gaskets are intact and in position,** especially gaskets against the cartridge ends (6).

Note! If the filter housing have been divided they must carefully be glued together. New gaskets have to be used and glued to the filterhousings (both sides).

8 **Check that the guide (4) slides into position** when remounting the wire gauze inserts and paper cartridges.

Note! Do not refill the system with drained oil because it is very dirty.

18.7.3 Cleaning of the filter by-pass valve

Normally, no regular maintenance is required for the by-passs valve (7), but if malfunction is suspected, the by-pass valve should be cleaned.

1 **Unscrew the plug,** which is holding the by-pass valve slide. On V-engines, remove the insert cover, unscrew the nuts and lift off the flange to have access to the by-pass valve slide.

2 **Withdraw the slide** and wash it with clean diesel oil. If necessary, the slide can be brushed with a brass wire brush.

3 **Clean the slide bore** with a tube brush.

4 **Grease the slide** and check that it moves easily in the bore.

5 **Assemble the safety valve.**

Note! Handle the slide carefully. The fingers in the end of the slide are easily damaged.

18.8 Centrifugal filter

18.8.1 Description

A by-pass filter of the centrifugal type is provided as a complement to the main filter. For V-engines two identical filters are used.

The filter comprises a housing (7) containing a hardened steel spindle (2) on which a dynamical balanced rotor unit (3) is free to rotate. Oil flows through the housing, up the central spindle into the rotor.

The rotor comprises two compartments, a cleaning chamber and a driving chamber. Oil flows from the central tube (4) into the upper part of the rotor, where it is subject to a high centrifugal force. The dirt is deposited on the walls of the rotor in the form of heavy sludge.

The oil then passes from the cleaning compartment into the driving compartment formed by the stand-tube (13) and the lower part of the rotor, which carries two driving nozzles (6). The passage of the clean oil through the nozzles provides a driving torque to the rotor and the oil returns through the filter housing to the engine oil sump.

18.8.2 Cleaning

It is very important to clean the filter regularly (chapter 04.) as it collects considerable quantities of dirt. A clean centrifugal filter unloads the main filter, which gives longer lifetime for the paper cartridges.

If it is found that the filter has collected the maximum quantity of dirt (corresponds to an 18 mm thick layer) at the recommended cleaning intervals, it should be cleaned more frequently.

Clean the filter as follows, the engine running, by closing the valve on the oil delivery pipe to the filter:

1 **Slacken off the nut** on the filter cover clamp (14), unscrew the cover nut (1) and lift off the filter body cover (8).

2 **Withdraw the rotor assembly** from the spindle (2) and drain oil from the nozzles before removing the rotor from the filter body. Hold the rotor body and unscrew the rotor cover jacking nut (9), then separate the rotor cover from the rotor body.

3 **Remove the washer (10)** and stand tube (13).

4 **Remove sludge** from the inside of the rotor cover and body by means of a wooden spatula or a suitably shaped piece of wood.

5 **Clean the stand tube.**

6 **Wash all details,** for example in gas oil.

7 **Clean out the nozzles** with brass wire and compressed air. Examine the top and bottom bearings in the tube assembly to ensure that they are free from damage of excessive wear. Examine the O-ring (15) for damage. Renew, if necessary.

Centrifugal filter

1. Cover nut
2. Spindle
3. Rotor unit
4. Central tube
6. Driving nozzle
7. Housing
8. Body cover
9. Jacking nut
10. Washer
13. Stand-tube
14. Cover clamp
15. O-ring
16. O-ring

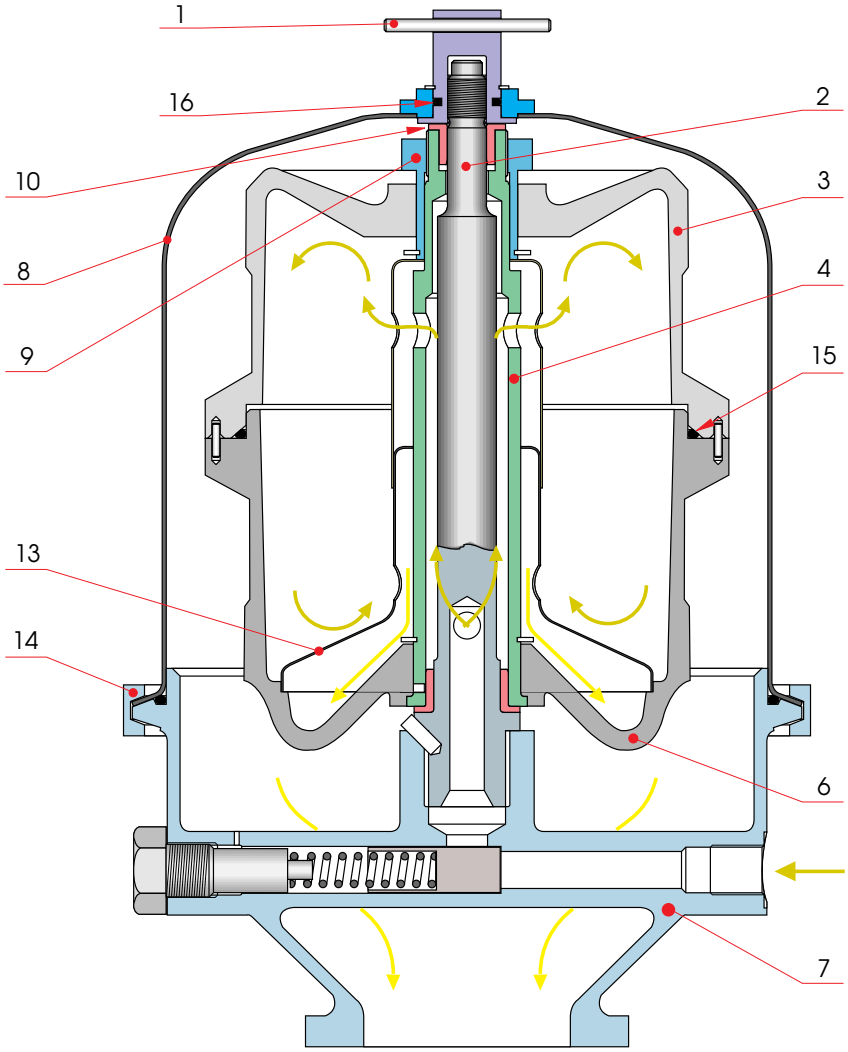


Fig 18-8 3218608932

8 **Reassemble the rotor complete,** align the location pins and tighten the rotor cover jacking nut (9), tightening torque = 100 Nm.

Overtightening of the rotor cover jacking nut can lead to rotor imbalance, which will effect filter performance.

9 Examine the spindle journals to ensure that they are free from damage or excessive wear. Examine the O-ring (16) for damage. Renew, if necessary.

10 Reassemble the filter complete, checking that the rotor assembly is free to rotate, then replace the filter body cover. Tighten the cover nut and secure the filter cover clamp.

18.9 Prelubricating pump

18.9.1 Description

The pump is of the screw type, driven by an electric motor. The pump is provided with an adjustable pressure control valve (15), Fig 18-9. The pressure should be limited to the min. value, about 2 bar, by unscrewing the adjusting screw (14) to the end position in order to prevent the electric motor from being overloaded when running with very cold oil.

The mechanical type shaft seal consists of two plane sealing surfaces facing each other — one of them (8) rotating with the shaft and the other one (6) being stationary.

18.9.2 General maintenance

See the manual of the manufacturer. Normally, no regular maintenance is required. After three to six years the shaft seal may have to be replaced due to ageing. Oil leaking out of the opening (5) indicates that the shaft seal is defective and has to be changed.

Take care not to damage the sealing ring faces. A slight scratch may disturb the sealing function. The rotating coal ring (8) is very fragile. Avoid touching sealing faces with fingers.

18.9.3 Dismantling

1 Loosen the pipes and fastening screws (9) and withdraw the pump.

2 Draw the coupling half (1) off the shaft.

3 Remove the front plate (10) together with the drive screw (2) and the shaft seal. Place the front plate on two rods, the shaft journal turned upwards.

4 Remove the drive screw locking ring (3). Give the shaft journal a few blows with a plastic hammer until the screw is disengaged from the ball bearing. Take care not to damage the screw by dropping it on the work bench.

5 Remove the sealing ring (8).

6 Force the sealing unit (13) off the drive screw (2). Pressing force may be relatively strong due to the rubber bellows.

7 Tap the stationary sealing ring (6) with the O-ring out of the front plate by using a mandrel.

8 To remove the ball bearing (4) from the front plate, remove first the locking ring.

Note! Always clean the ball bearing in fresh gas oil. Protect the bearing when the pump parts are being cleaned as the used washing liquid contains dirt particles that may damage the bearing.

18.9.4 Reassembly

The reassembly is performed in the reversed order.

1 Remount the ball bearing in the front plate, the protective washer turned outwards. Lock with the locking ring.

2 Oil the O-ring (7). Insert the stationary sealing ring (6) in the front plate. Take care not to damage the sealing faces and that the ring enters the pin (11).

3 Clean the drive screw carefully and enter the sealing unit (13) without the coal ring on to the shaft. Take care that the rubber bellows are pressed against the seal spring, supporting washer. Keep the seal in this position for a moment to enable the bellows to fix. A drop of lubricating oil on the drive screw shaft will facilitate reassembly.

4 Put the coal ring into position, the smaller sealing face upwards and the grooves matching the marks.

5 Place the front plate (10) over the drive screw shaft journal.

6 Force the ball bearing inner ring against its shoulder on the drive screw. Use a suitable sleeve matching the bearing inner ring.

7 Lock with the ring (3).

8 Install the end plate unit and screw the set in the pump housing. Do not forget the O-ring (12) which seals between the pump housing and the front plate. Fill the ball bearing with grease.

9 Install the coupling half (1) on the pump shaft and fasten the pump to the bracket. Check that the clearance between the coupling halves is 2 mm.

10 **If the electric motor has been disconnected or changed,** check that it rotates in the right direction by switching on a few times.

Prelubricating pump

1. Coupling half
2. Drive screw
3. Locking ring
4. Ball bearing
5. Opening
6. Sealing ring
7. O-ring
8. Sealing ring
9. Screw
10. Front plate
11. Pin
12. O-ring
13. Sealing unit
14. Adjusting screw
15. Control valve
16. Gasket

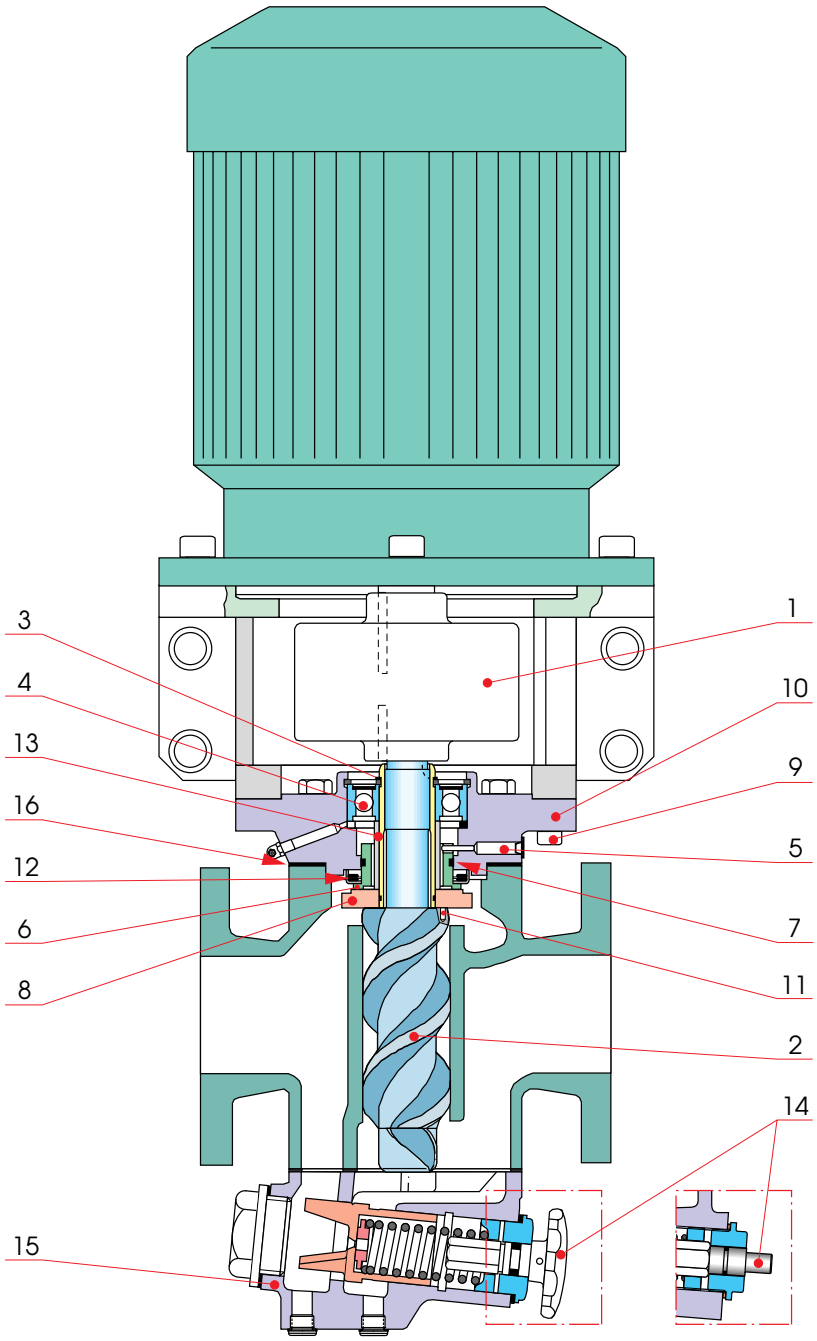


Fig 18-9 3218578932

19. Cooling Water System, V-engines

19.1 Description

19.1.1 General

The engine is cooled by a closed circuit cooling water system, divided into a high temperature circuit (HT) and a low temperature circuit (LT). The cooling water is cooled in a separate central cooler.

Cooling water system

1. Expansion tank
2. Venting box
3. Alarm switch
4. Alarm switch
5. Manometer
6. Manometer
7. Charge air cooler
8. LT-water pump
9. HT-water pump
10. LT-temperature control valve
11. HT-temperature control valve
12. Heater
13. Pump
14. Central cooler
15. Lube oil cooler

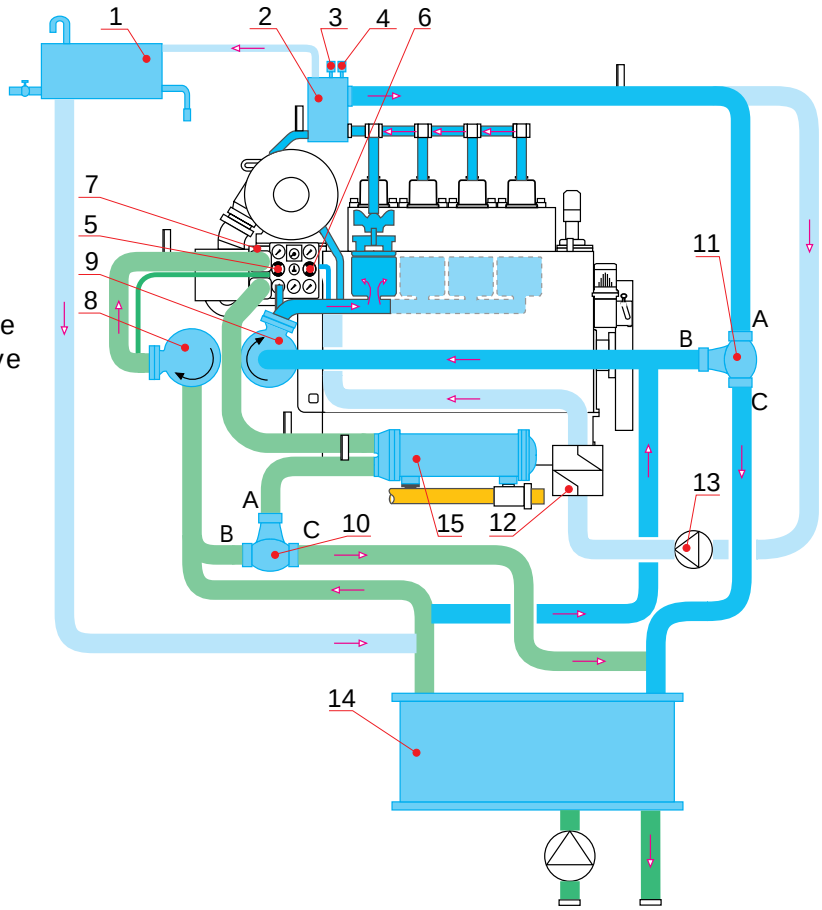


Fig 19-1 3219519045

19.1.2 HT circuit

The HT circuit cools the cylinders, cylinder heads and the turbochargers.

A centrifugal pump (9) pumps the water through the HT circuit. From the pump the water flows to the distributing duct, cast in the engine block (in V-engines the water is distributed to the distributing ducts of each cylinder bank through ducts cast into the pump cover at the free end of the engine). From the distributing ducts the water flows to the cylinder water jackets, further through connection pieces to the cylinder heads where it is forced by the intermediate deck to flow along the flame plate, around the valves to the exhaust valve seats, efficiently cooling all these components. From the cylinder head the water flows through a connection piece to the collecting pipe, further to the temperature control valve maintaining the temperature at the right level.

Parallel to the flow to the cylinders, part of the water flows to the turbochargers.

19.1.3 LT circuit

The LT circuit consists of a charge air cooler (7) and a lube oil cooler (15), not mounted on the engine, through which a pump (8), identical to the HT pump, pumps the water. The circuit temperature is controlled by a temperature control valve (10), not mounted on the engine. The necessary cooling is gained from the central cooler (14). The system outside the engine can vary from one installation to another.

19.1.4 Venting and pressure control

The collecting pipes from the cylinder and turbocharger cooling system are connected to a box (2) for venting of the system. From this box the vent pipe leads to the expansion tank (1) from which the expansion pipe is connected to the inlet pipe of the pumps (8 and 9). A static pressure of 0.7...1.5 bar is required before the pumps. If the expansion tank cannot be located high enough to provide this pressure, the system is to be pressurized.

19.1.5 Preheating

For preheating of the circuit, a heater circuit with the pump (13) and heater (12) are connected in the HT circuit before the engine. The non-return valves in the circuit force the water to flow in the right direction.

Before start, the HT circuit is heated up to 70...80°C by a separate heater. This is of utmost importance when starting and idling on heavy fuel.

19.1.6 Monitoring

Local thermometers:

- HT before and after engine
- HT after turbocharger
- LT before charge air cooler
- LT before lube oil cooler
- LT after lube oil cooler

The temperatures mentioned in chapter 01., section 01.2, should not be exceeded.

Manometers (5) and (6) on the instrument panel indicate HT and LT pressures after the pumps. The pressures depend on the speed and the installation. Guidance values, see chapter 01., section 01.2.

The HT water outlet after the engine is provided with an alarm switch (3) and a stop switch. Main engines are provided with alarm switches for low HT and LT pressure.

For further information, see chapter 23.

19.2 Maintenance

19.2.1 General

The installation — including expansion, venting, preheating, pressurizing — should be carried out strictly according to the instructions of the engine manufacturer to obtain correct and troublefree service.

The cooling water should be treated according to the recommendations in chapter 02., section 02.3, to prevent corrosion and deposits.

If risk of frost occurs, drain all cooling water spaces. Avoid changing the cooling water. Save the discharged water and use it again.

19.2.2 Cleaning

In completely closed systems the fouling will be minimal if the cooling water is treated according to our instructions in chapter 02., section 02.3. Depending on the cooling water quality and the efficiency of the treatment, the cooling water spaces will foul more or less in the course of time. Deposits on cylinder liners, cylinder heads and cooler stacks should be removed as they may disturb the heat transfer to the cooling water and thus cause serious damage.

The need of cleaning should be examined, especially during the first year of operation. This may be done through one of the plugs in the engine block or by overhauling a cylinder liner and checking for fouling and deposits on liner and block. The cylinder head cooling water spaces may be checked by opening the lower large plugs on the sides of the

cylinder heads. The turbochargers can be checked through the covers of the water space and the coolers by removing the water boxes of the inlet water.

The deposits can be of the most various structures and consistencies. In principle, they can be removed mechanically and/or chemically as described below. More detailed instructions for cleaning of coolers are stated in chapter 18., section 18.5.

a) Mechanical cleaning

A great deal of the deposits consists of loose sludge and solid particles which can be brushed and rinsed off with water.

On places where the accessibility is good, e.g. cylinder liners, mechanical cleaning of considerably harder deposits is efficient.

In some cases it is advisable to combine chemical cleaning with a subsequent mechanical cleaning as the deposits may have dissolved during the chemical treatment without having come loose.

b) Chemical cleaning

Narrow water spaces (e.g. cylinder heads, coolers) can be cleaned chemically. At times, degreasing of the water spaces may be necessary if the deposits seem to be greasy (see chapter 18., section 18.5).

Deposits consisting of primarily limestone can be easily removed when treated with an acid solution. Contrarily, deposits consisting of calcium sulphate and silicates may be hard to remove chemically. The treatment may, however, have a certain dissolving effect which enables the deposits to be brushed off if there is only access.

On the market there are a lot of suitable agents on acid base (supplied e.g. by the companies mentioned in chapter 02., section 02.3).

The cleaning agents should contain additives (inhibitors) to prevent corrosion of the metal surfaces. Always follow the manufacturer's instructions to obtain the best result.

After treatment, rinse carefully to remove cleaning agent residuals. Brush surfaces, if possible. Rinse again with water and further with a sodium solution of 5 % to neutralize possible acid residuals.

19.3 Water pump

19.3.1 Description

The water pump is a centrifugal pump and is driven by the gear mechanism at the free end of the engine. The shaft is made of stainless steel, the impeller and the sealing ring of bronze and the remaining details of cast iron.

The shaft is mounted in two ball bearings (13) and (15), which are lubricated by oil entering through the pipe fitting (27). The radial seal (12) prevents the oil from leaking out and, at the same time, dirt and leak water from entering. Also the slinger (11) assists in this.

The gear wheel (17) is fastened to the shaft by conical ring elements (25). When the screws (18) are tightened, the rings exert a pressure

between the gear wheel and the shaft. Due to the friction, the power from the gear wheel is transmitted to the pump shaft.

The water side of the pump is provided with a mechanical shaft seal. The ring (3) rotates along with the shaft and seals against it with a protection seal (4) fixed to the ring. The spring (5) presses the rotating ring against a fixed ring (2) which seals against the housing by means of its rubber coat. Possible leak-off water from the sealing can flow out through the opening (9).

Cooling water pump

1. Rear plate
2. Fixed ring
3. Ring
4. Protection seal
5. Spring
6. Screw
7. Impeller
8. O-ring
9. Opening
10. Nut
11. Slinger
12. Radial seal
13. Ball bearing
14. Opening
15. Ball bearing
16. Bearing retainer
17. Gear wheel
18. Screw
19. Pressure plate
25. Conical ring elements
26. Locking screw
27. Pipe fitting

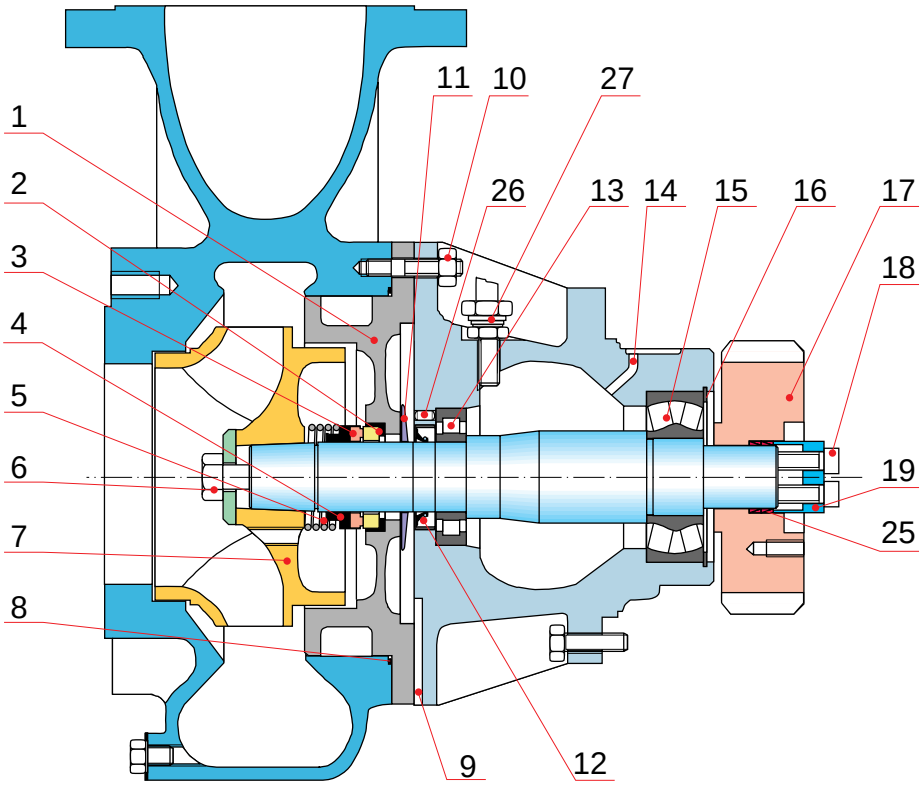


Fig 19-2 3219538935

19.3.2 Maintenance

Check the pump at intervals according to the recommendations in chapter 04. or, if water and oil leakage occurs, immediately.

a) Disassembling and assembling of impeller

1. **Remove the volute casing** by loosening the nuts (10).
2. **Loosen the fastening screws** (6).
3. **Pull off the impeller** by using the tool 32.83H01.

4 **When re-assembling the impeller,** coat the threads with Loctite 242 and tighten the nut to torque, see chapter 07.

5 **Check that the O-ring** (8) is intact and in position when re-installing the volute casing. Check that the volute casing is in position. The opening (14) should be turned upwards when the pump is installed.

If the bearing housing is turned wrongly, the bearings will be left without lubrication. Before mounting the pump on the engine, fill up the bearing housing with oil until oil flows out through the draining holes.

b) **Disassembling and assembling of mechanical seal**

1 **Remove the impeller** according to pos. a) above.

2 **Carefully dismantle all seal details.** Sealing rings are very fragile.

3 **Take particular care** not to damage sealing surfaces as a slight scratch may disturb the sealing function.

4 **Replace the complete seal** if it is leaky, if sealing faces are corroded, uneven or worn. Avoid touching the sealing faces with fingers.

5 **Reassemble the details** in proper order and install the impeller according to pos. a) above

c) **Replacing of bearings**

1 **Remove the pump** from the engine.

2 **Disassemble the impeller** and mechanical seal according to pos. a) and b) above.

3 **Remove the rear plate** (1) by undoing the screws (10).

4 **Loosen the screws** (18) and remove the pressure plate (19).

5 **Pull off the gear wheel** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The conical ring elements come loose together with the gear wheel.)

Using an extractor will only damage the shaft (axial scratches).

6 **Loosen the bearing retainer** (16) and the slinger.

7 **Remove the locking screws (26)** and mount three hexagon screws into the holes. Tighten the screws until the bearings come loose from the housing. Remove the shaft and bearings.

8 **Check the seal** (12) and the bearings for wear and damage, see pos. d) below.

9 **Remove the bearings** from the shaft.

10 **Press the new bearing** (13) by its inner ring with a suitable pipe.

11 **Before fitting the bearing,** oil the collar.

12 **Turn the shaft** according to Fig 19-3.

13 **Fit the distance ring** and oil the collar.

14 **Press the bearing** (15) by its inner ring with a suitable pipe. See Fig 19-3.

15 **Turn the bearing housing** according to Fig 19-3 and oil the outer surfaces of the bearings. Press the shaft into the housing by both the inner and outer ring of the bearing (15) with a suitable pipe.

Mounting of bearings

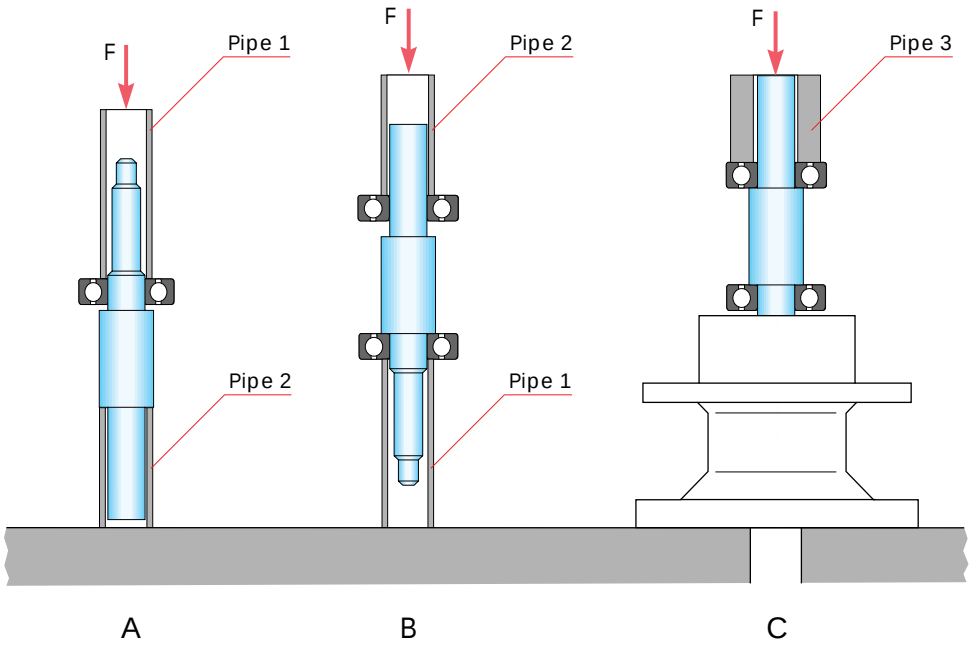


Fig 19-3 3219568935

16 **Fit the bearing retainer** (16).

17 **The axial clearance of the shaft** should be 0.05...0.10 mm. If necessary, use shims between the bearing (15) and the retainer (16).

18 **Before re-installing the gear wheel,** all contact surfaces should be cleaned and oiled.

19 **Re-install the gear wheel.**

20 **Re-install the conical ring elements (25).**

Re-install the ring elements exactly as situated in Fig 19-4.

Mounting of gear wheel to water pump

16. Bearing retainer
17. Gear wheel
18. Screw
19. Pressure plate
25. Conical ring elements

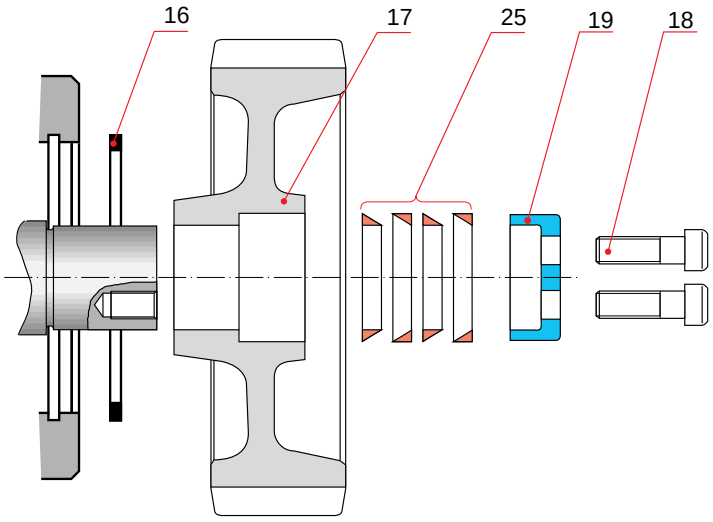


Fig 19-4 3219608935

The conical ring elements should fall easily in place and must not jam.

21 **Re-install the pressure plate** and the screws.

22 **Tighten the screws** a little and check that the gear wheel is in the right position.

23 **Tighten the screws** to torque according to chapter 07.

24 **Re-install the seal** (12), see pos. d) below.

25 **Mount the slinger (11)** and the rear plate (1).

26 **Re-install the mechanical seal,** impeller and volute casing according to pos. a) and b) above.

d) Replacing of radial seal

This will be most easily done at the same time as replacing the bearings. If, for some reason, the seal is leaky and there is no need to change the bearing, proceed as follows:

1 **Remove the volute casing** and mechanical seal according to pos. a) and b) above as well as the rear plate (1).

2 **Remove the slinger (11).** Take care not to deform the ring.

3 **Remove the seal (12)** by prying (damaging) without scratching the shaft. In connection with bearing changes the seal can easily be driven out axially.

4 **Inspect the shaft.** In case the seal has worn the shaft by more than 0.5 mm radially, the shaft should be replaced according to pos. c) above.

5 **Oil the new seal** and press it in until it levels with the bearing housing.

6 **Mount the slinger (11)** and the rear plate (1).

7 **Install the mechanical seal,** impeller and the volute casing according to pos. a) and b) above.

19.4 Temperature control system

19.4.1 General description

The LT and HT circuits are equipped with temperature control valves. Temperature ranges according to chapter 01., section 01.2. The valves are normally mounted outside of the engine.

19.4.2 LT and HT thermostatic valve

The thermostatic valve is equipped with positive three-way valve action in which the water is positively made to flow in the direction required. When the engine is started up and is cold, the thermostatic valve causes all of the water to be positively by-passed back into the engine, thus providing the quickest warm-up period possible. After warm up, the correct amount of water is by-passed and automatically mixed with the cold water returning from the heat exchanger or other cooling device to produce the desired water outlet temperature. If ever required, the thermostatic valve will shut off positively on the by-pass line for maximum cooling. The three-way action of the valve allows a constant water flow through the pump and engine at all times with no pump restriction when the engine is cold.

No adjustments are ever required on the thermostatic valve. The temperature is permanently set at the factory. The temperature can be

changed only by changing temperature element assemblies which is easily accomplished by unscrewing the housing. The valve is entirely self-contained, and there are no external bulbs or lines to become damaged or broken. There are no packing glands to tighten and no parts to oil.

Water flow in thermostatic valve

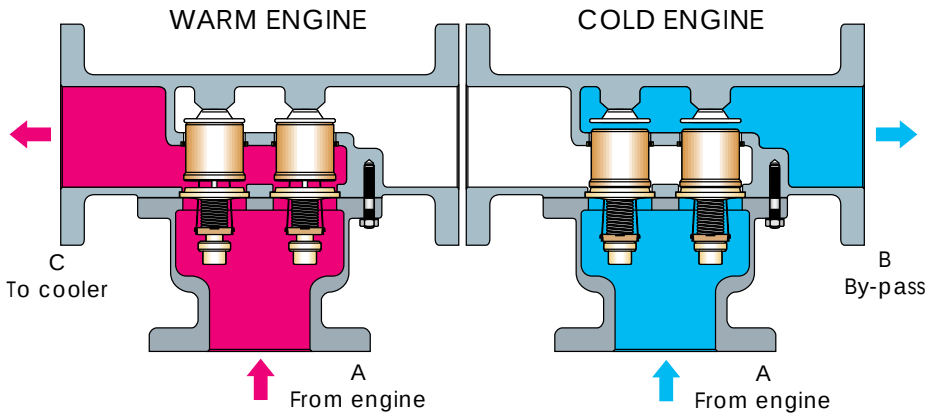


Fig 19-5 3219669250

The power creating medium utilizes the expansion of the element contents (9), which remains in a semi-solid form and is highly sensitive to temperature changes. Most of the expansion takes place during the melting period of approximately two minutes over a temperature change of approximately 8.5°C.

The thermostatic valve is provided with two or more elements (10), depending of the engine size. If failure of one element occurs, the remaining elements will take over with only a slight change in operating temperature. Since flow is diverted either to by-pass or heat exchanger, failure of an element would cause no change in pressure drop.

The contents of the elements (9) has an almost infinite force when heated and is positively sealed. When the elements are heated, this force is transmitted to the piston thus moving the sliding valve towards the seat (11) to the by-pass closed position. This force is opposed by a high spring force, which moves the sliding valve to the heat exchanger closed position when the elements are cooled. The high force available on heating is the basis of the fail safe feature in which failure of the element would cause the engine to run cold.

The HT thermostatic valve in main engine installations are provided with a possibility for manual override.

Cooling water thermostatic valve

9. Content of the element
10. Element
11. Seat

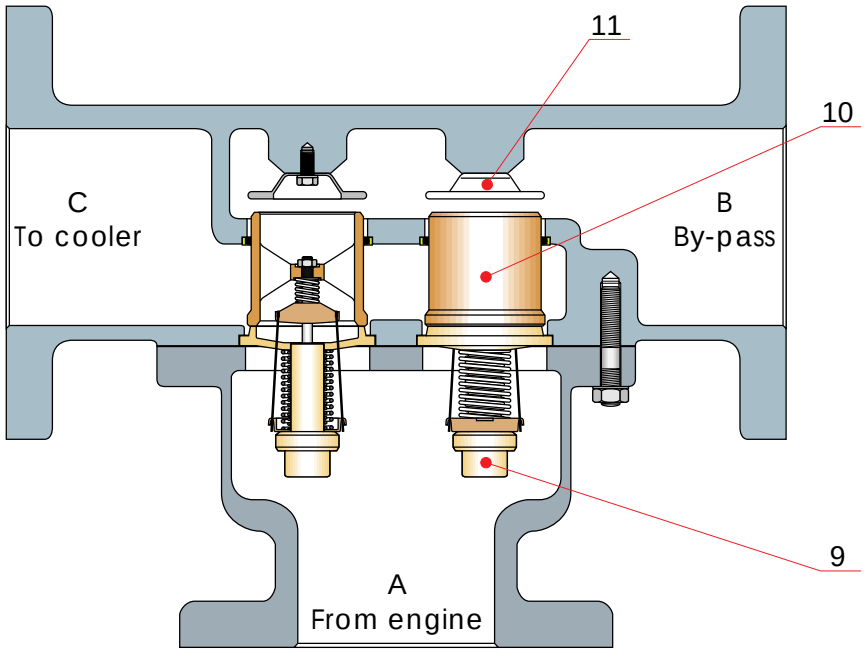


Fig 19-6 3219679250

19.4.3 Maintenance

Normally, no service is required. Too low a water temperature depends on a defective thermostat, too high a temperature may depend on a defective thermostat, although, in most cases, it depends on a dirty cooler.

1 **Remove the elements** by unscrewing the pipe before the valve and opening the cover.

2 **Check the element** by heating it slowly in water. Check at which temperatures the element starts opening and is fully open. The correct values can be found in chapter 01.; the lower value for the water temperature is the opening temperature, the higher for the fully open valve.

3 **Change the defective element.** Check sealings and replace, if necessary.

20. Exhaust System

20.1 Description

The exhaust pipes are cast of special alloy nodular cast iron, with separate sections for each cylinder, fixed by clamp rings (1). Metal bellows of multiply type absorb the heat expansion.

The complete exhaust system is enclosed by an insulation box built up of sandwich steel sheet. Sensors for measuring of the temperatures after each cylinder as well as before and after the turbocharger are mounted.

Exhaust system V-engine

1. Clamp ring
2. Sheet

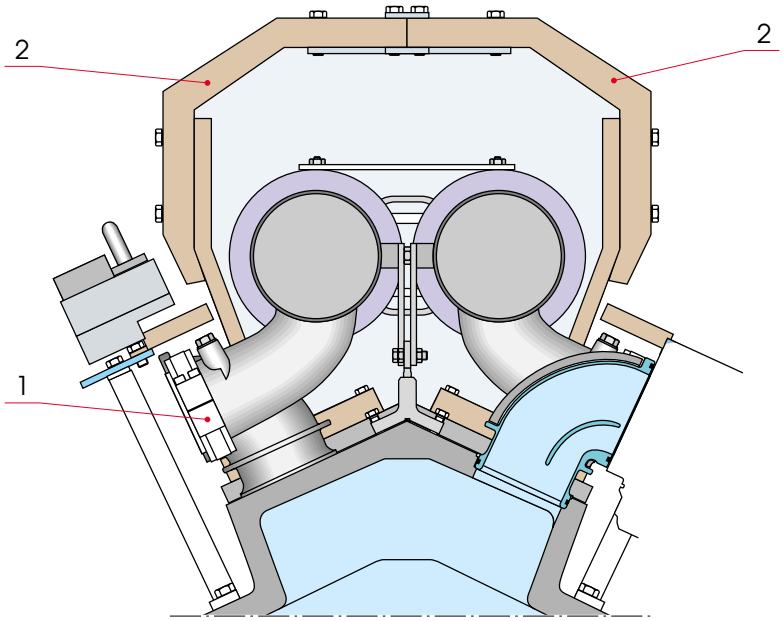


Fig 20-1 3220599548

20.2 Change of expansion bellows

1 Remove necessary sheets on the insulation box. On V-engine the sheets (2) on the top, see Fig 20-1.

2 Remove the screws (3) of the flange connection and remove the expansion bellows, see Fig 20-2.

3 Check that the exhaust pipe flanges are parallel and positioned on the same centre line to avoid lateral forces on the bellows.

Exhaust system

3. Screw

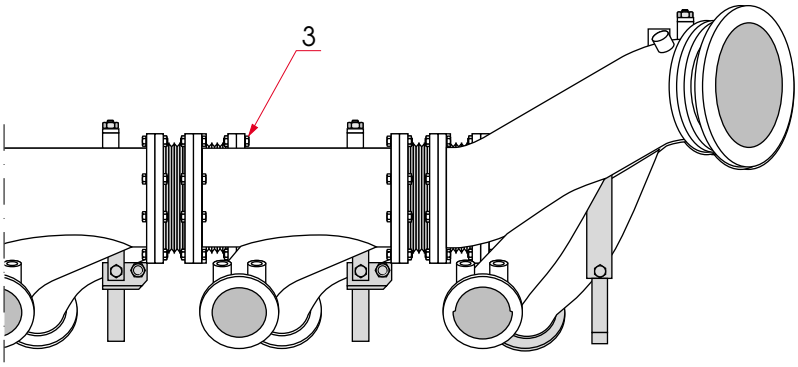


Fig 20-2

3220619720

21. Starting Air System

21.1 Description

The starting air supply pressure to the engine is 20...30 bar. The starting air pressure at the inlet to the starting motor is 8...10 bar. The starting air supply pressure can be checked from the local display unit.

The solenoid valve (4) can be operated by the push button for cranking the engine.

As a precaution the engine cannot be started when the turning gear is engaged. Control air to the air starter is led through a stop valve (2), mechanically blocked when the turning gear is engaged, thus preventing start.

Starting air and pneumatic system

1. Turbine starter
2. Blocking valve
3. Pressure regulator
4. Solenoid valve
5. Air throttle valve
6. Wastegate valve
7. Safety valve
8. Starter valve
10. Solenoid valve
11. I/P converter
12. Solenoid valve
13. Solenoid valve
14. Solenoid valve
15. Air vessel
16. Drain valve
17. Valve
18. Valve
19. Non-return valve
20. Filter
21. Pneumatic overspeed trip device
22. Valve
23. Booster sevomotor

301 Starting air inlet

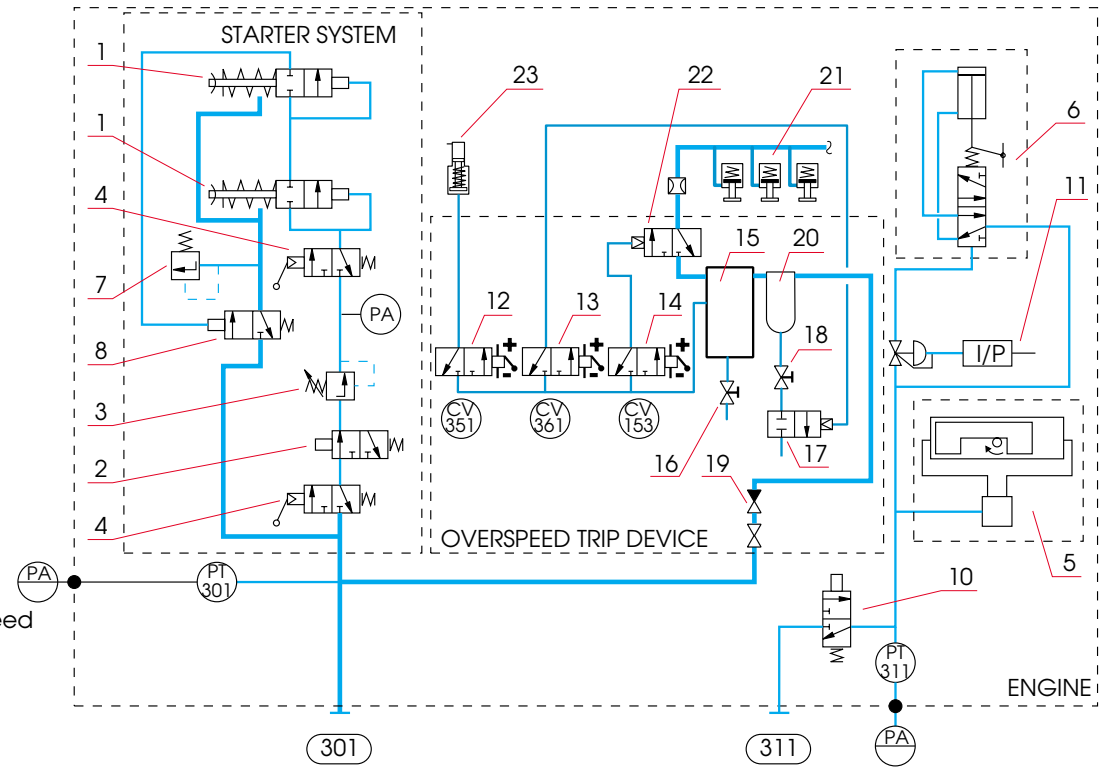


Fig 21-1

3221719938

21.2 Starting device

21.2.1 Description

The engine is provided with two air starters of turbine type. They are air operated, turbine driven, pre-engage starter drives and they are designed for operation with compressed air only. Small amounts of foreign matter or liquid in the air stream will normally not adversely affect the starter and no lubrication is required in the supply air. The air starter can be grouped into five basic segments:

- Housing exhaust cover,
- Motor housing,
- Intermediate gear case,
- Gear case,
- Drive housing.

When the engine has reached a speed of 120 RPM the current is cut off by the WECS system, and the air starter will be disengaged automatically.

Warning! Do not operate the starter with compressed air unless it is properly attached to the engine and will engage the flywheel.

A valve prevents starting with engaged turning device.

21.2.2 Disassembly

Mark each section of the starter for reference during assembly. Note the location of the long male elbow in the nozzle/valve seat and that the control line access hole in the containment ring and the port in the nozzle/valve seat must line up when reassembled. Mark the turbine rotor and note its direction of rotation.

Have a complete set of O-rings, seals, screws and other hardware available for assembly.

Note Do not wash bearing or the starter drive in cleaning solvents.

1 **Do not disassemble the starter** any further than necessary to replace worn or damaged parts.

2 **When grasping a part in a vise,** always use leather-covered or copper-covered vise jaws to protect the surface of the part and help prevent distortion. This is particularly true of threaded members.

Air starter

11. Housing exhaust cover
12. Motor housing
13. Intermediate gear cover
14. Gear case
15. Drive housing

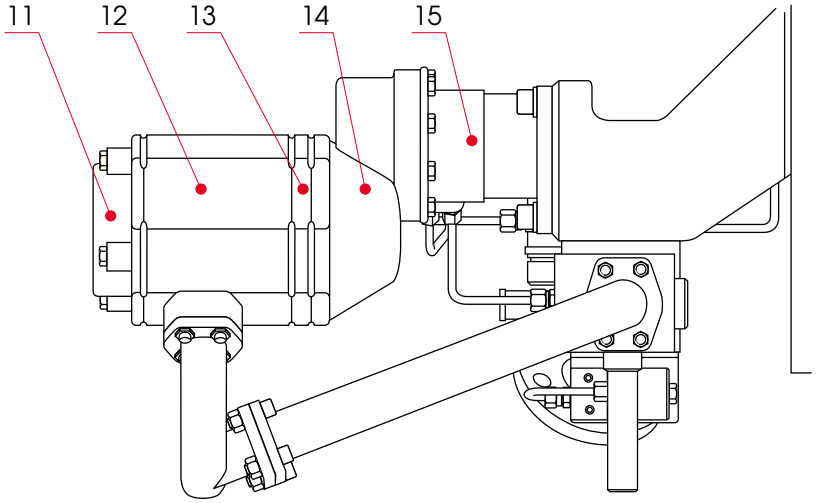


Fig 21-2 3221639601

3 **Do not remove any part** which is a press fit in or on a sub assembly unless the removal of that part is necessary for replacement or repairs.

4 **Always have a complete set of seals** and O-rings on hand before starting any overhaul of the starter. Always renew old seals and gaskets.

5 **Always mask adjacent parts on** the housing exhaust cover (11), motor housing (12), intermediate gear case (13), gear case (14) and drive housing (15) so these members can be located in the same relative position when the starter is reassembled.

6 **Do not press any needle bearing** from a part unless you have a new needle bearing on hand for installation. Needle bearings are always damaged during the removal process.

21.2.3 Cleaning and inspection

1 **Degrease all metal parts** except bearings and the starter drive using commercially approved solvents.

2 **Dry parts thoroughly.**

Caution! **Never wash the starter drive or shielded bearings in cleaning solvents.**

3 **Clean aluminum parts** using a cleaning solution, soak for five minutes. Remove parts, rinse in hot water, and dry thoroughly.

4 **Clean corroded steel parts** with commercially approved stripper.

5 **Clean corroded aluminum** parts by cleaning as stated above and then immersing the parts in a chromic-nitric-phosphoric acid pickle solution. Rinse in hot water and dry thoroughly.

6 **Check for acceptable condition of parts.**

7 **Check all threaded parts** for galled, crossed, stripped, or broken threads.

8 **Check all parts** for cracks, corrosion, distortion, scoring, or general damage.

9 **Check the splash deflector** and retaining spring for wear.

10 **Check all bearing bores** for wear and scoring. Bearing bores shall be free of scoring lines.

11 **Check gear teeth** for wear. If wear is apparent, check gear teeth dimensions.

21.2.4 Assembly

1 **Always press on the inner ring** of a ball-type bearing when installing the bearing on a shaft.

2 **Always press on the outer ring** of a ball-type bearing when pressing the bearing into a bearing recess.

3 **Whenever grasping a starter or** part in a vise, always use leather-covered or copper-covered vise jaws. Take extra care with threaded parts or housings.

4 **Except for bearings, always clean** every part and wipe every part with a thin film of oil before installation.

5 **Check every bearing for roughness.** If an open bearing must be cleaned, wash it thoroughly in a suitable cleaning solution and dry with a clean cloth. Sealed or shielded bearings should never be cleaned. Work grease thoroughly into every open bearing before installation.

6 **Apply a film of O-ring lubricant to** all O-rings before final assembly.

7 **Unless otherwise noted, always press** on the stamped end of a needle bearing when installing the needle bearing in a recess. Use a bearing inserting tool.

All screw threads are treated at the factory with a fastener retention compound. Every screw, 1 inch diameter or larger, must have a drop of Loctite 290 applied to the threads before being re-used, screws

smaller than 1 inch diameter must have a drop of Loctite 222 applied to the threads.

Note! **See also chapter 08.2 Trouble shooting for air starter.**

21.3 Starting air vessel and piping

An oil and water separator should be located in the feed pipe, between the compressor and the starting air vessel. At the lowest position of the piping there should be a drain valve.

Drain the starting air vessel from condensate through the drain valve before starting.

The piping between the air vessels and the engines should be carefully cleaned when installing. Also later on they should be kept free from dirt, oil and condensate.

The starting air vessels should be inspected and cleaned regularly. If possible, they should then be coated with a suitable anti-corrosive agent. Let them dry long enough.

At the same time, inspect the valves of the starting air vessels. Too strong tightening may result in damages on the seats, which in turn cause leakage. Leaky and worn valves, including safety valves, should be reground. Test the safety valves with pressure.

21.4 Pneumatic system

21.4.1 General description

The engine is equipped with a pneumatic system for control of the throttle valve and the wastegate valve. The control is described in chapter 23. The system includes a shut-off valve and an I/P-converter, see Fig 21-3.

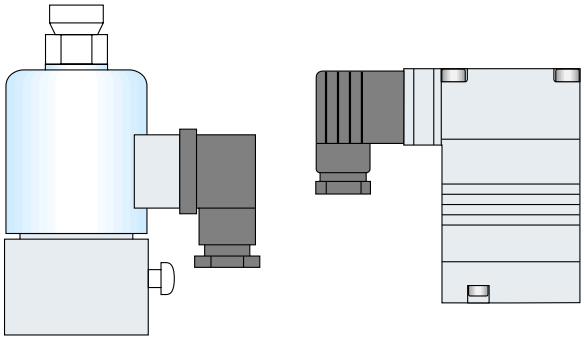
21.5 Maintenance

The system is built up of high class components. Usually it requires no other maintenance than check of function.

21.5.1 Maintenance

The components requires no maintenance. Should there be malfunction, change the complete component.

Pneumatic components



Solenoid valve I/P converter

Fig 21-3 2021699936