Contents,

00.1 Contents of the Instruction Book

This Manual contains data and instructions for operation and maintenance of the engine. 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.

Wärtsilä Diesel 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.

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.

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.**

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 replacing 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:

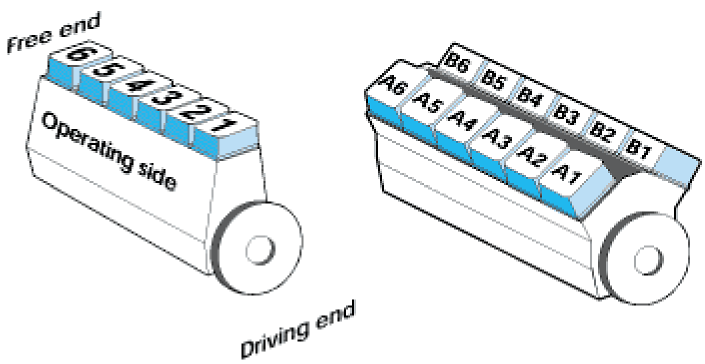

figure: 00-1 Terminology

Designation of bearings. The designation of bearings begins from the driving end. The thrust main bearing is No 1. If the engine is provided with an extra main bearing, a so-called shield bearing, this is termed 0. For the camshaft bearing the thrust bearing is No 0.

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 center, 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.

Flywheel graduation. The flywheel is divided in 360°, starting from **TDC at firing** for cylinder 1. TDC at firing for every cylinder is indicated on the flywheel. There is a common mark for a pair of 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.

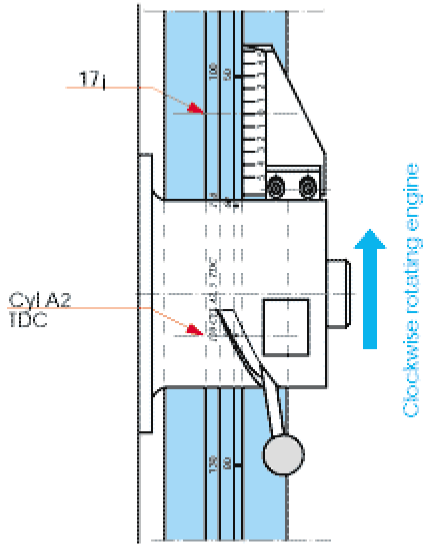

figure: 00-2 Example of reading the flywheel

Example: *On a VASA 12V22 engine, the fuel timing is read to 17° for cylinder A2 when the flywheel is in the position shown in the above figure.*
High temperature cooling water circuit (HT-circuit). The cooling water for the engine block, cylinder head and turbocharger.
Low temperature cooling water circuit (LT-circuit). The cooling water for the charge air cooler and the lubricating oil cooler.

00a Risk Reduction

version : 00a-200145-00

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			
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.

01.1 Main data for Vasa 22

```
Cylinder bore ............................................................... 220 mm
Stroke ...................................................................... 240 mm
Piston displacement per cylinder ............................................ 9.12 l
```

Firing order		
Engine type	Clockwise rotation	Counter-clockwise rotation
4R22	1-3-4-2	1-2-4-3
6R22	1-5-3-6-2-4	1-4-2-6-3-5
8R22	1-3-7-4-8-6-2-5	1-5-2-6-8-4-7-3
12V22	A1-B1-A5-B5-A3-B3-A6-B6-A2-B2-A4-B4	A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5-B1
16V22	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

Normally, the engine rotates clockwise.

Lubricating oil volume in the engine					
Engine type	4R22	6R22	8R22	12V22	16V22
Appr. oil volume in litres	320	450	580	670	870
Oil volume between max. and min. marks, appr. litres	60	100	125	150	195
Anti corrosive oil, appr. litres	65	90	110	130	160

Appr. cooling water volume in the engine in litres					
Engine type	4R22	6R22	8R22	12V22	16V22
Engine and inverse cooling system	95	130	170	270	350

01.2 Recommended operating data

Apply to normal operation at nominal speed.

	Normal values	Alarm (stop) limits

Load	100 %	30 %	30...100%	30 %
Temperatures, (°C)				
Lube oil before engine	62...70	73...80	80	90
Lube oil after engine	10...18 higher	5...8 higher		
HT water after engine	90...95		95(105)	
HT water before engine	5...8 lower	2...3 lower		
HT water rise over turbocharger	8...12(15)	6...10		
LT water before engine	28...38	65...70		
Charge air in air receiver	40...60	60...70	75	-
Exhaust gas after cylinder	See test records		50 higher x)	
Preheating of HT and LT water	70			
Gauge pressures (bar)				
Lube oil before engine at a speed of 900 RPM	3.5...4.0	3	3.0(2.0)	
1000 RPM	4.0...4.5	3.5		
1100 RPM	4.5...5.0	4.0		
1200 RPM	4.5...5.0	4.0		
LT and HT water before pumps (=static)	0.7...1.5			
HT water before engine	2.0...4.5 xx)		xxx)	
LT water before charge air cooler	2.0...4.5 xx)		xxx)	
Fuel before engine	5...7		4	
Starting air	max. 30		18	
Charge air	See test records			

Other pressures (bar)		
Firing pressure	See test records	
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	

01.3 Reference conditions

Reference conditions according to ISO 3046/I (1986):

Air pressure .... 100 kPa (1.0 bar)
Ambient temperature .... 298 K (25°C)
Relative air humidity .... 30 %
Cooling water temperature of charge air cooler . 298 K (25°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) %

01.4 General engine design

The engine is a turbocharged intercooled 4-stroke diesel engine with direct 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 camshaft bearing sites are integrated.

The charge air receiver is cast into the engine block as well as the cooling water headers. The crankcase and camshaft covers, made of light metal, seal against the engine block by means of O-rings.

The lubricating oil sump is welded.

The cylinder liners are of wet type. The cooling effect is optimised to give the correct temperature of the inner surface.

To eliminate the risk of bore polishing, the liner can be provided with an antipolishing ring.

The main bearings are fully interchangeable trimetal or bimetal bearings which can be removed by lowering the main bearing cap.

The crankshaft is forged in one piece and is balanced by counterweights as required.

The connecting rods are drop forged. The big end is split diagonally and the mating faces are serrated. 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 made of nodular iron and are cooled by oil. Cooling oil enters the cooling space through the connecting rod, gudgeon pin and bores in the piston and escapes through bores in the piston, matched to achieve optimal shaker effect. The piston skirt is pressure lubricated. The two top ring grooves are hardened.

The piston ring set includes three compression rings - the two top rings chromium-plated - and a chromium-plated spring-loaded oil scraper ring located above the gudgeon pin.

The cylinder head, made of special cast iron, is fixed by four hydraulically tensioned screws.

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 water-cooled seat rings, made of a corrosion and pitting resistant material, are changeable.

The camshaft is 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 injection valve is completely embedded in the cylinder head. The injection pipe is connected sideways by a high pressure connection piece and therefore fuel oil can under no circumstances mix with lubricating oil.

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. On 12V and 16V engines 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 gear pump, oil filter, cooler with thermostat valve, 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. All components are mounted on the engine.

The starting system. The air supply into the cylinders is controlled by the starting air distributor run by the camshaft.

The four-cylinder engine is started by means of an air driven starting motor.

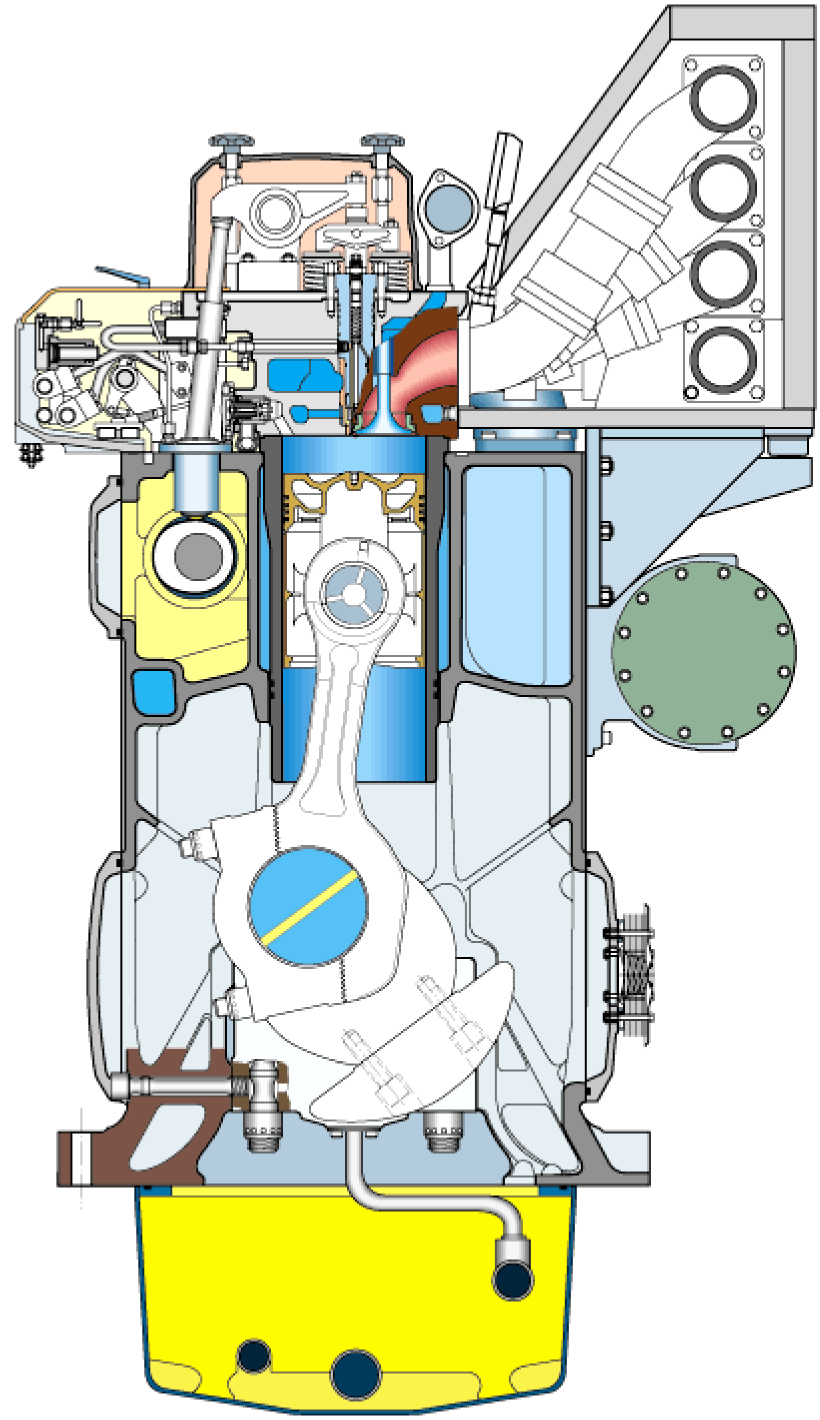

figure: 01-1 Cross section of Wärtsilä VASA 22, in-line engine

01.1 Identification

The VASA 22 engines have been designed to use different fuels and a large speed range. Engines with the capability to use fuels with a viscosity lower than are designated "HF" (Heavy Fuel) and if not "MD" (marine Diesel). The stroke of the engine is either 240 mm or 260 mm. If the stroke is 260 mm it is indicated by 26 or 22/26. Information about a specific engine number and its designation can be found either from the engine plate on the engine or from the Operating Manual of that engine, chapter 09. The VASA 22/26 is available only as in-line configuration.
The data figures presented in the Operation Manual refer to both 22 and 22/26 engine if not otherwise instructed.

01.2 Main data

Basic data		
	VASA 22	VASA 22/26
Cylinder bore (mm)	220	220
Stroke (mm)	240	260
Piston displacement per cylinder (litre)	9.12	9.88

Firing order		
Engine type	Clockwise rotation	Counter-clockwise rotation
4R22, 22/26	1-3-4-2	1-2-4-3
6R22, 22/26	1-5-3-6-2-4	1-4-2-6-3-5
8R22, 22/26	1-3-7-4-8-6-2-5	1-5-2-6-8-4-7-3
8V22	A1-B1-A3-B3-A4-B4-A2-B2	A1-B2-A2-B4-A4-B3-A3-B1
12V22	A1-B1-A5-B5-A3-B3-A6-B6-A2-B2-A4-B4	A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5-B1
16V22	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

Normally, the engine rotates clockwise.

Lubricating oil volume in the engine						
Engine type	4R22 4R22/26	6R22 6R22/26	8R22 8R22/26	8V22	12V22	16V22
Oil volume c. litres	320	450	580	580	670	870
Oil volume between max. and min. marks c. litres/mm	60	100	125	100	150	195
Anticorrosive oil c. litres	65	90	110	90	130	160

Cooling water volume in the engine, c. litres						
Engine type	4R22 4R22/26	6R22 6R22/26	8R22 8R22/26	8V22	12V22	16V22
Engine and inverse cooling system	95	130	170	190	270	350

01.3 Recommended operating data (22)
Apply to normal operation at nominal speed.

	Normal values		Alarm (stop) limits	
Load	100 %	30 %	30...100 %	30 %
Temperatures, (°C)				
Lube oil before engine	62...70	73...80	80	90
Lube oil after engine	10...18 higher	5...8 higher		
HT water after engine	MD 77...85, HF 90...95		MD 95 (105), HF 105 (110)	
HT water before engine	5...8 lower	2...3 lower		
HT water rise over turbocharger	8...12(15)	6...10		
LT water before engine	28...38	65...70		
Charge air in air receiver	40...60	60...70	75	-
Exhaust gas after cylinder	See test records		50 higher [x)]	
Preheat. of HT- and LT-water	70			
Gauge pressures (bar)				
Lube oil before engine at a speed of 900 RPM	4.0...4.5	4.0	3.0(2.0)	
1000 RPM	4.0...4.5	4.0		
1200 RPM	4.5...5.0	4.5		
LT and HTwater before pumps (=static)	0.7...1.5			
LT water before engine	1.8...4.2[xx)]		[xxx)]	
HT water before engine	1.8...4.5[xx)]		[xxx)]	
LT water before charge air cooler	1.8...4.5[xx)]		xxx)	

Fuel before engine	MD 2...4, HF 5...7	MD 1.5, HF 4.0
Starting air	max. 30	18
Charge air	See test records	
Other pressures (bar)		
Firing pressure	See test records	
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	

01.4 Recommended operating data (22/26)
Apply to normal operation at nominal speed.

	Normal values		Alarm (stop) limits	
Load	100 %	30 %	30...100%	30 %
Temperatures, (°C)				
Lube oil before engine	62...70	73...80	80	90
Lube oil after engine	10...18 higher	5...8 higher		
HT water after engine	MD 77..85, HF 90..95		MD95 (105), HF105 (110)	
HT water before engine	5...8 lower	2...3 lower		
HT water rise over turbocharger	8...12(15)	6...10		
LT water before engine	28...38	65...70		
Charge air in air receiver	40...60	60...70	75	-
Exhaust gas after cylinder	See test records		50 higher [x)]	
Preheating of HT and LT water	70			
Gauge pressures (bar)				

Lube oil before engine at a speed of 720 RPM	3.5...4.0	3.5	
750 RPM	3.5...4.0	3.5	
825 RPM	4.0...4.5	4.0	
900 RPM	4.0...4.5	4.0	3.0(2.0)
1000 RPM	4.0...4.5	4.0	
1100 RPM	4.0...4.5	4.0	
LT and HTwater before pumps (=static)	0.7...1.5		
LT water before engine	2.1...4.2		
HT water before engine	1.8...5.0[xx)]		[xxx)]
LT water before charge air cooler	1.8...4.4[xx)]		[xxx)]
Fuel before engine	MD 2...4, HF 5...7		MD 1.5, HF 4.0
Starting air	max. 30		18
Charge air	See test records		
Other pressures (bar)			
Firing pressure	See test records		
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		

01.5 Reference conditions

Reference conditions according to ISO 3046/I:

```
Air pressure.............................................................100kPa (1.0 bar)
Ambient temperature.........................................................298K (25°C)
Relative air humidity.........................................................30 %
Cooling water temperature of charge air cooler................................298 K (25°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) %

01.6 General engine design

The engine is a turbocharged intercooled 4-stroke diesel engine with direct 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 camshaft bearing sites are integrated. The charge air receiver is cast into the engine block as well as the cooling water headers. The crankcase and camshaft covers, made of light metal, seal against the engine block by means of O-rings. The lubricating oil sump is welded.

The cylinder liners are of wet type and made of special cast iron and honed to an optimal finish.

The main bearings are fully interchangeable trimetal or bimetal which can be removed by lowering 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 diagonally and the mating faces are serrated. 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 made of nodular iron and are cooled by oil. Cooling oil enters the cooling space through the connecting rod, gudgeon pin and bores in the piston and escapes through bores in the piston, matched to achieve optimal shaker effect. The piston skirt is pressure lubricated. The two top ring grooves are hardened.
The piston ring set includes three compression rings - the two top rings chromium-plated - and a chromium-plated spring-loaded oil scraper ring located above the gudgeon pin.
The cylinder head, made of special cast iron, is fixed by four hydraulically tensioned screws.
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 water cooler seat rings, made of a corrosion and pitting resistant material, are changeable.
The camshaft is 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 injection valve is completely embedded in the cylinder head. The injection pipe is connected sideways by a high pressure connection piece and therefore fuel oil can under no circumstances mix with lubricating oil.
The turbochargers are located at the free end of the engine.
On V12 and V16 engine there are two chargers, one for each bank.
The charge air coolers are made as removable inserts, on the V-engines two indentical ones (one cooler on 8V22).
The lubricating oil system includes gear pump, oil filter, cooler with thermostat valve, 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. All components are mounted on the engine.
The starting system. The air supply into the cylinders is controlled by the starting air distributor run by the camshaft.
The four-cylinder engine are normally be provided with an air driven starting motor.

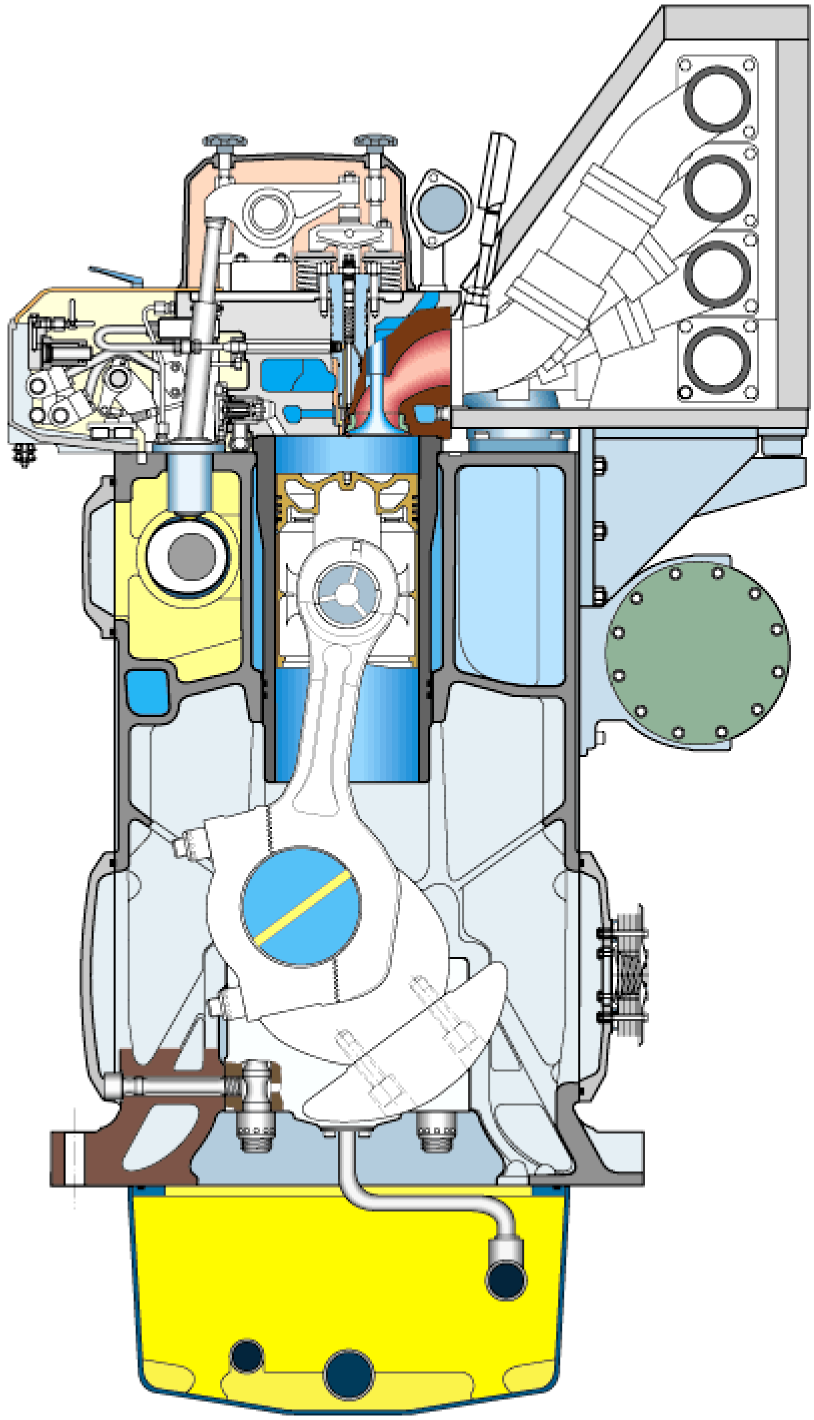

figure: 01-1 Cross-section of Wärtsilä VASA 22/26, in line engine

02.1 Fuel

02.1.1 General

The engine is designed to operate on heavy fuel (residual fuel) with a maximum viscosity of 55 cSt/100°C (approx. 730 cSt/50°C, approx. 7200 sec. RI/100°F) and will operate satisfactorily on blended (intermediate) fuels of lower viscosity, as well as on distillate fuel. Avoid the use of fuels having a lower viscosity than about 2.8 cSt at 40°C as such fuels may cause fuel injection pump plunger or fuel nozzle needle seizure.

The maximum limits of fuel characteristics for a certain engine are stated in the sales contract.

Blended fuels (residuals and distillate) with a viscosity between approx. 4 and 7 cSt/100°C (12 and 30 cSt/50°C, 65 and 200 sec. RI/100°F) containing between 30 and 60 % distillate should, however, be avoided due to the risk of precipitation of heavy components in the blend, with filter clogging and large amount of centrifuge sludge as consequence.

When difficulties with filter clogging are experienced, fuel incompatibility can be tested by ASTM D 2781 method or similar.

02.1.2 Fuel treatment

02.1.2.1 Purification

Heavy fuel (residuals, and mixtures of residuals and distillate) must be purified in an efficient centrifuge before entering the day tank. The fuel is to be heated before centrifuging.

Recommended temperatures, depending on the fuel viscosity, are stated in the diagram, chapter 02, [Fig 02-1].

Be sure that the correct gravity disc is used. Never exceed the flow rates recommended for the centrifuge for the grade of fuel in use. The lower the flow rate the better the efficiency.

Recommended centrifuge flow rate

	Fuel in use					
Max. viscosity (cSt/100°C)	10	15	25	35	45	55
Approx. viscosity (cSt/50°C)	50	90	205	350	530	730
Centrifuge flow rate (% of rated capacity)	60	40	30	25	20	15

For marine diesel oil (max. viscosity 14 cSt at 40°C) a flow rate of 80 % and a temperature of 45°C are recommended.

In case pure distillate fuel is used, centrifuging is still recommended as fuel may be contaminated in the storage tanks.

Rated capacity of the centrifuge may be used provided the fuel viscosity is less than 12 cSt at centrifuging temperature.

Marine Gas Oil viscosity is normally less than 12 cSt at 15°C.

02.1.2.2 Heating

See diagram, [Fig 02-1]. Keep the fuel temperature about 10°C above the minimum storage temperature indicated in the diagram in order to minimize the risk for wax formation and the temperature after the final heater 5 to 10°C above the recommended temperature before injection pumps to compensate for heat losses between heater and engine.

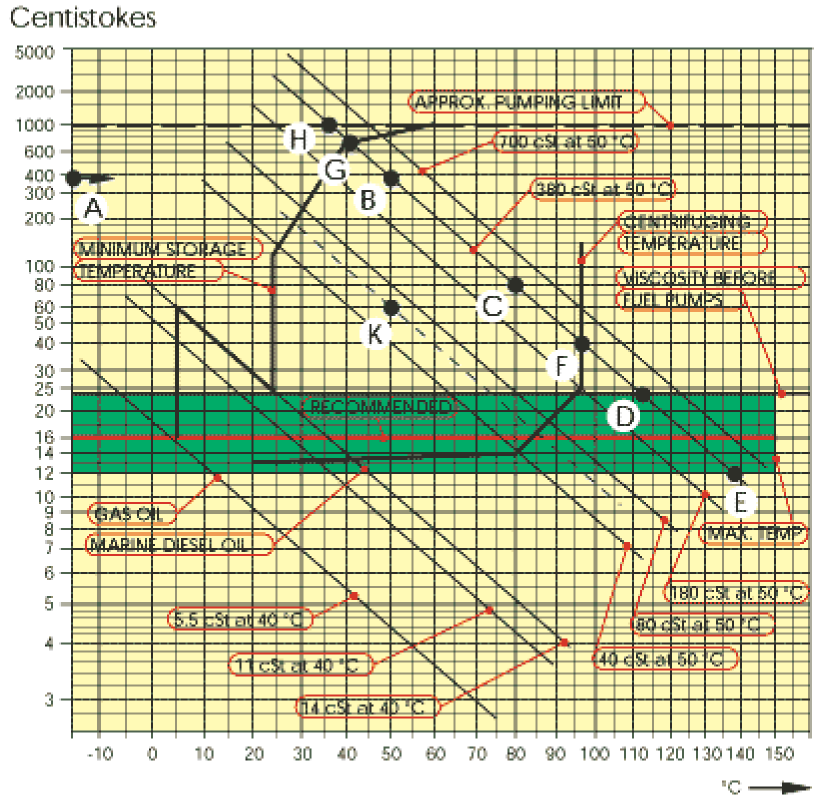

figure: 02-1 Fuel oil viscosity-temperature diagram

Example: *A fuel oil with a viscosity of 380 cSt (A) at 50°C (B) or 80°C (C) must be preheated to 115-130° C (D-E) before the fuel injection pumps, to 98°C (F) at the centrifuge and to minimum 40°C (G) in storage tanks. The fuel oil may not be pump able below 36°C (H).*

To obtain temperatures for intermediate viscosities, draw a line from the known viscosity/temperature point in parallel to the nearest viscosity/temperature line in diagram.

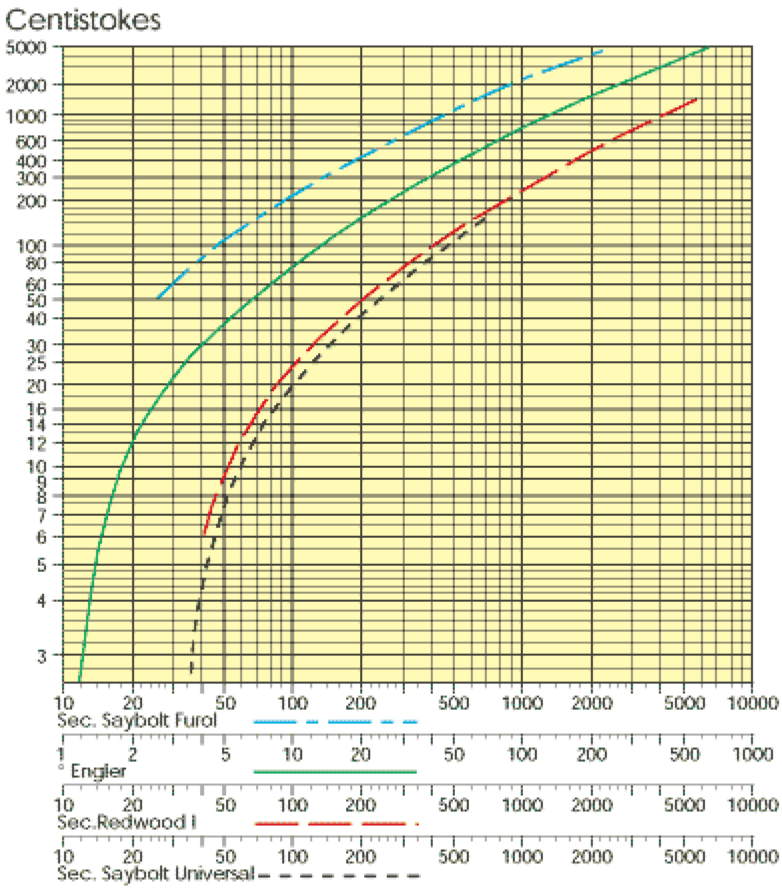

figure: 02-2 Viscosity conversion diagram

When converting viscosities from one of the units on the abscissa to centistokes or vice-versa, keep in mind that the result obtained is valid only at one and the same temperature. When converting the viscosity in any unit at a given temperature to a viscosity at another temperature a viscosity-temperature diagram or conversion rule must be used.

02.1.2.3 Viscosity control

An automatic viscosity controller, or a viscosimeter, at least, should be installed in order to keep the correct viscosity of the fuel before the fuel enters the engine fuel system.

02.1.3 Maximum limits of fuel characteristics

The diesel engine Wärtsilä Vasa 22 is designed and developed for continuous operation, without reduction in the rated output, on fuels with the following properties:

Fuel characteristics, max. limits		**Heavy fuel (HF)**	**Marine diesel fuel (MD)**
Density at 15°C	(g/ml)	1.010[1)]	0.900
Viscosity, kinematic, at 100°C Viscosity, kinematic, at 40°C Viscosity, kinematic, at 50°C Viscosity, kinematic, at 100°F	(cSt) (cSt) (cSt) sRI	55 - 730 7200	- 14.00 11.00 70.00
Water content	(% volume)	1.0	0.25
Water content (before engine)	(% weight)	0.3	0.20
Carbon residue, Conradson	(% weight)	22	-

Asphaltenes	(% weight)	14	-
Flash point, closed Pensky-Martens, min	(°C)	60.0	60.0
Pour point, upper max.	(°C)	30	6

The requirements above also correspond to the demands of:

ISO 8217: 1987(E), ISO-F-RMH 55 and RML 55[1)]

BS 6843: Part 1: 1987, ISO-F-RMH 55 and RML 55[1)]

CIMAC 1990, class H 55 and K 55[1)]

[1)] Provided the fuel treatment system can remove water and solids.
2) According to the actual fuel
The maximum limits of fuel characteristics for a certain engine are stated in the sales contract.

02.1.4 Comments on fuel characteristics

A) Viscosity is no criterion of the fuel quality, but determines the complexity of the fuel heating and handling system, which should be considered when estimating installation economy.

The standard engine fuel system is designed for max. 55 cSt/100°C fuel (approx. 730 cSt/50°C or approx. 7200 sec. RI/100°F).
B) With a density of more than 0.991 g/ml at 15°C, water, in particular and to some extent solid matter can no longer be removed with certainty by a centrifuge. Centrifuging systems that are claimed to be able to clean fuel oils with densities up to 1.010 g/ml at 15°C are available. If such systems are installed, fuels with densities up to 1.010 g/ml at 15°C may be used.
Caution!

Fuel oils having high density in combination with low viscosity may have low ignition quality.

C) High sulphur content increases the risk for corrosion and wear, particularly at low loads, and may contribute to high-temperature deposit formation.
D) High ash content causes abrasive wear, and may cause high-temperature corrosion and contributes to deposit formation. The most harmful ash constituents are vanadium and sodium.
E) High vanadium content causes hot corrosion on exhaust valves particularly in combination with high sodium content. The corrosion increases with increased temperatures (increased engine output).
F) Sodium contributes to hot corrosion on exhaust valves when combined with high vanadium and sulphur content. It also contributes to deposit formation on valves, nozzle rings, etc.

The aggressiveness of the fuels depends on, not only the quantity, but also of the proportions of sodium and vanadium. The worst combination is when the sodium content is about 25-40 % of the vanadium content.
G) High conradson carbon may cause deposit formation in combustion chamber and exhaust system, particularly at low engine output.
H) High content of asphaltenes may contribute to deposit formation in combustion chamber and exhaust systems at low loads.

Asphaltenes may under certain circumstances precipitate from the fuel and block filters and/or cause deposits in the fuel system. Precipitating asphaltenes may also cause excessive centrifuge sludge.
I) Heavy fuels may contain considerable amounts of water (up to 1 %). Water may also originate from the installation bunker tanks. To avoid difficulties in the engine fuel injection system the water content must be reduced to max. 0.3 % by centrifuging.
J) Ignition quality. Heavy fuels may have very low ignition quality at low load operation. This may cause trouble at start and low load operation particularly if the engine is not sufficiently preheated. Low ignition quality may also result in long ignition delay and as a consequence, in high firing pressure rise ratio, which may damage engine components, e.g. piston rings.
Ignition quality is not defined, nor limited, in marine residual fuel standards. The same applies to ISO-F-DMC marine distillate fuel. The ignition quality of these fuels cannot - for a variety of reasons - be determined by methods used for pure distillates, i.e. Diesel Index, Cetane Index and Cetane Number.
Shell and BP have developed equations for prediction of the ignition quality of residual fuels. Both equations provide sufficient accuracy for prediction of the ignition quality of the vast majority of fuels bunkered, although they may fail on some very unusual blends. Both equations can easily be solved with a scientific pocket calculator. Only the fuel density and viscosity need to be known.

Shell Calculated Carbon Aromaticity Index (CCAI)

$$CCAI = D - 81 - 141 \log_{10} \log_{10} (V_k+0.85)$$

D = density (kg/m^3 at 15°C)
V_k = viscosity (cSt at 50°C)
CCAI can also be determined (but with limited accuracy) by the diagram, [Fig 02-3].
Note!

An increased CCAI value indicates decreased ignition quality.

BP Calculated Ignition Index (CII)

$$CII = (270.795 + 0.1038T) - 254.565 D + 23.708 \log_{10}\log_{10} (V_t+0.7)$$

D = density (kg/l at 15°C)
V_t = viscosity in cSt measured at any temperature between 50 and 100°C
T = temperature (°C) between 50 and 100
Note!

A decreased CII value indicates decreased ignition quality

Basically a low viscosity in combination with a high density will result in a high CCAI and a low CII, i.e. low ignition quality.

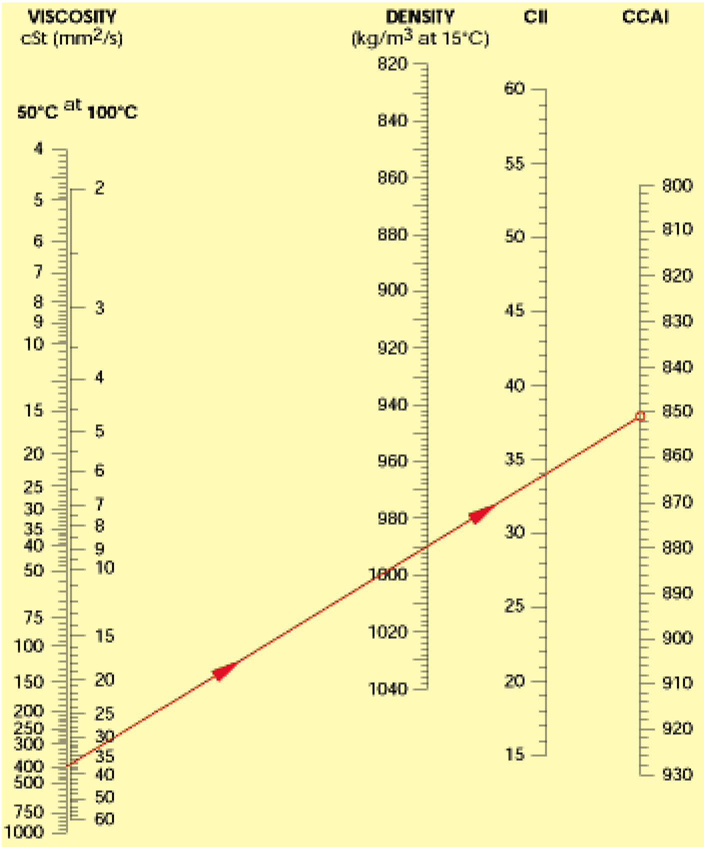

figure: 02-3 Nomogram for deriving CII and CCAI

What do the values mean?
Straight run residues show CCAI values in the 770 to 840 range and are very good igniters. Cracked residues delivered as bunkers may range from 840 to - in exceptional cases - above 900. Most bunkers remain in the 850 to 870 range at present.
The CCAI value is not an exact tool for judging fuel ignition. The following guidelines can, however, be given:

engines running at constant speed and load >= 50 % can use fuels with CCAI <= 870,

engines running at variable speed and load can use fuels with CCAI <= 860.

To avoid difficulties with poor ignition quality fuels the following should be noted:

sufficient preheating of the engine at start,

proper function of inverse cooling system,

proper function of injection system, in particular injection nozzle condition.

Symptoms of low ignition quality are:
"Diesel Knock", i.e. hard, high pitch combustion noise
Effects of diesel knock are:
Increased mechanical load on components surrounding the combustion space, increased thermal load, increased lub. oil consumption and increased lub. oil contamination.
Caution!

Although low ignition quality produces long ignition delay, advancing the ignition timing makes things only worse; fuel is injected at a lower compression temperature and this will produce even longer ignition delay.

K) Abrasive particles. Fuel may contain highly abrasive particles composed of aluminium and silicon oxides known as "catalytic fines" from certain refining processes. If not removed by efficient fuel treatment, considerable wear on vital engine components, like injection equipment, may be experienced.
02.1.5 Measures to avoid difficulties when running on heavy fuel
Poor fuel quality will, however, influence wear, engine part life time and maintenance intervals adversely.
In order to obtain maximum operating economy it is recommendable:
A) to limit maximum continuous output as much as operating conditions allow if fuel is known or suspected to have high vanadium content (above 200 ppm) and especially if the sodium content simultaneously is about 25 - 40 % of the vanadium content.
B) to limit low load operation as much as operating conditions allow if fuel is known or suspected to have high sulphur content (above 3 %), carbon content (Conradson carbon above 12 %) and/or asphaltene content (above 8 %).
Operation below 20 % of rated output should be limited to max. 100 hours continuously, by loading the engine above 70 % of rated load for one hour before continuing the low load operation or shutting down the engine.

Idling (i.e. main engine declutched, generator set disconnected) should be limited as much a possible. Warming-up of the engine at no load for more than 3 minutes before loading, as well as idling more than 3 minutes before stopping is unnecessary and should be avoided.

02.1.6 General advice

To avoid stability and incompatibility problems (precipitation of heavy components in the fuel), avoid if possible blending of fuels from different bunker stations, unless the fuels are known to be compatible.

If stability and compatibility problems occur, never add distillate fuel, as this will probably increase precipitation. A fuel additive with a highly powerful dispersing characteristics can be of help until a new fuel delivery takes place.

The characteristics of heavy fuels blended from residuals from modern refinery processes like catalytic cracking and visbreaking may approach at least some of the maximum limits of fuel characteristics given in the table in chapter 02, section [02.1.3].

Compared with "traditional" heavy fuels blended from straight run residuals the "modern" heavy fuels may have reduced ignition and combustion quality.

Fuels blended from catalytic cracking residuals may contain very abrasive catalytic fines (silicon and aluminium oxides) which, if allowed to enter the injection system, may wear down injection pumps and nozzles in a few hours.

Some of the difficulties that may occur when operating on heavy fuels blended from cracked residuals can be avoided by:

sufficient separating capacity. The best and most disturbance-free results are obtained with purifier and clarifier in series. Alternatively the main and stand-by separators may be run in parallel, but this makes heavier demands on correct gravity disc choice and constant flow and temperature control to achieve optimum results. The flow rate through the centrifuges should not exceed the maximum fuel consumption by more than 10 %,

sufficient heating capacity to keep centrifuging and injection temperatures at recommended levels. It is important that the temperature fluctuations are as low as possible (±2°C before centrifuge) when centrifuging high viscosity fuels with densities approaching 0.991 g/ml at 15°C,

sufficient preheating of the engine and the fuel systems before starting the engine,

keeping fuel injection equipment and the inverse cooling system in good condition.

02.2 Lubricating oil

02.2.1 System oil characteristics

Viscosity. Viscosity class SAE 30 or SAE 40. SAE 40 is preferred.

Alkalinity. The required lubricating oil alkalinity is tied to the fuel specified for the engine, which is shown in the table below.

Fuel standards and lubricating oil requirements			
Category	**Fuel standard**		**Lube oil BN**
A	ASTM D 975-81, BS 6843: 1987 BS 2869-1983, ISO 8217: 1987(E)	GRADE ID, 2D, PROPOSED 3D ISO-F-DMX, DMA CLASS A1, A2 ISO-F-DMX, DMA	**10 - 40**
B	ASTM D 975-81, BS 6843: 1987 ISO8217: 1987(E)	GRADE 4D ISO-F-DMB ISO-F-DMB	**15 - 40**
C	ASTM D 396, BS 6843: 1987 CIMAC 1986, ISO 8217: 1987(E)	GRADE NO 4-6 ISO-F-DMC, RMA10-RML55 CIMAC A10-K55 ISO-F-DMC, RMA10-RML55	**25 - 40**

It is recommended to use BN 40 lubricants with category C fuels. If very low sulphur residual fuel is used, BN 30 lubricants can be used. BN 30 lubricants can also be used if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.

Additives. The oils should contain additives that give good oxidation stability, corrosion protection, load carrying capacity, neutralization of acid combustion and oxidation residues, prevent deposit formation on internal engine parts (piston ring zone and bearing surfaces in particular).

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 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.

Classification. The oil should meet the API Service CD classification.

02.2.2 Lubricating oil qualities

Approved system oils - all fuel categories - for Wärtsilä Vasa 22, 22/26 engines				
Lubricating oil supplier	**Designation (brand name) of**	**Visc**	**BN**	**Fuel**

	lubricating oil supplier			categ.
Adnoc-Fod	Marine Engine Oil X324 Marine Engine Oil X424 Marine Engine Oil X330 Marine Engine Oil X430	SAE 30 SAE 40 SAE 30 SAE 40	24 24 24 24	A, B, C A, B, C A, B, C A, B, C
Agip	Cladium 400 SAE 30 Cladium 400 SAE 40	SAE 30 SAE 40	40 40	A, B, C A, B, C
BP	Energol IC HF 303 Energol IC HF 304 Energol IC HF 404	SAE 30 SAE 40 SAE 40	30 30 40	A, B, C A, B, C A, B, C
Caltex	DELO 3000 Marine SAE 30 DELO 3000 Marine SAE 40 DELO 3400 Marine SAE 30 DELO 3400 Marine SAE 40	SAE 30 SAE 40 SAE 30 SAE 40	30 30 40 40	A, B, C A, B, C A, B, C A, B, C
Castrol	MLC 30 MLC 40 Marine 215 MXD Marine 220 MXD MXD 303 MXD 304 MXD 403 MXD 404	SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40	12 12 22 22 30 30 40 40	A A A, B A, B A, B, C A, B, C A, B, C A, B, C
Compañia Española de Petroleos, S.A.	CEPSA Troncoil 3030 CEPSA Troncoil 3530 CEPSA Troncoil 4030 CEPSA Troncoil 30340 CEPSA Troncoil 3540 CEPSA Troncoil 4040 Ertoil Koral 30 SAE 30 Ertoil Koral 35 SAE 30 Ertoil Koral 40 SAE 30 Ertoil Koral 30 SAE 40 Ertoil Koral 35 SAE 40 Ertoil Koral 40 SAE 40	SAE 30 SAE 30 SAE 30 SAE 40 SAE 40 SAE 40 SAE 30 SAE 30 SAE 30 SAE 40 SAE 40 SAE 40	30 35 40 30 35 40 30 35 40 30 35 40	A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C
Chevron	DELO 3000 Marine 30 DELO 3000 Marine 40 DELO 3400 Marine 30 DELO 3400 Marine 40	SAE 30 SAE 40 SAE 30 SAE 40	30 30 40 40	A, B, C A, B, C A, B, C A, B, C
Compagnie Francaise de Raffinage	Total HMA SAE 330 Total HMA SAE 340 Total HMA SAE 430 Total HMA SAE 440	SAE 30 SAE 30 SAE 40 SAE 40	30 40 30 40	A, B, C A, B, C A, B, C A, B, C
Esso	Exxmar 12TP 30 Exxmar 12TP 40 Exxmar 24TP 30 Exxmar 24TP 40 Exxmar 30TP 30 Exxmar 30TP 40 Exxmar 40TP 30 Exxmar 40TP 40 Exxmar 30TP 30 PLUS Exxmar 30TP 40 PLUS Exxmar 40TP 30 PLUS Exxmar 40TP 40 PLUS	SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40	12 12 24 24 30 30 40 40 30 30 40 40	A A A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C

Elf Lub Marine	Aurelia XT 3055	SAE 30	55	A, B, C
	Aurelia XT 4055	SAE 40	55	A, B, C
	Aurelia XT 4040	SAE 40	40	A, B, C
	Aurelia XT 3040	SAE 30	40	A, B, C
	Aurelia 3030	SAE 30	30	A, B, C
	Aurelia 4030	SAE 40	30	A, B, C
Engen Petroleum	Genmarine EO 3030	SAE 30	30	A, B, C
	Genmarine EO 4030	SAE 40	30	A, B, C
	Genmarine EO 4040	SAE 40	40	A, B, C
Fina	Stellano 330	SAE 30	30	A, B, C
	Stellano 430	SAE 40	30	A, B, C
	Stellano 340	SAE 30	40	A, B, C
	Stellano 440	SAE 40	40	A, B, C
Indian Oil Corp..	Servo Marine C-303	SAE 30	30	A, B, C
	Servo Marine C-304	SAE 40	30	A, B, C
	Servo Marine C-403	SAE 30	40	A, B, C
	Servo Marine C-404	SAE 40	40	A, B, C
Kuwait Petroleum	Q8 MOZART HPM 30	SAE 30	12	A
	Q8 MOZART HPM 40	SAE 40	12	A
Mobil	Mobilgard 312	SAE 30	15	A
	Mobilgard 412	SAE 40	15	A
	Mobilgard 324	SAE 30	30	A, B, C
	Mobilgard 424	SAE 40	30	A, B, C
	Mobilgard 342	SAE 30	40	A, B, C
	Mobilgard 442	SAE 40	40	A, B, C
Neste	NST 30	SAE 30	30	A, B, C
	NST 40	SAE 40	30	A, B, C
Nippon Oil Co.	Super MDL MX 40	SAE 40	22	A, B
	Super MDL SX 30	SAE 30	33	A, B
	MDL SL 230	SAE 30	20	A
	MDL SL 240	SAE 40	20	A
Norol	Marine HA 303	SAE 30	30	A, B, C
	Marine HA 304	SAE 40	30	A, B, C
	Marine HA 404	SAE 40	40	A, B, C
Olje-Energi	Goth Oil 325	SAE 30	25	A, B, C
Petrobras	Marbax CCD-330	SAE 30	30	A, B, C
	Marbax CCD-430	SAE 40	30	A, B, C
	Marbax CCD-340	SAE 30	40	A, B, C
	Marbax CCD-440	SAE 40	40	A, B, C
Phillips Oil Trading Ltd	Marine SR 30	SAE 30	30	A, B, C
	Marine SR 40	SAE 40	30	A, B, C
Repsol	Neptuno 3000 SAE 30	SAE 30	30	A, B, C
	Neptuno 3000 SAE 40	SAE 40	30	A, B, C
	Neptuno 4000 SAE 30	SAE 30	40	A, B, C
	Neptuno 4000 SAE 40	SAE 40	40	A, B, C

Shell	Sirius FB Sirius FB Argina T 30 Argina T 40 Argina X 40	SAE 30 SAE 40 SAE 30 SAE 40 SAE 40	9 9 30 30 40	A A A, B, C A, B, C A, B, C
Teboil	Teboil Ward S 30 T SAE 30 Teboil Ward S 30 T SAE 40 Teboil Ward L 30 T SAE 30 Teboil Ward L 30 T SAE 40 Teboil Ward L 40 T SAE 30 Teboil Ward L 40 T SAE 40 Teboil Ward O 30 T SAE 30 Teboil Ward O 30 T SAE 40 Teboil Ward O 40 T SAE 30 Teboil Ward O 40 T SAE 40	SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40 SAE 30 SAE 40	30 30 30 30 40 40 30 30 40 40	A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C A, B, C
Texaco	Taro XD 30 Taro XD 40 Taro DP 30 Taro DP 40 Taro XL 40	SAE 30 SAE 40 SAE 30 SAE 40 SAE 40	16 16 32 32 42	A A A, B, C A, B, C A, B, C

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 engine manufacturer's procedures.

Never blend different oil brands unless approved by oil supplier and, during guarantee time, by 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 preheated at least to 80 - 95°C. Many oil manufacturer 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. The gravity disc to be chosen according 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 after about 250, 500 and 1000 operating hours. 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. After that the oil can be analysed at about 500 operating hours intervals.

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 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. Maximum permissible viscosity for a SAE 30 grade oil is 140 cSt at 40°C and 15 cSt at 100°C.

Maximum permissible viscosity for a SAE 40 grade oil is 212 cSt at 40°C and 19 cSt at 100°C.

Minimum permissible viscosity is 70 cSt at 40°C and 9 cSt at 100°C.

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

Water content. Should not exceed 0.2 %. At 0.5 % measures must be taken; either centrifuging or oil change.

BN(Base Number).

- fuel category A: The minimum allowable BN value of a used oil is 50% of the nominal value of a new oil,
- fuel categories B and C:
  For lubricating oils with nominal BN value between 30 and 40, the minimum allowable value of a used oil is 50% of the nominal value of a new oil.
  For lubricating oils with nominal BN values between 24 and 30, the minimum allowable value of a used oil is BN 15.

Insolubles. The quantity allowed depends on various factors. The oil supplier's recommendations should be followed. However, an n-Pentan insoluble value above 1.5 % calls for attention. A value higher than 2% cannot be accepted for longer periods.

In general it can be said that the changes in the analyses give a better basis of estimation than the absolute values.

Fast and great changes may indicate abnormal operation of the engine or of a system.

C) Compensate for oil consumption by adding maximum 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, a sudden increase motivates pulling the pistons, if no other reason is found.

D) Guidance values for oil change intervals are to be found in chapter [04]. The intervals between changes are influenced by operating conditions, fuel quality, centrifuging efficiency and total oil consumption. Efficient centrifuging and large systems (dry sump operation) generally allow for long intervals between changes. It is recommended to follow up that the BN value of the lubricating oil keeps within Wärtsilä Diesel's limits during the whole oil change interval.

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].

02.2.4 Lubricating oil for the governor

See the Instruction Book for the governor (attached). An oil of viscosity class SAE 30 and SAE 40 is normally suitable and usually the same oil can be used as in the engine system. Turbocharger oil can normally also be used in governor. Oil change interval: 2000 h service.

Caution!

If turbine oil is used in the governor, take care not to mix it with engine lubricating oil. Only a small quantity may cause heavy foaming.

02.2.5 Lubricating oils for ABB-VTR turbochargers with ball and roller bearings

See the Instruction Book for the turbocharger, attached. Only such lubricant may be used which have a viscosity of 61 - 90 cSt at 40°C and 7.5 - 12 at 100°C, turbine oils are preferred. Oil change interval is 500 h service for normal mineral oils, 1500 h service for special mineral oils and 2500 h service for synthetic lubricating oils.

Caution!

Take care that the turbine oil is not mixed with engine lubricating oil. Only a small quantity may cause heavy foaming.

Mineral oils: oil change interval 500 h				
Manufacturer	**Brand name**	**Viscosity (cSt)**		**Viscosity Index (VI)**
		40°C	**100°C**	
Agip	Ote 68	64	8.6	107
BP	Energol THB 68 Turbinol 68 Bartran 68	65 68 68	8.4 8.7 8.7	99 100 100
Caltex	Regal Oil R & O 68 Rando Oil 68 Rando Oil HD 68 Rando Oil HDZ 68	65.5 64.9 67 66	8.5 8.5 8.8 10.7	100 101 104 152
Castrol	Perfekto T 68 Hyspin AWS 68 Hyspin AWH 68 Hyspin AWH-M 68	64 68 68 68	8.25 8.6 10.9 10.9	95 96 150
Chevron	Chevron GST 68 Mechanism LPS 68	68 68	9.02 10.9	107 151
Cosmo	Turbine Super 68	68	8.7	100

Elf	Turbine T 68 Turbelf SA 68 Visga 68 Hydrelf DS 68	71 68 73 72.5	9.0 8.94 11.7 11.6	100 105 155 151
Esso	Esso Tro-Mar T / Teresso 77 Teresso 68 Nuto H 68	76 67 64	9.5 8.8 8.4	103 108 101
Fina	Turbine oil medium(68) / BAKOLA 68 Turbine oil heavy (80) Hydran LZ 68	68 80 70.6	9.2 10.2 9.07	112 108 100
Hindustan Petroleum	Turbinol 68 Turbinol 77	62-66 75-83	8.2 9.6	95 95
Idemitsu	Daphne super turbine HT-68	68.1	9.1	110
Indian Oil Corp.	Servoprime 68 Servoprime 76 Servopress 68 Servosystem HLP 68	64-72 74-80 64-72 64-72	8.15 9.13 8.5 8.5	95 95 95 95
Kuwait Petroleum	Van Gogh 68	68	8.7	98
Mobil	Rarus 427 (Not US version) DTE Oil Heavy Medium DTE 16 M	81 61.2 71	9.9 8.6 10.3	95 100 130
Repsol	Telex E-68 Aries 68	68 68	9.0 9.5	105 95
Shell	Turbo Oil T 68 Turbo Oil T 78 Tellus Oil 68	68 78 68	8.7 9.4 8.8	98 96 102
Statoil	Turbway 68 Hydraway HMA 68	67 63	8.5 8.0	96 95
Texaco	Regal Oil R & O 68 Rando Oil HD 68	64.7 61.5	8.3 8.2	96 101
Total	Preslia 68	68.0	8.7	100

Special mineral oils: oil change interval 1 500 h

Manufacturer	Brand name	Viscosity (cSt)		Viscosity Index (VI)
		40°C	100°C	
BP	Energol RC 68	68	8.8	104

Shell	Madrela AP 68	68	8.5	94
Valvoline	Compressor oil 62	90	10.0	92

Synthetic lubricating oils: oil change interval 2 500h				
Manufacturer	**Brand name**	**Viscosity (cSt)**		**Viscosity Index (VI)**
		40°C	**100°C**	
Castrol	Aircol SN 68	65.0	7.7	69
Chevron	Tegra 68	64.6	10.4	149
Elf	Barelf CH 68	69.9	8.9	100
Esso	Synesstic 68	65.0	7.7	67
Kuwait Petroleum	Schumann 68	68.0	10.3	138
Mobil	Rarus SHC 1026	66.8	10.4	144
Nyco	Nycolube 3060	93.0	10.0	85

These lubricating oils are in regard of viscosity and quality according to the recommendations.

02.2.6 Lubricating grease for the fuel feed pump

For further information about the pump see chapter [17] or the separate instructions attached. Regreasing interval: see chapter [04].

Caution!

The pump should be regreased after one hour of operation when the pump is new or has been overhauled.

The following grease is recommended: Klüber Unisilikon L50/2.

The pump is to be regreased only under running conditions!

02.2.7 Lubricating grease for the electric driven prelubricating pump

For further information about the pump see chapter [18] or the separate instructions attached. Regreasing interval: see chapter [04].

Caution!

The pump should be regreased after one hour of operation when the pump is new or has been overhauled.

The following greases are recommended:

BP Energrease LS2,

Caltex Regal Starfak Premium 2,

Esso Beacon 325,

Nynäs FL3-42,

Shell Alvania 3.

The pump is to be regreased only under running conditions!

02.2.8 Lubricating oil for the pneumatically operated starting motor (4R22, 4R22/26 only)

For further information about the pump see chapter [21] or the separate instructions attached.

Check regularly that the oil level in the lubricator is between the maximum and minimum values. The following oil qualities are recommended:

Gali HI 33EP,

Shell Turbo 27,

Castrol Hyspin 80,

BP Energol HP46,

Mobil Deterrgent Light.

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 dºH, 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.

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 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 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 from 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.

02.0.4. Summary of the most common cooling water additives

Additive	Advantages	Disadvantages	Suitability
Sodium nitrite	- good efficiency - small active quantities 0.5 % by mass - cheap	- determination of the concentration can be done only with special equipment	- suitable as additive except in air cooled heat exchangers with large soft solder surfaces
Nitrite + borate	- no increased risk of corrosion at over or under-doses - innocuous for the skin - allowed for use in fresh water generators intended for house-keeping purposes	- tendency to attack zinc coverings and soft solderings **- toxic**: lethal dosage 3...4 g solid nitrite	
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 concen-tration: spot corrosion - injurious for the skin **- toxic**: lethal dosage 1 g - prohibited for use in fresh water generators intended for housekeeping 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 exeeds 2m/s - commercial products very expensive - increased risk of corrosion when too low concent-ration: spot corrosion	- limited suitability
Sodium molybdate	- not toxic - harmless to handle	- more expensive than toxic additives - increased risk of corrosion, sensitive to correct dosage	

Approved cooling water treatment products

Supplier	**Product designation**
Drew Ameroid Marine Division Ashland Chemical Company One Drew Plaza Boonton, NJ 07005, USA	Maxicard DEWT-NC powder Liquidewt Vecom CWT Diesel QC-2
Grace Dearborn Ltd. Widnes, Chesire W A8 8UD United Kingdom	Dearborn 547
Houseman Ltd The Priory, Burnham Slough SL 1 7LS, UK	Cooltreat 651
Tampereen Prosessi-Insinöörit Sarankulmankatu 12 FIN-33900 Tampere, Finland	Ruostop XM
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 powder Nalco 39-Lliquid Nalcool 2000
Nalfleet Marine Chemicals P.O.Box 11 Winnington Avenue Northwich Cheshire, CW 8 4DX, UK	Nalfleet 9-108 Nalfleet 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. B-9052 Ghent/Zwijnaarde Belgium	TEXACO ETX 6282

Unitor A/S, Mastermyr 1410 Kolbotn, 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.

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.

03.1 Start

Before starting the engine, check that:

the lubricating oil level is correct,

the fuel system is in running order (correct preheating, correct pressure, sufficient precirculation to heat the fuel injection pumps),

the circulating system and raw water system are in running order (correct pressures, circulating water preheated and precirculated sufficiently to heat the engine),

the oil level in the governor and turbocharger(s) is correct,

the starting air pressure exceeds 15 bar,

the starting air system is drained of condensate,

voltage to DESPEMES to ensure alarm functions.

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.

Note!

Never leave the engine running when covers are removed.

03.1.1 Manual start

1 **Start the prelubricating oil pump** to obtain a lubricating oil pressure, about 0.5 bar. Normally, the prelubricating oil pump is running when the engine is stopped (switch in auto-mode). The prelubricating oil pump is automatically switched off when the engine has reached 300 RPM in this running mode.

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 **Turn the crankshaft two revolutions** or run the engine on starting air for some revolutions keeping the **stop lever in stop position** and the indicator valves open. In doing so the risk of water locks is eliminated.

4 **Disengage the turning gear** from the flywheel.

5 **Check that the automatic alarm** and and stop devices are set in start position (chapter [23]).

6 **Check that the stop lever is in work position,** open the starting air valve, shut the blow-off valve when there is no more condensate.

7 **Push the start button** until the engine starts firing. If the engine does not start after 2 - 3 seconds the reason should be checked.

8 **On engines equipped** with pneumatic starting motors, never make a second starting attempt before the flywheel has stopped.

9 **Check immediately after start** that the pressure and temperature values are normal.

10 **Check that the automatic alarm** and stop devices are set in work position.

03.1.2 Remote and automatic start

If the engine has been out of operation for more than a week the first start is to be carried out manually according to point 1.

Engines with automatic starting must be tested once a week.

1 **When starting the engine remotely,** start the lubricating oil priming pump at first. Usually, the operation of the pump is indicated by a signal lamp. The engine can be started when the lube oil pressure gauge shows an oil pressure of about 0.5 bar.

In automatically starting engines the priming pump operates continuously thus keeping the engine ready for start. At least every second day, make sure that the pump is running.

2 **Press the remote start button** of the remotely controlled engine. The solenoid valve located on the engine will then be energized and allow starting air to the engine. Press the start button long enough (1 - 2 s.) to make the engine start. The start will be indicated by the remote tachometer or by a signal lamp showing when the engine is running. In some cases the remote control is automated so that, when pressing the button, the priming pump starts and after an increase of the oil pressure (to about 0.5 bar) the engine starts automatically as described in point 3.

3 **In engines with automatic starting** the solenoid valve is controlled by a program relay. The normal program is as follows: As soon as the program relay gets a starting impulse the solenoid valve is energized for 2 - 4 seconds and opens, then starting the engine.

If the engine fails to start, a new starting attempt takes place after 20 seconds, whereby the solenoid valve will be energized for 10 seconds. If this attempt also fails, the program relay will connect the alarm circuit. On engines equipped with pneumatic starting motors the period between the starting attempts should be long enough to guarantee that the flywheel has stopped.

4 **When the engine has reached a predetermined speed,** an auxiliary relay energized by the remote tacho transmitter cuts off the starting circuit, and the starting air solenoid valve closes.

At the same time the current to the priming pump will be disconnected thus preventing the pump from operating when the engine is running.

On certain installations the priming pump will continue to operate at low engine speed to assist the engine driven lubricating oil pump to maintain the oil pressure. After a fixed time (10 - 30 s.) the system for alarm, stop and speed remote control will be automatically connected.

03.2 Stop
03.2.1 Manual stop

1 **Engines with built-on circulating water pump:** Idle the engine 3 - 5 minutes before stopping. **Engines with separate circulating water pump:** 2 - 3 minutes will be enough, but the water pump should run for some 5 minutes 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.

03.2.2 Remote stop

1 **Point 1 above is valid.**

2 **Press the remote control stop button.** The shut-down solenoid, built on the governor, will then be energized for a fixed time and at the same time, parallel to governor, the pneumatic stop coil is also activated. The control racks of the injection pumps move into stop position. The time for the solenoid to be energized is set so (20 - 50 s.) that the solenoid operates until the engine stops. During this time the engine cannot be restarted.After a predetermined time the shut-down solenoid will return to its initial position.

3 **When the engine stops** and the speed decreases below a certain limit, the system for alarm, stop and speed remote control will be disconnected and the signal lamp indicating that the engine is running goes out.

In engines equipped with automatic lubricating oil priming pumps, the pump will be started at the same time.

03.2.3 Automatic stop
When the shut-down solenoid is energized from the automatic shut-down system due to some disturbance, the engine will stop as in remote stop. Before this an alarm device will normally initiate an alarm signal indicating the reason for the shut-down.
When the engine stops because of overspeed, the mechanical overspeed trip device and the electro-pneumatic overspeed trip device may have tripped.

03.2.4 General
The engine can always be stopped manually (with the stop lever) independent of the remote control or automation system.

Caution!

When overhauling the engine, make absolutely sure that the automatic start and the priming pump are disconnected.

Close the starting air shut-off valve located before the solenoid valve. **Move the stop lever into STOP position.**
If the engine is to be stopped for a lengthy time, close the indicator valves. It is also advisable to cover the exhaust pipe opening.
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.
Blow the engine with open indicator valves and start the engine once a week to check that everything is in order.

03.3 Normal operation supervision
03.3.1 Every second day or after every 50 running hours

1 **Read all thermometers** and pressure gauges and the load of the engine. 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].**

if the difference between exhaust gas temperatures of various cylinders is larger than 80°C at loads higher than 25 % the reason for this should be looked for, 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 03-1]. At loads lower than 40 % it is favourable to have a charge air temperature as high as possible.

2 **Check the indicator for pressure drop over fuel filters.**

When the pressure drop over the filters increases, the pressure in the system decreases. Very low pressure (less than 0.5 bar) reduces the engine performance and may cause uneven load distribution between the cylinders (risk of breakdown!). Too high pressure drop may also result in deformation of filter cartridges (risk of injection pump seizure).

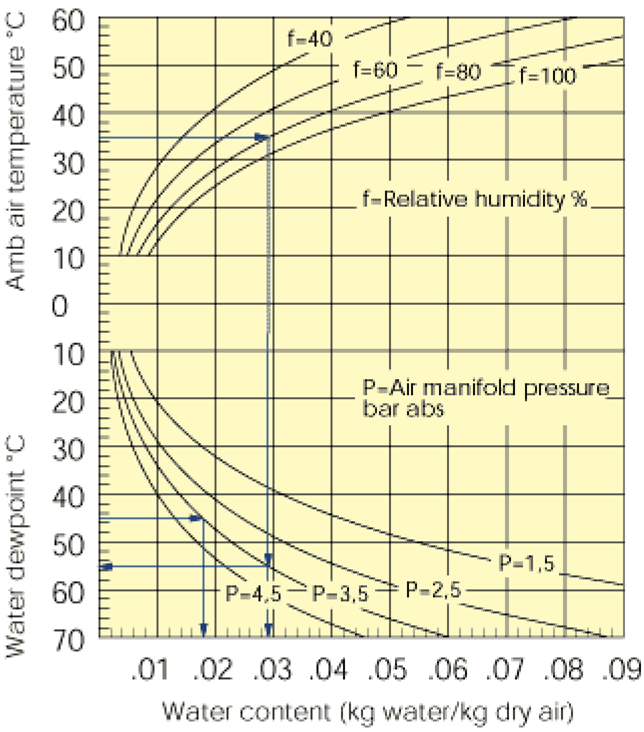

figure: 03-1 Condensation in charge air coolers

Example: *If the ambient air temperature is 35°C and the relative humidity is 80 % the water content in 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.*

3 **Check the indicator for pressure drop** over the lubricating oil filters. Too large 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 consistence 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 maximum 10 % fresh oil at a time.

5 **Check that the ventilation** (de-aerating) of the engine circulating water system (the expansion tank) is working. Check that the leakage from the gossip hole of the circulating water pump and the raw water pump is normal (slight).

6 **Check the quantity of leak-fuel** from the draining pipes.

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

8 **Check that the gossip holes** of the oil coolers and the circulating water coolers are open.

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

10 **Drain the fuel day tank** of water and sediments, if any, and drain the starting air receiver of water.

11 **Marine engines** (propulsion and auxiliary engines): On a stopped engine, prime the engine and **turn the crankshaft into a new position.** This reduces the risk of crankshaft and bearing damage due to vibrations.

03.3.2 Every second week or after every 250 running hours

1 **Clean the centrifugal lubricating oil filters.** If the deposits are thicker than 20 mm, reduce the cleaning interval to retain filtering efficiency. Maximum deposit capacity is 40 mm.

2 **Keep the injection pump racks clean** (free from sticky deposits), check that the parts of the fuel control shaft system move easily. Is to be done on a stopped engine.

3 **Clean the turbine side of the turbocharger** by injecting water. See chapter [15] and the instruction book of the turbocharger.

03.3.3 Once a month or after every 500 running hours

1 **Check content of additives** in the circulating water.

2 **Check the cylinder pressures.** At the same time, note the load of the engine (the position of the load indicator or the injection pump racks offers an accurate measure of the engine load).

Note!

Measurement of cylinder pressures without simultaneous notation of the engine load is practically worthless.

3 **Check the function** of the load dependent "inverse" cooling system with engine loaded below 30 % of rated output.

03.3.4 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].

03.3.5 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 **Forms,** "Operating data" and "Service Report", are delivered with every installation. Use them!

3 **Strong gas blow-by** past the pistons is one of the most dangerous things that can occur in a diesel engine. If gas blow-by is suspected (e.g. because of a sudden increase of the lubricating oil consumption) check the crankcase pressure. If the pressure exceeds 30 mm H_2O, check the crankcase venting system, if in order, pull the pistons!

4 **Operation at loads below 20 %** of rated output should be limited to maximum 100 hours continuously when operating on heavy fuel by loading the engine above 70 % of rated load for one hour before continuing the low load operation or shutting down the engine. Continuous operation on marine diesel fuel at loads below 10 % of rated output should be limited to maximum 100 hours by loading the engine by more than 70 % of rated output for one hour before continuing the low load operation or shutting down the engine.

Idling (i.e. main engine declutched, generator set disconnected) should be limited as much as possible. Warming-up of the engine for more than 3 - 5 minutes before loading, as well as idling more than 1 minute before stopping is unnecessary and should be avoided.

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

03.4.1 Manual start

1 **Check**

the lubricating oil level,

the circulating water level in the expansion tank,

the raw water supply,

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 - minimum 15 bar,

that the control shaft system and the injection pump racks move freely. Otherwise **risk of overspeed.**

2 **Observe all points** in chapter 03 pos. [03.1.1]. **Point 3 grows more important the longer the engine has been stopped.**

3 **After starting,** check that the starting air distributing pipe is not heated at any cylinder (leakage from the starting valve).

4 **Vent fuel and lubricating oil filters.**

03.5 Start after overhaul

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

2 **The speed governor control lever** being in maximum position and the stop lever in work position, release the overspeed trip manually. Check that all injection pump racks move to a value less than 4 mm.

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

4 **Check the cooling water system** for leakage, especially:

the lower part of the cylinder liners,

the oil cooler,

the charge air cooler.

5 **Check/adjust the valve clearances.** Guidance values, see chapter [06].

6 **Vent the fuel oil system** if it was opened.

7 **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.

8 **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.

9 **See the instructions** in section [03.1] and [03.4] when starting.

03.6 Operation supervision after overhaul

1 **At the first start,** listen carefully for possible jarring sounds. If anything suspected, stop the engine immediately, otherwise stop the engine after 5 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, fuel, heating oil or lubricating oil. Especially observe the fuel lines, injection pumps and injection valves. Watch the quantities emerging from the leak oil pipes!

3 **Check that the starting air distributing pipe is not heated** at any cylinder (leaky starting valve). May cause **explosion!**

4 **After overhauling,** the following instructions are especially important:

check pressure and temperature gauges,

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 of the engine circulating water system,

check the quantity of leak fuel,

check the gossip holes of the coolers,

check the content of additives in the circulating water,

check the cylinder pressures,

listen for jarring sounds,

check the crankcase pressure,

check the starting air pipes,

vent the filters.

03.7 Running-in

The running-in of a new engine must be performed according to programme B in [Fig 03-2]. It is also recommended that running-in procedure is performed after following maintenance jobs.

1 **After piston overhaul,** follow programme A in [Fig 03-2], as closely as possible. The piston rings have slided into new positions and need time to refit. If the program cannot be followed, **do not load the engine fully for 4 h, at least.**

2 **After changing piston rings,** pistons or cylinder liners, after honing of cylinder liners, follow programme B in [Fig 03-2], as closely as possible.

If the program cannot be followed, **do not load the engine fully for 10 h, at least.**

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.
The running-in may be performed either on distillate or heavy fuel, using the normal lubricating oil specified for the engine.

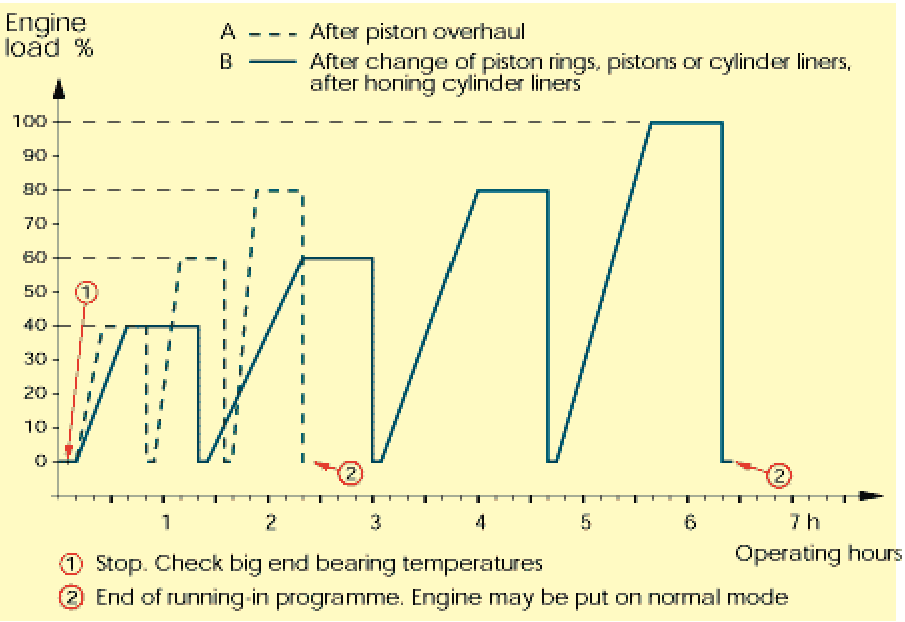

figure: 03-2 Running-in programme

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. When using diesel oil or intermediate fuels of comparatively good quality as fuel oil it may be possible to lengthen the stated maintenance intervals considerably depending on the engine load. See also the instruction books of the turbocharger and the governor, separate instructions for additional equipment and chapter [03].

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

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

3 **Before dismantling,** check that all systems concerned are **drained or pressure is released**. After dismantling immediately cover holes for lubricating oil, fuel oil and air with tape, plugs, clean clothes or similar.

4 **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.

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

6 **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.

04.1.1 How to select application and fuel quality

There are two different types of applications defined:

Average load is above 75 % of nominal engine output.

Average load is below 75 % of nominal engine output.

Four types of fuel are defined:

HFO 1 Heavy fuel oil of normal quality.

HFO 2 Heavy fuel oil of below normal standard quality.

DO Diesel oil or light fuel oil (LFO).

Fuel characteristics, maximum limits			
		HFO 1	HFO 2
Sulphur	mass-%	2.0	2.0 - 5.0
Ash	mass-%	0.05	0.05 - 0.20
Vanadium	mg/kg	100	100 - 600
Sodium	mg/kg	20	20 - 50
Al + Si	mg/kg	30	30 - 80
CCAI		850	850 - 870

Note!

If any of specified fuel properties exceed HFO 1 maximum value the fuel should be classified as HFO 2.

04.2	Every second day, irrespective of the engine being in operation or not	
Automatic prelubrication	**Check operation**	[03.2.2] [18.10]
Crankshaft	**Marine engine:** In a stopped engine, turn the crankshaft into a new position.	

04.3	Once a week, irrespective of the engine being in operation or not	
Start process	**Test start (if the engine on stand-by).**	[03.1]

04.4	Interval: 50 operating hours	
Air cooler(s)	**Check draining of air cooler(s)**	[15.2.1]
	Check that the draining pipe is open, check if any leakage.	[03.3.1]
Cooling system	**Check water level in cooling system**	[19]
	Check the water level in the expansion tank(s) and/or the static pressure in the engine cooling circuits.	
Connecting rod	**Check tightening of the connecting rod screws**	[11.2.4]
	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.**	[07.3]
Fuel and lubricating oil filters	**Check pressure drop indicators**	[17.4]
	Change filter cartridges if high pressure drop is indicated.	[03.3.1] [23.1.3]
Gauges and indicators	**Take readings**	[03.3.1]
	Read and record (using eg. form No. WV98V009) all temperature and pressure gauges, and at the same time the load of the engine.	
Governor, actuator	**Check oil level in governor**	[02.2.4]
	Check oil level, and look for leaks, use governor manual.	[22.4]
Injection and fuel system	**Check leak fuel quantity**	[03.3.1]
	Check the amount of leak fuel from the injection pumps and nozzles.	
Lubricating oil sump	**Check oil level in sump**	[18.2]
	Check oil level by means of dip stick, compensate for consumption.	[02.2].
Main bearings	**Check tightening of main bearing screws**	[10.2]
	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.**	[07.3]
Turbocharger	**Water cleaning of compressor**	[15.1.5]
	Clean the compressor by injecting water.	[03.3.1]
Turbocharger	**Check turbocharger oil level**	[15]
(ABB VTR)	Check oil level, and look for leaks. Change oil after the first 100 service hours in both oil spaces, use TC:s manual.	[02.2.5]
Valve mechanism	**Check valve clearances**	[12.2.4]
	Check the valve clearances after 50 hours' running in new and overhauled engines.	[06.1]

04.5	Interval: 250 operating hours	
Centrifugal filter	**Clean centrifugal filter(s)**	[18.9]
	Clean more often if necessary. Remember to open the valve before the filter after cleaning.	[03.3.2]
Control mechanism	**Maintenance of control mechanism**	[22.2]
	Check for free movement, clean and lubricate.	

Fuel	Overhaul interval
HFO 2	250
HFO 1	250
DO	-

04.6	Interval: See table above	
Turbocharger	**Water cleaning of turbine**	[18.9]
	Clean the turbine by injecting water; more often if necessary.	[03.3.2]

04.7	Interval: 500 operating hours	
Circulating water	**Check water quality**	
	Check content of additives.	[02.3.3]
Cylinder pressure	**Check cylinder pressure**	[03.3.3]
	Record firing pressures of all cylinders.	
Lubricating oil	**Take oil sample**	
	In a new installation or after change to use of a new lubricating oil brand, take samples for analysing.	[02.2]

04.8	Interval: 1000 operating hours	
Air filter (on-built)	**Clean turbocharger air filter**	[15.2]
	Remove the filter(s) and clean according to instructions of the manufacturer (more often, if necessary).	
Automation	**Functional check of automation**	[23.1.4]
	Check function of the alarm and automatic stop devices.	[01.3][01.4]
Electrical fuel feed pump	**Lubricate electrical fuel feed pump**	[17.5]
	Regrease the pump under running condition.	[17.4] [18.10]
El. prelubricating pump	**Regrease prelubricating pump**	[18.10]
	Regrease the pump under running condition	

Fuel filter	**Replace fuel oil filter cartridges**	[17.6]
	Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced when the pressure difference indicator shows too high pressure drop). *)	[17.1][17.2][03.3.4]
Lubricating oil	**Change lubricating oil**	[18.2]
	Change oil in a new installation (wet sump installations). Take samples for analysing. If the analysing values are positive and if the oil supplier or engine manufacturer so recommend, the intervals between changes can be prolonged in steps of 500 operating hours. In dry sump installations the oil change intervals may be in the order of 800 hours or more. Clean all oil spaces when changing lub. oil.	[02.2][03.3.4]
Lubricating oil filter	**Replace lubricating oil filter cartridges**	[18.8.2]
	Drain the filter housings. Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced when the pressure difference indicator shows too high pressure drop.)*)	[03.3.4]
Valves	**Check of valve condition**	[12.3]
	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. Check cylinder tightness (valves, piston rings) with a pneumatic test.	[06.1]
Turbocharger	**Change lubricating oil in turbocharger(s)**	[15.1]
(ABB VTR)	Change lubricating oil in the turbocharger. Take care that the turbine oil is not mixed with the engine lubricating oil.	[02.2.5]

NOTE!

It is important to vent the air from the filter housing after the change of the filter.

04.9	**Interval: Interval: 2000 operating hours**	
Charge air cooler(s)	**Check water side of charge air cooler(s)**	[15.2]
	The first time check and possible cleaning of the **waterside.** If in good condition and deposits insignificant: future intervals 4000 running hours.	
Injection valves	**Inspect injection valves**	[16.5]
	Test the opening pressure. Dismantle and clean nozzles. Check the effective needle lift. Check the springs. Replace the O-rings. Check the nozzle condition in a test pump. **Recommendation:** Replace the complete injection valves by new or reconditioned ones.	[06.1]
Measuring instruments	**Checking of gauges**	
	Check pressure and temperature gauges. Replace faulty ones.	[23.1]
Governor	**Change oil in governor**	
	Change lubricating oil, use governor manual.	[02.2.4] [22.4]
Overspeed trip device	**Check function of overspeed trip**	[22.5]
	Check function and tripping speed.	[22.6]

04.10	**Interval: 4000 operating hours**	
Air cooler(s)	**Clean the charge air cooler(s)**	[15.2]
	Clean and pressure test. Look carefully for corrosion. Every second time the ultra sonic wash is recommended.	
Camshaft	**Inspect contact faces of camshaft**	[14.2]
	Check the contact faces of the cams and tappet rollers. Check that the rollers rotate. Rotate the engine with the turning gear.	[11.1.1]

Control mechanism	Check control mechanism	[22.2]
	Check for wear in all connecting links between the governor and all injection pumps.	
Crankshaft	**Check crankshaft alignment.**	[11.1.2]
	Check alignment, use form No. WV98V036. Alignment check is performed on a warm engine.	
Crankshaft	**Check thrust bearing clearance**	[11.1.3]
	Check axial clearance.	
Cylinder liners	**Inspect jacket water spaces**	
	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.	[02.3] [10.4] [19.2.2]
Exhaust manifold	**Check the nuts of the flange connections**	[20.1]
	Tighten loose nuts. Check the nuts of the vertical studs inside the insulating box.	
Lubricating oil coolers	**Clean the lubricating oil cooler**	[18.5]
	Look carefully for corrosion.	[18.6]
Starting fuel limiter	**Check starting fuel limiter**	[22.3.5]
	Check the adjustment and function.	[22.7]
Turbocharger	**Inspect and clean**	[15.1]
	Clean the compressor and turbine mechanically if necessary. Inspect turbocharger cooling water ducts for possible deposits and clean if the deposits are thicker than 1 mm.	

04.11	**Interval: 8000 operating hours**	
Balancing shaft gear	**Inspect balancing shaft gear and bearing bushes**	[11.3]
4R22, 4R22/26	Replace parts if necessary.	[11.4]
Camshaft driving gear	**Inspect camshaft driving gear**	[13]
	Replace parts if necessary.	
Governor driving gear	**Inspect governor driving gear**	[22.4]
	Replace parts if necessary.	
HT-water pump	**Inspect HT-water pump**	[19.3]
	Dismantle and check. Replace worn parts.	
HT-water pump driving gear	**Inspect HT-water pump driving gear**	[19.3]
	Replace parts if necessary.	
HT-water thermostatic valve	**Clean and inspect HT-water thermostatic valve**	[19.4.4]
	Clean and check the thermostatic element, valve cone-casing and sealings.	
LT-water pump	**Inspect LT-water pump**	[19.3]
	Dismantle and check. Replace worn parts.	
LT-water pump driving gear	**Inspect LT-water pump driving gear**	[19.3]
	Replace parts if necessary.	
LT-water thermostatic valve	**Clean and inspect LT-water thermostatic valve**	[19.4.2]
	Clean and check the thermostatic element, valve cone-casing, indicator pin and sealings.	
Lubricating oil pump	**Inspect the lubricating oil pump**	[18.3]
	Replace parts if necessary.	
Oil pump driving gear	**Inspect oil pump driving gear**	[18.3]

	Replace parts if necessary.	
Oil thermostatic valve	**Clean and inspect oil thermostatic valve**	[18.7]
	Clean and check the thermostatic element, valve cone-casing and sealings.	
Turbocharger	**Replace turbocharger bearings**	[15.1]
(ABB VTR)	See manufacturers instructions.	

Fuel	**Overhaul interval**	
	Average load > 75 %	**Average load < 75 %**
HFO 2	8 000	10 000
HFO 1	12 000	14 000
DO	16 000	20 000

04.12	**Interval: See table above**	
Connecting rods	**Inspect big end bearing**	[11.2]
	Replace big end bearing if necessary. Inspect mating surface serrations. Measure the big end bore, use form No. 2211V003.	[06.2]
Connecting rods	**Replace connecting rod screws**	[10.7]
	Replace connecting rod screws by new ones on 24 000 h at the latest. Inspect the small end bearings on 16 000 h at the latest. Replace if necessary.	[06.2]
Cylinder heads	**Overhaul of cylinder head**	[12]
	Dismantle and clean the underside, inlet and exhaust valves and ports. Inspect cooling spaces and clean, if necessary. Grind the valves (often lapping by hand is enough). Inspect the valve rotators. Replace the O-rings in the valve guides.	[06.2]
Cylinder liners	**Inspect the cylinder liners**	[10.4]
	Measure the bore using form No. 2210V013, replace liner if wear limits are exceeded. **Hone the liners.** Inspect anti-polishing ring if assembled. Replace if necessary.	[06.2]
Cylinder liners	**Inspect cylinder liner water side**	[19.2.2]
	Pull one cylinder liner, on V-engines one per cylinder bank. 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.	[10.4][02.3]
Main bearings	**Inspect the bearing shells**	[10.2]
	Replace parts if necessary.	[06.2]
Piston, piston rings	**Inspect pistons and piston rings**	[11.2]
	Pull, inspect and clean. Check the height of the ring grooves (the height clearance of the rings), use form No. 2210V001. Check the retainer rings of the gudgeon pins. Replace complete set of piston rings. Note the running-in program.	
Starting valves	**Check starting valves.**	
In cylinder head	Check starting valves in cylinder head. Replace parts if necessary.	[21.4]

04.13	**Interval: 16000 operating hours**	

Centrifugal filter for lubricating oil	**Basic service**	09
Fuel feed pump	**Inspect fuel feed pump.**	[17.5]
	General overhaul and replace gaskets.	[06.2]
Governor drive	**Check the governor drive bearing**	[22.4]
	Check governor driving shaft bearing clearance in situ.	[06.2]
Turning device	**Change oil**	[03.1]
	Regrease the drive shaft.	
Viscous vibration damper	**Take oil sample from vibration damper**	[11.1]
	Take oil sample for analysing.	[02.2]
Vibration damper	**Check vibration damper**	[11.1]
Geislinger	Dismantle and check the vibration damper.	

Fuel	**Overhaul interval**	
	Average load > 75 %	**Average load < 75 %**
-	16 000	20 000

04.14	**Interval: See table above**	
Camshaft	**Inspect camshaft bearings**	[14.3]
	Replace if necessary.	[06.2]
Camshaft driving gear bearings	**Inspect camshaft driving gear bearings**	[13]
	Replace parts in necessary	
Crankshaft	**Check the big end and main bearing clearance**	[10.2]
	Check condition. Note the type of bearing in use and do the inspection accordingly.	[11.2][06.2]
Valve mechanism	**Check valve mechanism bearings**	[12.2.4]
	Check tappets and rocker arms.	[06.2]

Fuel	**Overhaul interval**
HFO 2	16 000
HFO 1	16 000
DO	20 000

04.15	**Interval: See table above**	
Injection pumps	**Overhaul of injection pumps**	[16.3]

	Clean and inspect injection pumps, replace worn parts. Replace the erosion plugs if necessary.	[06.2]
04.16	**Interval: 24000 operating hours**	
Balancing shaft	**Inspect balancing shaft bearing**	[11.3]
4R22, 4R22/26	Take one bush out for inspection. If in bad condition check the other too. Replace if necessary.	
Coupling	**Check the flexible coupling**	
Flexible coupling	Dismantle and check flexible coupling acc. to makers recommendations.	
Engine fastening screws	**Check tightening of engine fastening screws**	
	Replace if necessary.	
Governor	**Check function and adjustments of governor**	[06.2]
	Replace worn parts. **Recommendation:** The overhaul should be carried out by the authorised service personnel.	
Engine foundation	**Check flexible elements of engine foundation**	
Flexible mounted, main engine	Replace if necessary.	
04.17	**Interval: 48000 operating hours**	
Balancing shaft gear	**Inspect balancing shaft gear bearing bushes**	[11.3]
4R22, 4R22/26	Replace if necessary.	
Balancing shaft	**Inspect balancing shaft bearing bushes**	[11.3]
4R22, 4R22/26	Replace if necessary.	
Crankshaft	**Inspect crankshaft**	[11.1]
	Inspect the crankshaft for wear.	[06.2]
Turbocharger	**Replace rotor**	[15.1]
	See manufacturers instructions.	
04.18	**Interval: 64000 operating hours**	
Engine	**General overhaul**	

05 Maintenance Tools version : 05-200222-00

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 22 engine.

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 nessercary spare parts and consumable parts are available.

05.1.2 Ordering of Maintenance tools

1 **Find the part(s)** that intrests 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 list. You can use the code numbers in the following pages 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

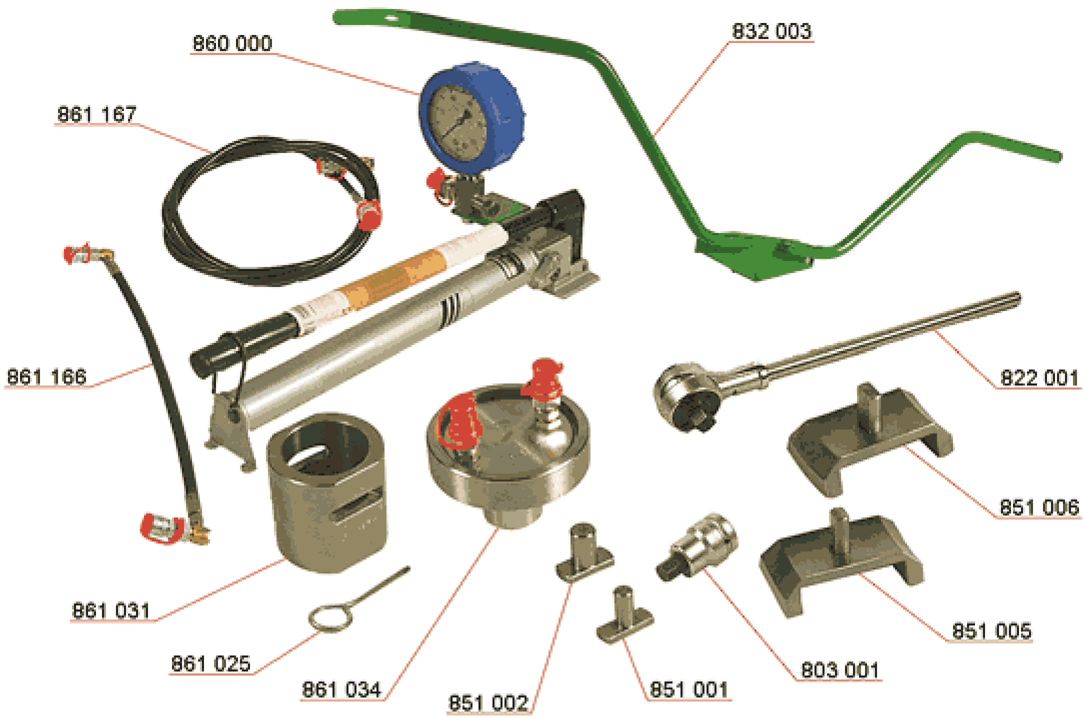

figure:

Code	Description	Drawing No.
803001	Bit, hexagon socket screw 22 with 1" square drive	4V80L0001
822001	Torque multipler X - 4	4V82L0001
832003	Lifting tool for main bearing shell	1V83C0119
851001	Turning tool for main bearing shell	4V85B0007
851002	Turning tool for main bearing shell	4V85B0012
851005	Turning tool for thrust washer & bearing sheal	3V85B0008
851006	Turning tool for thrust washer & bearing sheal	3V85B0017
860000	High presseure pump	4V86A0038
861025	Pin for tightening of nuts	4V86B0011
861031	Distance sleeve	3V86B0067
861034	Hydraulic cylinder	3V86B0082
861166	Flexiblie hose 600, including quick couplings	
861167	Flexiblie hose 3000, including quick coupling	
832003	Lifting tool for bearing cap	1V83C0120

Cylinder Liner 100

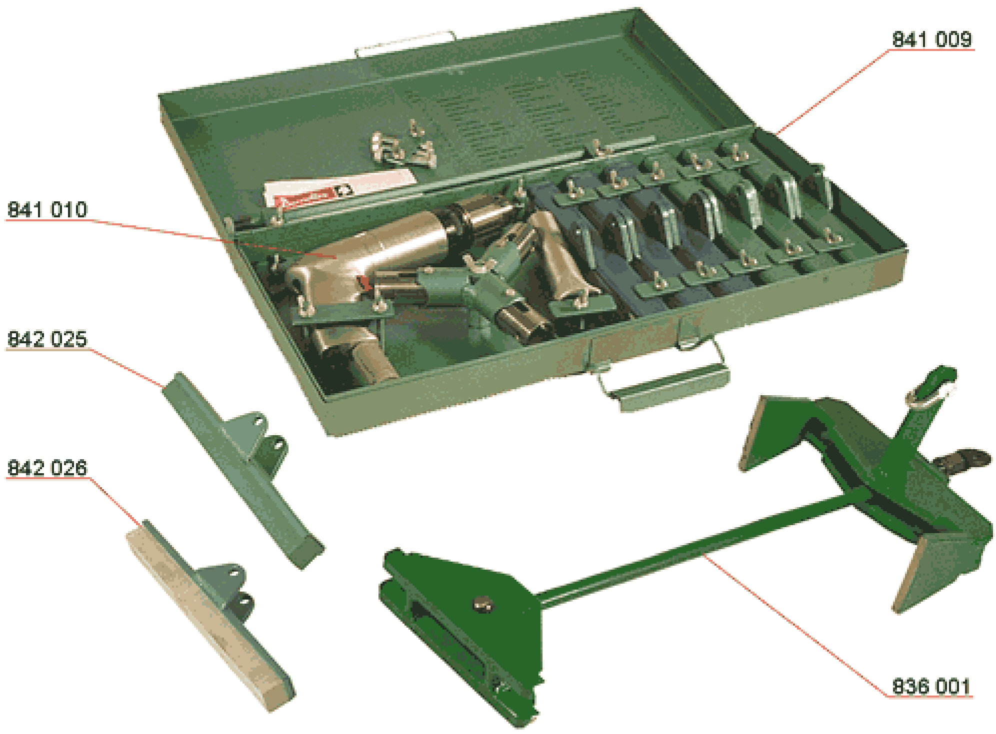

figure:

Code	Description	Drawing No.
[836001]	Extracting & lifting tool for cylinder liner	
841009	Honing tool for cylinder liner	1V-T22088
841010	Drilling machine for honing tool	4V84B0136
842025	Honing stones 25x25x250, coarse, including holder	
842026	Honing stones 25x25x250, fine, including holder	

Connecting Rod, V-Engine 111

figure:

Code	Description	Drawing No.
803011	Stud remover M30x2	4V80G0018
807011	Long Socket wrench 27x12,5L	DIN3124
835003	Protecting sleeve for connecting rod, upper	2V83F0071
835004	Protecting sleeve for connecting rod, lower	3V83F0068
860000	High pressure pump (1000 bar)	4V86A0038
861025	Pin for tightening of nuts	4V86B0011
861026	Distance sleeve	4V86B0141
861027	Hydraulic cylinder	3V86B0062
861166	Flexible hse 600 mm, including quick couplings	
861167	Flexible hose 300 mm, including quick coupling	

Connecting Rod, L-Engine 111

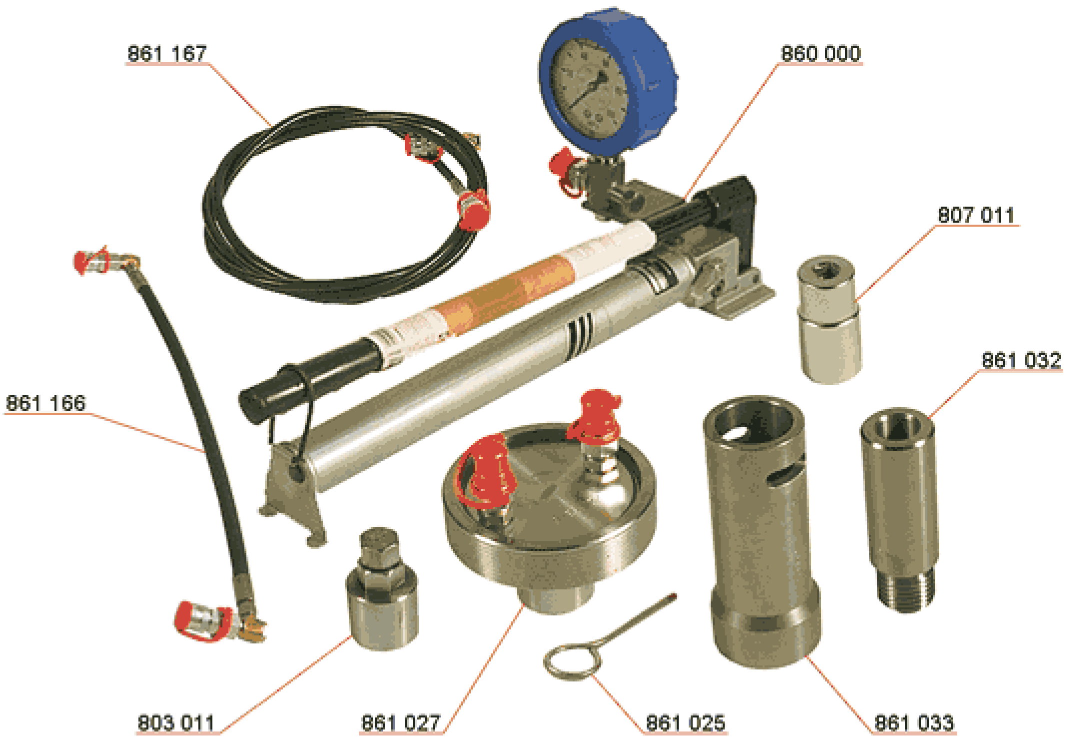

figure:

Code	Description	Drawing No.
803011	Stud remover M30x2	4V80D0018
807011	Long socket wrench 27x12.5L	DIN3124
860000	High pressure pump (1000 bar)	4V86A0038
861025	Pin for tightening of nuts	4V86B0011
861027	Hydraulic cylinder	3V86B0060
861032	Distance piece	3V86B0071
861033	Distance sleeve	3V86B0142
861166	Fexible hose 600 mm, including quick couplings	
861167	Flexible hose 300 mm, including quick coupling	

Piston 113

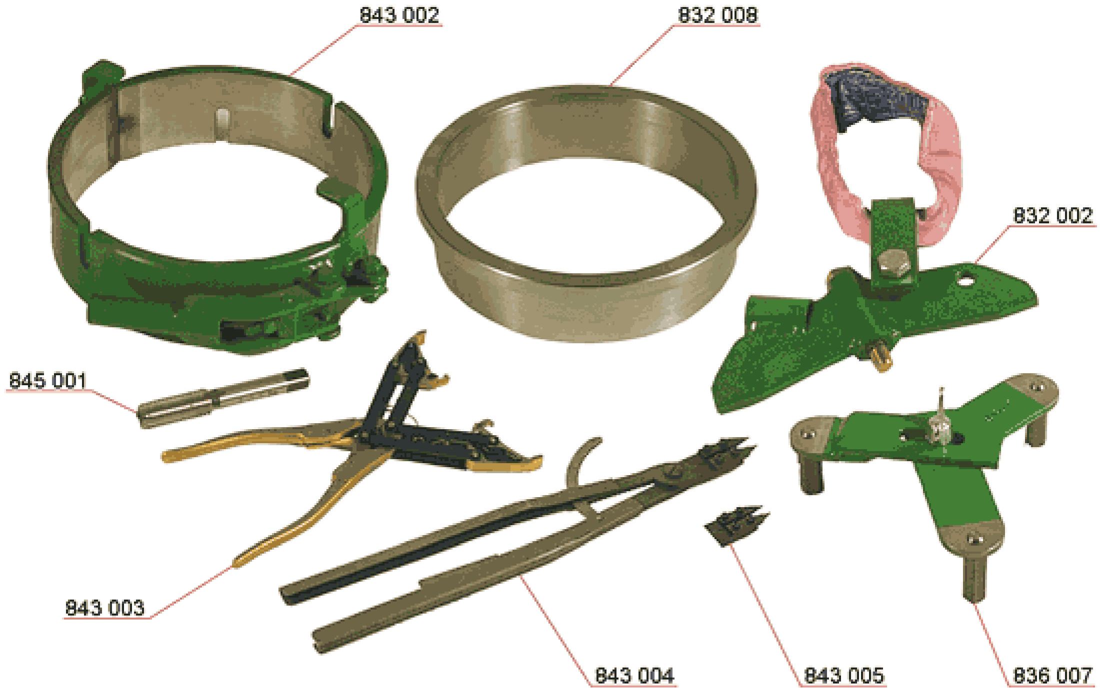

figure:

Code	Description	Drawing No.
[832002]	Lifting tool	3V83C0064
832008	Mouting tool when using antipolishing ring	3V74L0037
836007	Dismantling tool for antipolishing ring	3V10T1366
843002	Clamp tool for piston rings	2V84D0010
[843003]	Piston ring pliers	4V84L0018
[843004]	Pliers for retaining rings	4V84L0016
843005	Spare tips for pliers 843004, straight	
845001	Tap M12	DIN 352

Cylinder Head 120

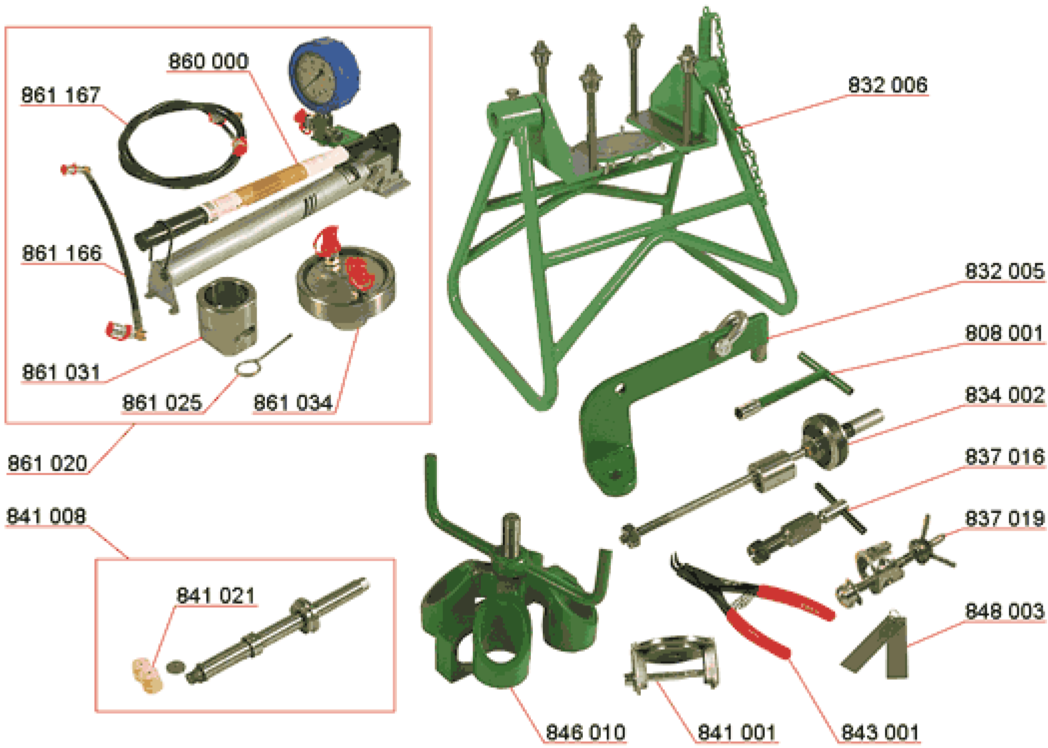

figure:

Code	Description	Drawing No.
[808001]	T-wrench for indicator valve	4V80K0006
832005	Lifting tool for cylinder head	3V83C0082
832006	Service trestle for cylinder head	1V-T20524
[834002]	Fitting tool for exhaust valve seat ring	
837016	Extractor for push rod protection pipe	3V83H0097
[837019]	Extractor for inlet valve seat ring	2V38L0008
841001	Lapping tool for valves	
[841008]	Cleaning tool for injection sleeve bottom	
841021	Felt for cleaning tool	4V84B0071
[843001]	Cirlip pliers	DIN 5254
846010	Dismantling tool for valve springs	2V84G0207
848003	Valve clearence feeler gauge	3V84K0052
860000	High presseure pump (1000 bar)	4V86A0038
861020	Hydraulic tightening tool, complete	
861025	Pin for tightening of nuts	4V86B0011
861031	Distance sleeve	3V86B0067
861034	Hydraulic cylinder	3V86B0082
861166	Flexible hose 600 mm, including quick couplings	
861167	Flexible hose 3000 mm, including quick couplings	
837050	Extractor	

Injection Equipment 160

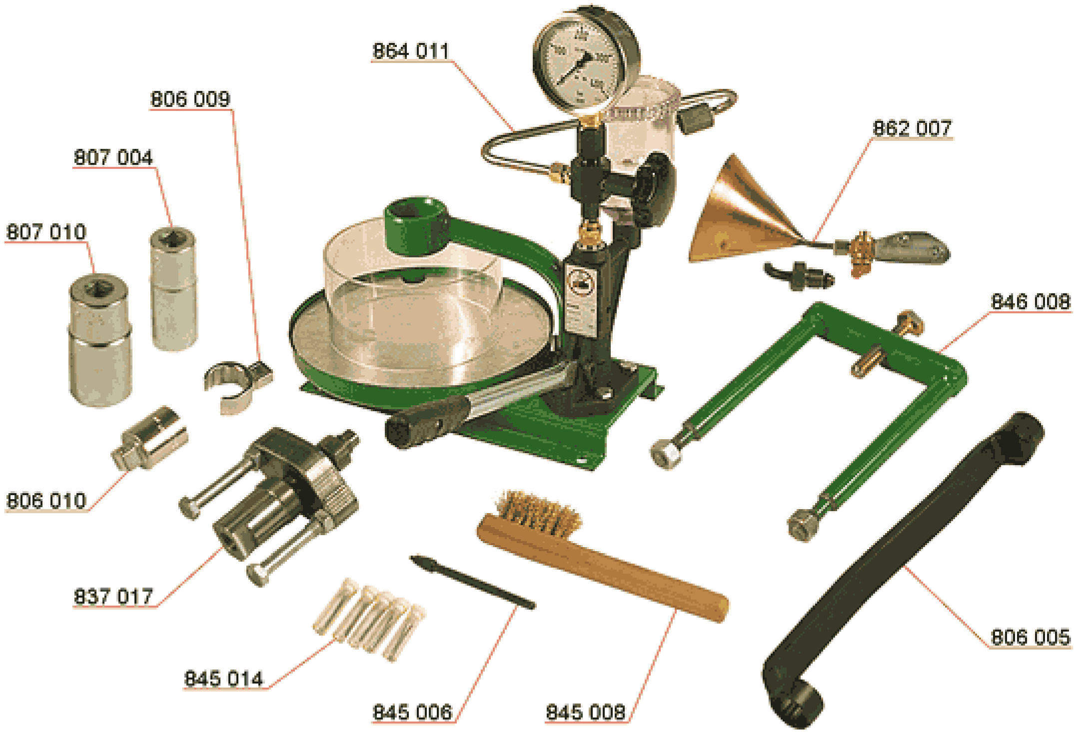

figure:

Code	Description	Drawing
[806005]	Special socket wrench 19 for flange nuts	3V80G0022
[806009]	Crowfoot wrench 27 for injection pipes	4V80L0002
806010	Adapter A10x12.5	DIN 3123
807004	Long socket wrench 22x12.5L for connecting pie	DIN 3124
807010	Long socket wrench 30x12.5L for nozzle nut	DIN 3124
837017	Extractor for injection valve (L'Orange)	3V83H0098
[845006]	Shaft for nozzle needles	4V84L0015
845008	Brass wire brush	4V84L0014
845014	Nozzle needles 0.36, 50 pack	4V84L0013
846008	Mounting tool for injection pump tappet	
[862007]	Checking tool for fule injection timing	
[864011]	Testing tool for injection valve	

Turbocharger 372

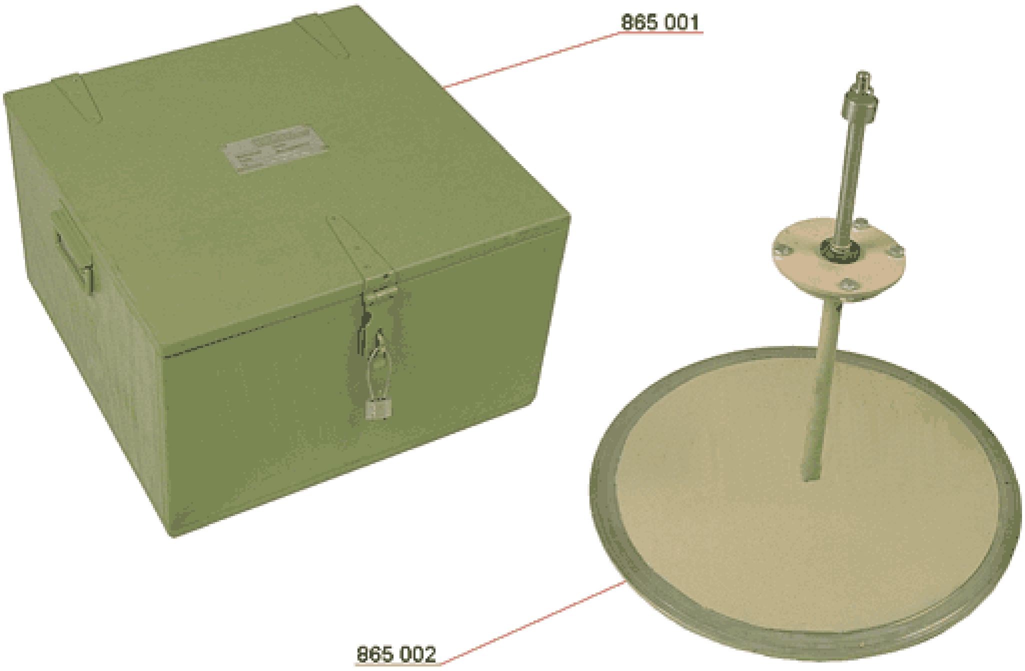

figure:

Code	Description	Drawing
865001	Maintance tools VASA 22*	
865002	Blanking tool for turbocharger*	

Tightening Tools 900

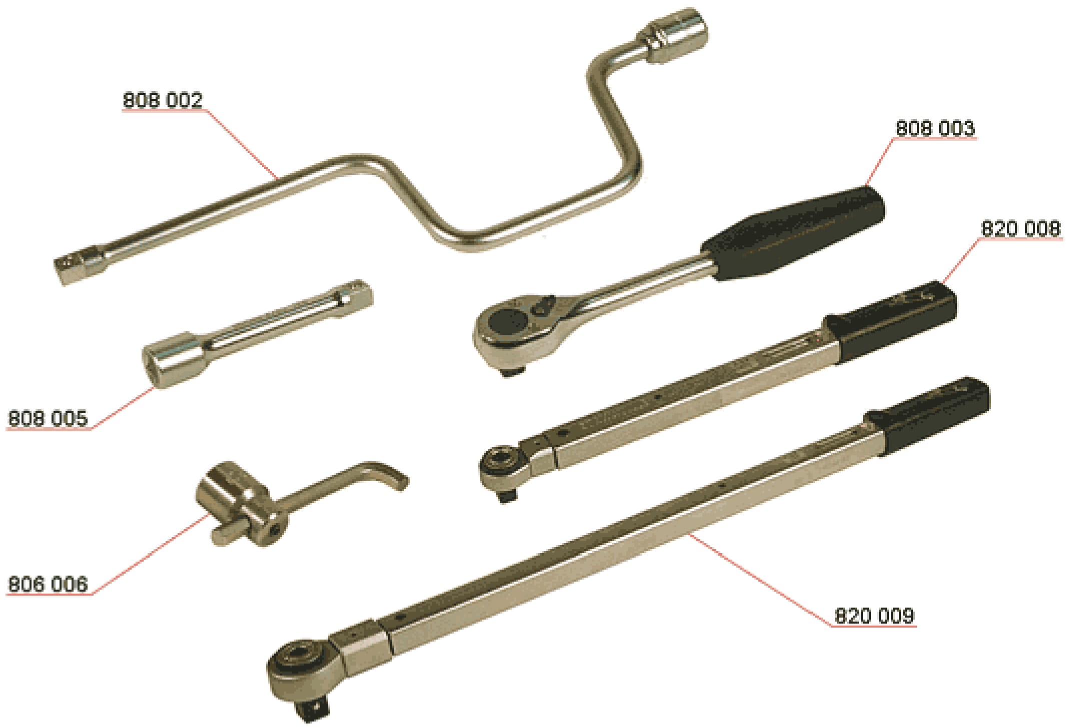

figure:

Code	Description	Drawing
806006	Special key for hexagon socket screw 8	4V80G0021
808002	Speed brace B12.5x500 with 1/2" square drive	DIN3122
808003	Ratcheat handle 12.5x300 with 1/2" square drive	DIN3122
808005	Extension bar B12.5x125 with 1/2" square drive	DIN3123
820008	Torgue wrench 20-100 Nm	4V92K0207
820009	Torgue wrench 75-400 Nm	4V92K0207
806007	Special key hexagon socket screw 14	4V80G0027
820002	Extension for torque wrench	3V82A0021

Miscellaneous Tools 900

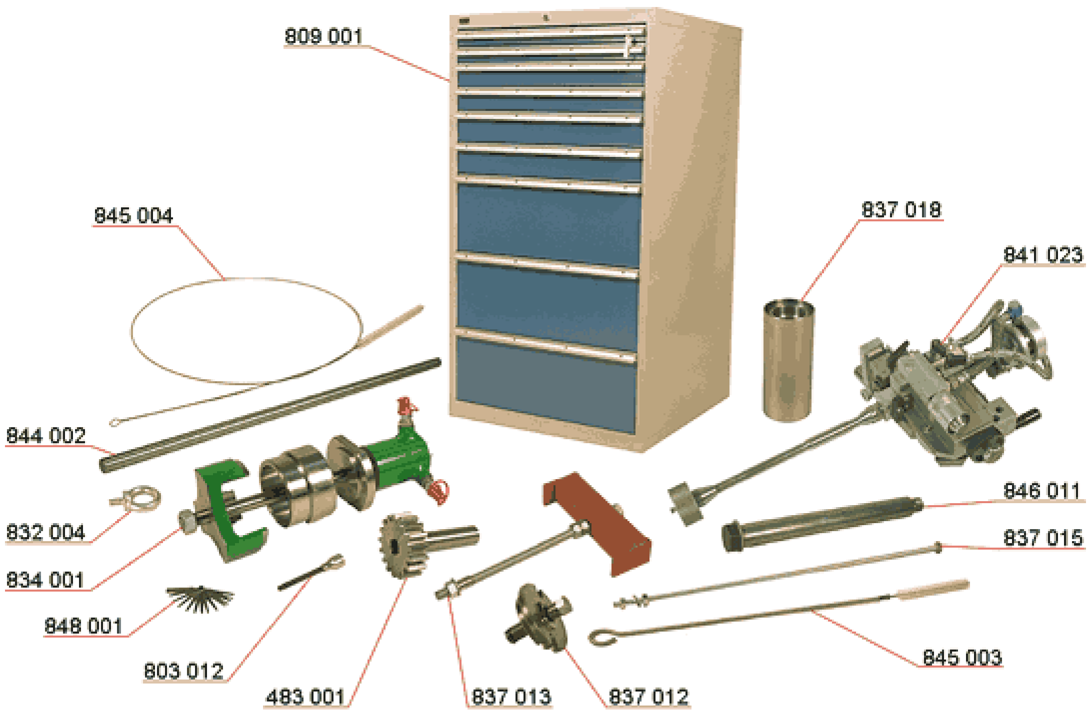

figure:

Code	Descriptions	Drawing No.
483001	Turning tool	3V48D0038
803012	Wrench combinatin for dismantling elctric motor	4V80D0016
809001	Tool locker	4V80L0003
832004	Eye bolt for charge air cooler insert	DIN 580
834001	Mounting & removing tool for camchaft bearing buch	3V83L0039
837012	Extractor for gear wheels	
837013	Dismantling tool for centrifugale filter rotor	4V83L0001
837015	Mounting tool for overspeed trip tool	4V83H0073
837018	Mounting tool for water pump sealing	4V84G0177
841023	Valve seat grinder	4V84B0130
844002	Barring lever	4V84E0001

845003	Brushes for cleaning of charge air cooler (3 pack)	4V84F0007
845004	Brushes for cleaning oil & circulation water coolers	4V84F0006
848001	Feeler gauge set	DIN 2275
837037	Extractor for protection cup	4V83H0111
846011	Mounting screw for plate heat exchanger	4V84G0228
848002	MEasure gauge for crankshaft deflection	4V84L0012

Additional Tools for Engines with Shield Bearing

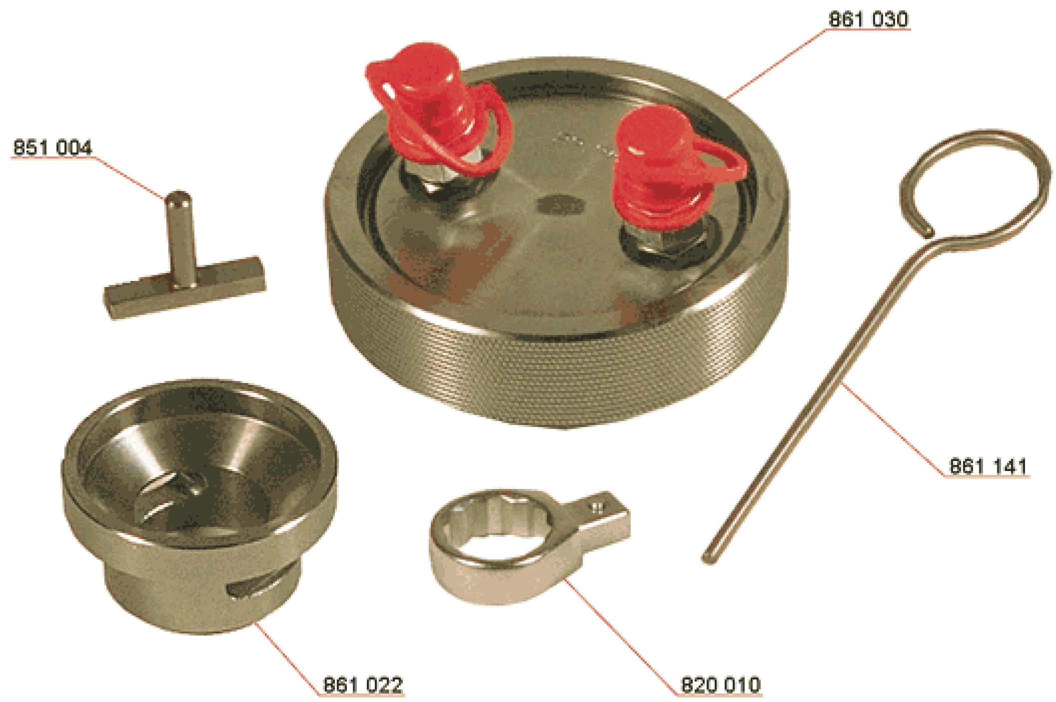

figure:

Code	Description	DrawingNo.
820010	Change key for torque wrench 24 mm	4V92K0208
851004	Turning tool for shield bearing shell	4V85B0010
861022	Distance sleeve fo shield bearing	4v86B0065
[861030]	Hydraulic cylinder for shield bearing	
861141	Pin for tightening of nuts	4V86B0034

Additional Tool for 4R22 and 8V22

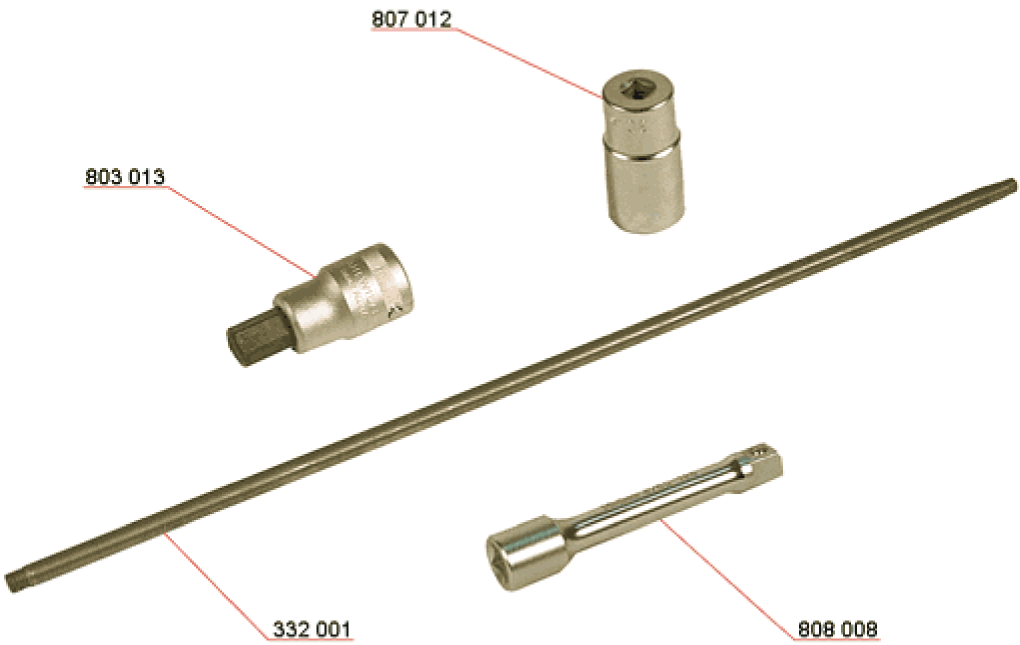

figure:

Code	Description	DrawingNo.
332001	Guiding pin	4V33C0028
803013	Bit, hexagon socket screw 14 with 3/4" square drive	4V80L0001
807912	Socket wrench for balancing shafts 30X20	DIN 3124
808008	Extension lever for balancing shaft 3/4"	4V80K0012

High Pressure Pump 900

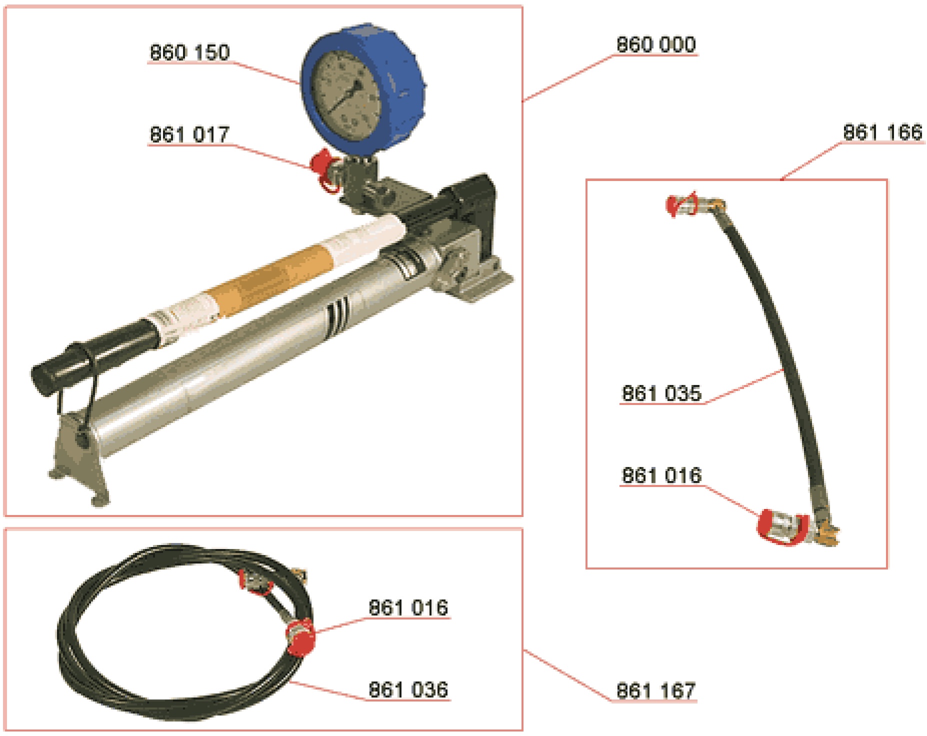

figure:

Code	Description	DrawingNo.
860000	High pressure pump (1000 bar)	4V86A0038
860150	Manometer	4V51L0085
861016	Quick coupling, female	4V86A0035
861017	Quick coupling, male	4V86A0040
861035	Flexible hose 600 mm	4V86A0013
861036	Flexible hose 3000 mm	4V86A0030
861166	Fexible hose 600 mm, including quick couplings	
861167	Flexible hose 3000 mm, including quick coupling	
834051	Quick coupling, male	4V86A0034

06.1 Adjustments
Valve timing:
The valve timing is fixed and cannot be changed individually, cylinder by cylinder.

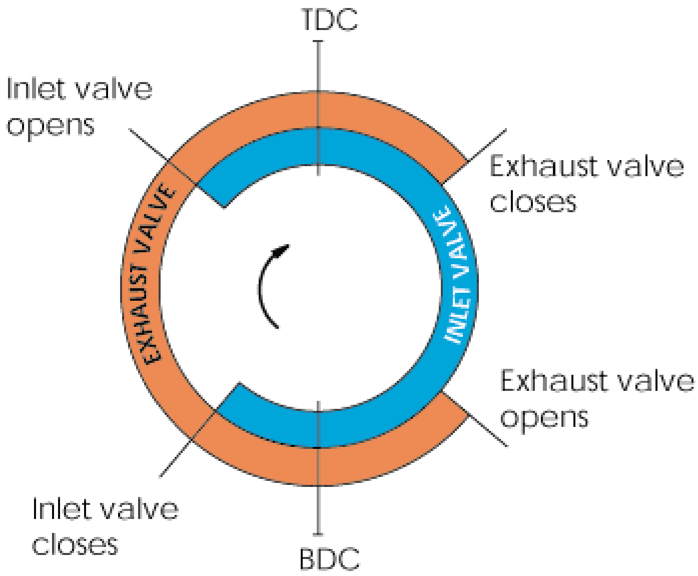

figure: 06-1 Valve timing

Valve clearances, cold engine:

```
Inlet valves.........................................................................0.4 mm
Exhaust valves.......................................................................0.8 mm
Start of fuel delivery................................................acc. to techn. spec.
Fuel rack position, heavy fuel............................................see test records
Opening pressure of fuel injection valve.........................................320 bar
```

Tripping speed of electro-pneumatic and

mechanical overspeed trip devices:

Nominal engine speed	Electro-pneumatic tripping speed	Mechanical tripping speed
900 RPM	1015 RPM	1035 RPM
1000 RPM	1130 RPM	1150 RPM
1200 RPM	1350 RPM	1380 RPM

Tripping speed tolerance ±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.		
10	Main bearing clearance (also flywheel bearing)			0.180-0.268	
	Journal diameter	200.000	199.975		

	Journal circularity	0.015			
	Journal taper (конусность)	0.015/100			
	Main bearing shell thickness (толщина вкладыша)	7.430	7.415		7.38 (Bi-metal)
	Bore of main bearing housing (отверстие для рамового)	215.029	215.000		
	Assembled bearing bore	200.239	200.180		
	Main thrust bearing, axial clearance			0.180-0.295	0.5
	Main thrust bearing width (ширина)	99.820	99.640		
	Corresponding crankshaft width	100.035	100.000		
	Camshaft bearing clearance (also thrust)			0.102-0.179	
	Camshaft diameter	120.000	119.978		
	Camshaft bearing shell, thickness	4.950	4.935		4.90
	Camshaft bearing housing, bore	130.025	130.000		
	Camshaft bearing diameter	120.102	120.157		
	Camshaft diameter at thrust bearing	75.000	74.981		
	Camshaft thrust bearing housing, bore	90.000	90.022		
	Camshaft thrust bearing diameter, in situ	75.056	75.108		
	Camshaft thrust bearing, axial clearance			0.22-0.39	
	Camshaft thrust bearing, width	69.740	69.650		
	Cylinder liner, diameter	220.046	220.000	top: 220.45 bottom: 220.25	
	Cylinder liner cylindricity	0.02			0.20
11	Big end bearing clearance			0.144-0.228	
	Crank pin, diameter (мотылевая шейка)	180.000	179.975		179. 825

	Crank pin circularity	0.015			0.05
	Crank pin, taper	0.015/100			
	Big end bearing shell, thickness	4.940	4.925		4.90
	Connecting rod bore, lower	190.029	190.000		*)
	Big end bearing assembled diameter (с вкладышем)	180.203	180.144		
	Gudgeon pin bearing clearance			0.09-0.15	
	Gudgeon pin diameter (головной)	95.000	94.990		
	Gudgeon pin circularity	0.008			
	Gudgeon pin taper (конусность)	0.005			
	Connecting rod bore, upper	115.022	115.000		
	Gudgeon pin bearing diameter, in situ	95.142	95.090		95.18
	Connecting rod axial clearance in piston			0.30-0.65	
	Clearance gudgeon pin piston			0.040-0.065	
	Bore diameter in piston	95.055	95.040		
	Piston ring gap (clamped ø220) Compression rings Oil scraper rings			0.65-0.95 0.80-1.05	2.05
	Piston clearance at bottom in cross direction of engine			0.115-0.190	
	Corresponding piston diameter	219.885	219.855		
	Crankshaft oil slinger (driving end) Axial clearance: radial clearance around crankshaft flange:			0.39-1.03 0.62-0.93	
12	Valve guide diameter	16.095	16.075		16.200
	Valve stem diameter	16.000	15.982		15.97
	Valve stem clearance			0.075-0.113	0.20

	Valve seat deviation relative guide (max. value) – несоосность клапана и направляющей	0.10			
	Inlet valve seat bore in cylinder head	78.019	78.000		
13	Intermediate gear of camshaft drive bearing clearance axial clearance			0.03-0.106 0.15-0.35	0.20 0.50
	Bearing diameter in situ	60.046	60.00		
	Bearing journal diameter	59.97	59.94		
	Camshaft driving gear backlash:				
	Crankshaft gear - intermediate gear			0.10-0.45	
	Intermediate gear -camshaft gear			0.10-0.45	
	Base tangent length:				
	- crankshaft gear	99.781/7	99.725/7		99.60
	- large intermediate gear	146.022/10	145.964/10		14.00
	- small intermediate gear	99.853/7	99.798/7		
	- camshaft gear	130.704/9	130.648/9		
	*) Allowed minimum diameter= 189.920mm. Maximum allowed difference between max.D and min.D= 0.10 mm.				
14	Valve tappet, diameter	54.97	54.94		
	Guide diameter	55.03	55.00		
	Diameter clearance			0.03-0.09	0.15
	Tappet roller bore diameter	30.021	30.000		
	Bush diameter, outer	29.960	29.947		
	Bush diameter, bore	22.028	22.007		

	Tappet pin diameter	21.993	21.980		21.95
	Bearing clearance roller-bush bush-tappet pin			0.04-0.07 0.014-0.048	0.10 0.13
	Rocker arm bearing diameter in situ	50.064	50.025		
	Bearing journal diameter	50.000	49.984		49.95
	Bearing clearance			0.03-0.08	0.25
	Yoke pin diameter	19.935	19.922		
	Yoke bore diameter	20.021	20.000		
	Diameter clearance			0.065-0.100	0.15
16	Nozzle needle lift	0.4			0.5
	Injection pump tappet:				
	Tappet roller bore diameter	36.025	36.000		
	Bush diameter, outer	35.950	35.911		
	Bush diameter, bore	28.065	28.098		
	Tappet pin diameter	27.980	27.947		
	Bearing clearance roller-bush bush-tappet pin			0.050-0.114 0.085-0.153	0.15 0.20
17	Fuel feed pump, engine driven				
	Shaft diameter	20.009	19.996		
	Bush diameter, bore	20.070	20.050		
	Bearing clearance			0.04-0.08	0.15
	Axial clearance			0.04-0.12	
	Backlash for driving gear			0.30-0.50	
	Base tangent length for pump gear	53.702	53.658		53.50

	Crankshaft gear for pump operation				
18	Lubricating oil pump for 22				
	Shaft diameter	49.920	49.895		
	Bush diameter, bore	50.033	50.000		
	Bearing clearance			0.08-0.15	0.22
	Axial clearance			0.24-0.35	
	Backlash for driving gear			0.30-0.50	
19	Water pump backlash for driving gear			0.30-0.50	
22	Driving shaft for governor	20.000	19.979		
	Bearing for driving shaft	20.053	20.020		
	Bearing clearance			0.020-0.07	0.15
	Axial clearance			0.10-0.15	
	Backlash for driving gear			0.10-0.20	0.30
23A 4R	Backlash, balancing shaft gears				
	Crankshaft gear intermediate gear			0.1-0.6,	
	Intermediate gear balancing shaft gear			0.1-0.5,	
	Balancing shaft gear			0.1-0.35	
23B 8V	Backlash, balancing arrangement gears				
	Balancing shaft driving gear- water pump driving gear			0.175-0.55	
	Balancing shaft driving gear- intermediate gear			0.175-0.55	
	Shaft diameter	59.970	59.940		
	Bush diameter (assembled)	60.090	60.030		

	Bearing clearance			0.060-0.139	
	Axial clearance			0.15-0.045	

07.1 Tightening torques for screws and nuts

Note!

See section [07.3] for hydraulically tightened connections!

The position number in the tables below refers to 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 due to risk of overtensioning of screws.

1 Nm = 0.102 kpm

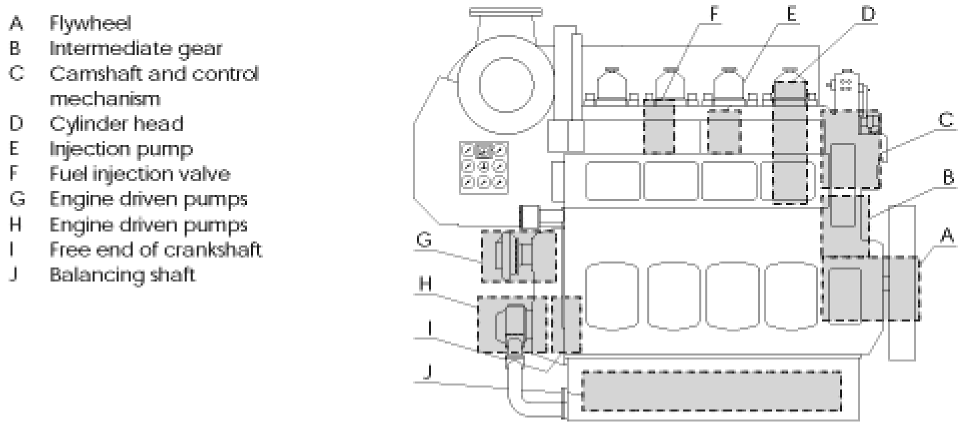

figure: 07-1 Tightening torques

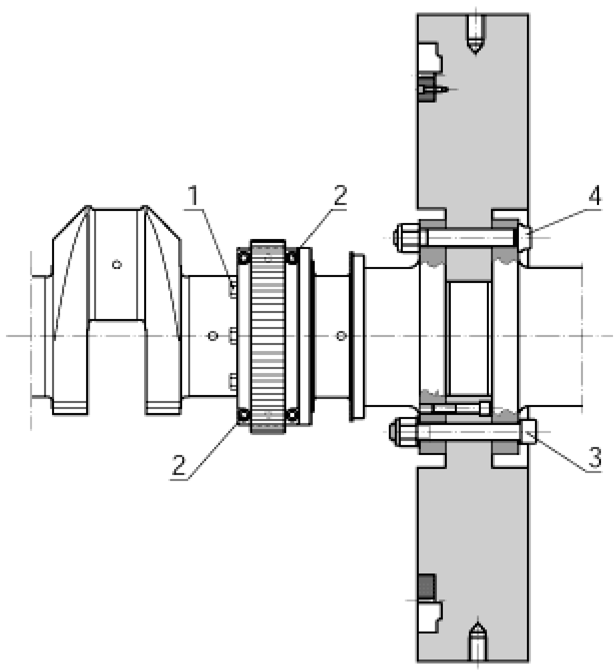

figure: 07-2 A: Flywheel

	Pos.	Screw connection VASA 22	Torque (Nm)	Screw connection VASA 22/26	Torque (Nm)
	1.	Split gear screws, **Apply Loctite 242 on threads,** see section	120±5	Split gear screws, **Apply Loctite 242 on threads,** see section	120±5

		[07.2]		[07.2]	
	2.	Split gear on crankshaft: **Apply Loctite 242 on threads**, see section [07.2]	140±5	Split gear on crankshaft: **Apply Loctite 242 on threads**, see section [07.2]	140±5
Alternative 1	3A.*)	Crankshaft flange screws M24 8.8. Lubricate the contact surfaces between the screwhead and the flywheel with **molykote G-n Plus** and the threads with oil. Use the torque multiplier X-4.	480±20	Crankshaft flange screws M30 10.9. Lubricate the washers with **molykote G-n Plus** and the threads with oil. Use the torque multiplier X-4.	800±20
	4.	Crankshaft flange screws, M24 12.9,20 pcs without nuts. Lubricate the washers with **molykote G-n Plus** and the threads with oil. Use the torque multiplier X-4.	1160±20	Crankshaft flange screws. Fitted bolts ø32. Lubricate the contact surfaces between the screws and the holes with **molykote G-n Plus** and the threads with oil. Use the torque multiplier X-4.	650±20
Alternative 2	3B.*)	Crankshaft flange screws .Fitted bots ø27. Lubricate the contact surfaces between the screws and the holes with **molykote G-n Plus** and the threads with oil. Use the torque multiplier X-4.	640±20	No such option on Vasa 22/26	

*) **NOTE**! The flywheel of the Vasa 22 engine can be fitted in two different ways depending on installation specification:
1. With 20 pcs of M24 screws (12.9) bolted directly to the crankshaft without nuts and fitted bolts.
2. With M24 screws and fitted bolts.

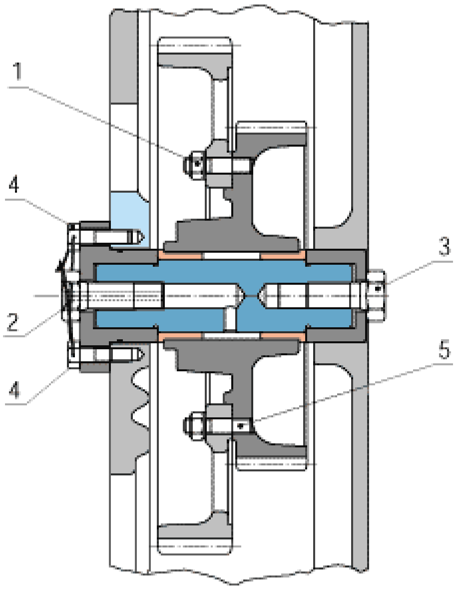

figure: 07-3 B: Intermediate gear

Pos.	Screw connection	Torque (Nm)
1.	Nut, M12. **Note!** Tighten the screws in two steps.	85±5 65..85
2.	Special screw for the intermediate gear.	400±10
3.	Centre bolts, M24.	400±10
4.	Screw, M12.	85±5
5.	Stud, M12 (locked with Loctite 242).	35±5

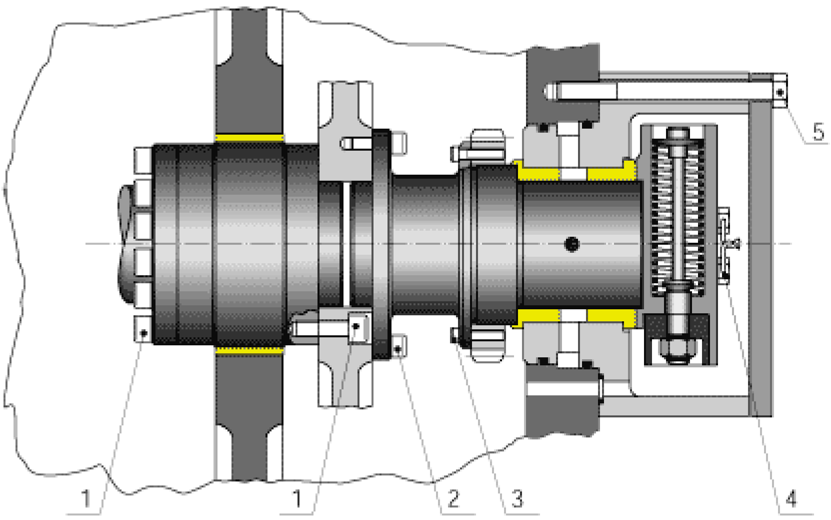

figure: 07-4 C: Camshaft and control mechanism

Pos.	Screw connection	Torque (Nm)
1.	Camshaft flange connection screws, (M10 12.9). **Torque wrench setting with tool 4V80G21.** The screws are treated with locking compound and can be used three times the locking effect being intact, then replace. **Do not wash screw threads but keep clean and dry.**	80±5 65
2.	Hexagon socket screw, (M8 12.9).	37±2
3.	Camshaft gear for governor drive, flange connection screws, (M6 8.8). **Apply Loctite 242 on threads,** see section [07.2].	9±1
4.	Overspeed trip device, fastening screws to camshaft, (M10 8.8 SK).	45±5
5.	Overspeed trip housing fastening screws, (M12 8.8).	80±5

Note!

Torque wrench settings must be recalculated if an other tool combination than 4V80G21 (item 26-06 in chapter [05]) and torque wrench (item 26-01 in chapter [05]) is used for the camshaft flange connection.

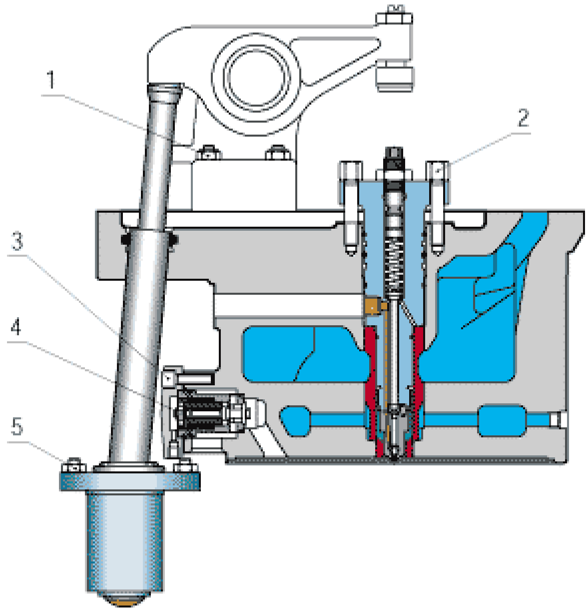

figure: 07-5 D: Cylinder head

Pos.	Screw connection	Torque (Nm)
1.	Rocker arm bearing bracket, fastening nuts. When reassembling stud bolts, **apply Loctite 270 on threads**.	85±5
2.	Injection valve fastening nuts.	50±5
3.	Starting valve fastening screws. **Note!** Tighten the screws in two steps.	40±4 20..40
4.	Nut for starting valve spindle.	14±2
5.	Nuts for valve tappet guide block.	85±5

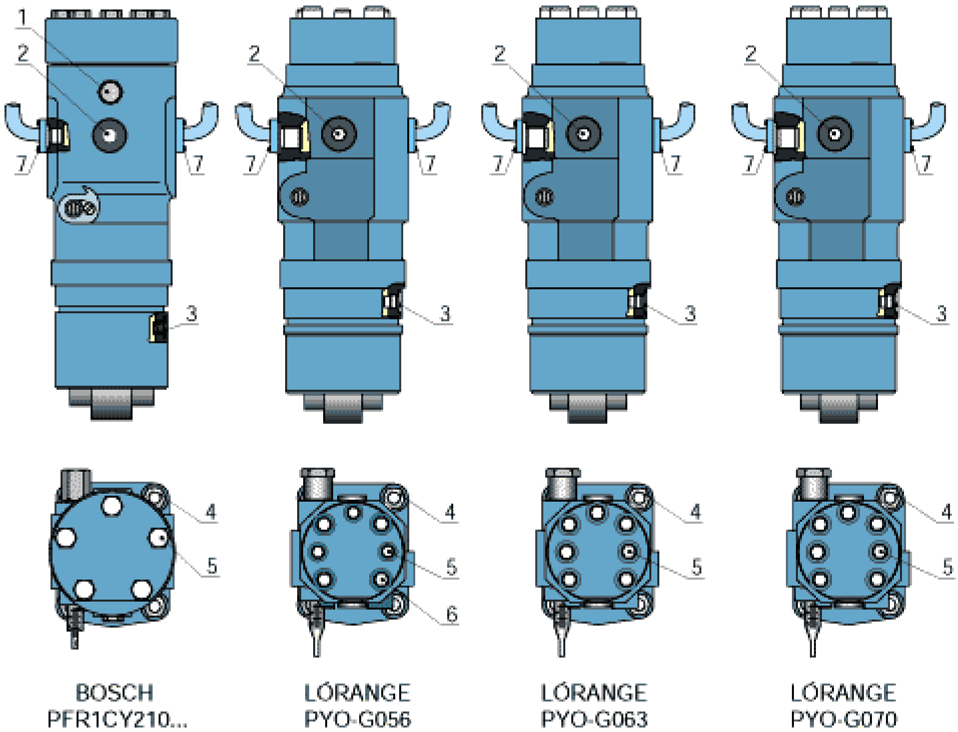

figure: 07-6 E: Injection pump

<table>
<tr><th rowspan="2">Pos.</th><th rowspan="2">Screw connection</th><th colspan="4">Torque (Nm)</th></tr>
<tr><th>Bosch PFR1CY210</th><th>L'Orange PYO-G056</th><th>L'Orange PYO-G063</th><th>L'Orange PYO-G070</th></tr>
<tr><td>1.</td><td>Hexagon socket screw.</td><td>30±5</td><td></td><td></td><td></td></tr>
<tr><td>2.</td><td>Erosion plug.</td><td>70±5</td><td>70±5</td><td>70±5</td><td>70±5</td></tr>
<tr><td>3.</td><td>Side screw.</td><td>15+5</td><td>15+5</td><td>15+5</td><td>15+5</td></tr>
<tr><td>4.</td><td>Nuts for injection pump fastening flange.</td><td colspan="3">85±5</td><td></td></tr>
<tr><td>5.</td><td>Injection pump cover fastening screws.</td><td>100±5</td><td>65±5</td><td>100±5</td><td>100±5</td></tr>
<tr><td></td><td>Note! Tighten the screws crosswise in steps.</td><td>0..50..80..100</td><td>0..30..50..65</td><td>0..50..80..100</td><td>0..50..80..100</td></tr>
<tr><td>6.</td><td>Injection pump cover fastening screws.</td><td></td><td>100±5</td><td></td><td></td></tr>
<tr><td></td><td>Note! Tighten the screws crosswise in steps.</td><td></td><td>0..50..80..100</td><td></td><td></td></tr>
<tr><td>7.</td><td>Fuel pipe fastening screw.</td><td colspan="4">25±2</td></tr>
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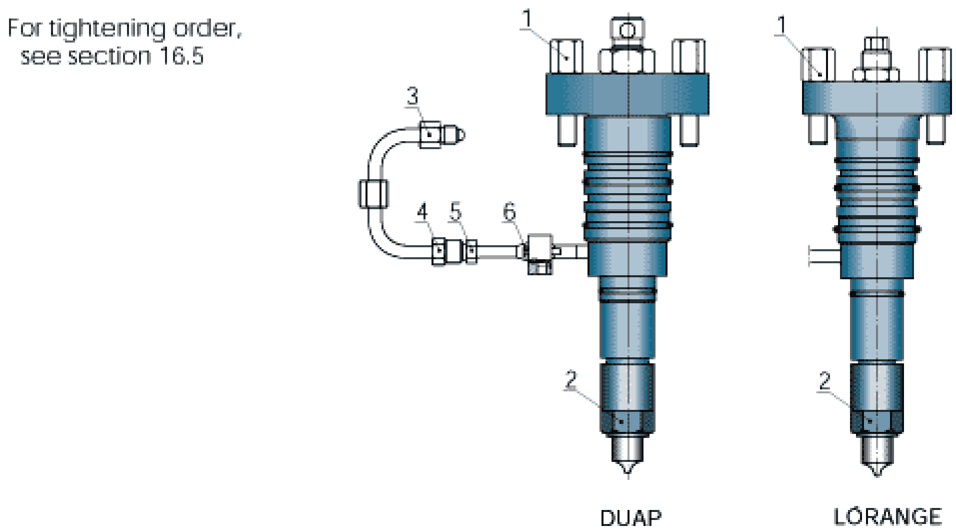

figure: 07-7 F: Fuel injection valve

Pos.	Screw connection	Torque (Nm)	
		L'Orange	Duap
1.	Injection valve fastening nuts.	50±5	50±5
2.	Injection nozzle cap nut.	110±5	110±5
3.	Injection pipe cap nuts.	50±3	
4.	Connection piece to nozzle holder.	50±5	
5.	Nozzle holder to connection piece.	65±5	
6.	Flange screws.	25±2	

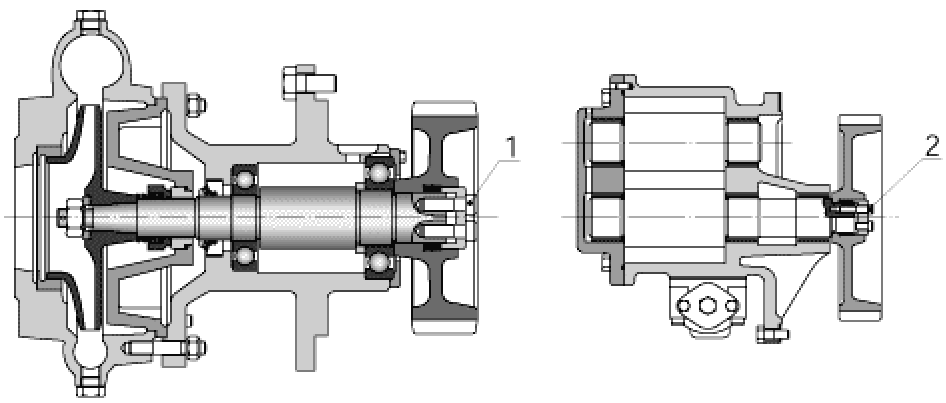

figure: 07-8 G, H: Engine driven pumps

Pos.	Screw connection	Torque (Nm)

1.	Fastening screws for water pump driving gear (connection with three Inbus Plus fastening screws, M8x35 10.9).	34±3
2.	Fastening screws for lubricating oil pump driving gear (connection with four Inbus Plus fastening screws, M10x45 12.9).	75±5
	Alternative! Fastening "nut. for lubricating oil pump driving gear.	210±10

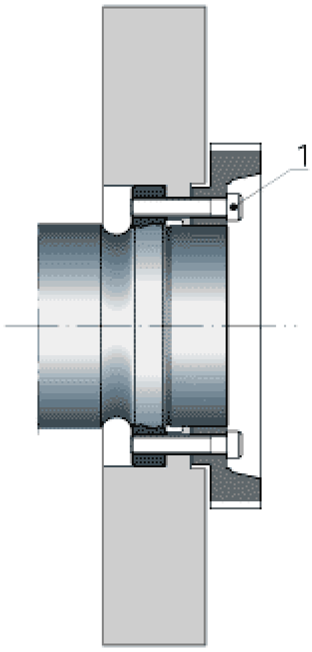

figure: 07-9 I: Free end of crankshaft

Pos.	Screw connection	Torque (Nm)
1.	Screws of pump driving gear at free end of crankshaft, (M20 12.9). Use the torque multiplier X-4.	600±20

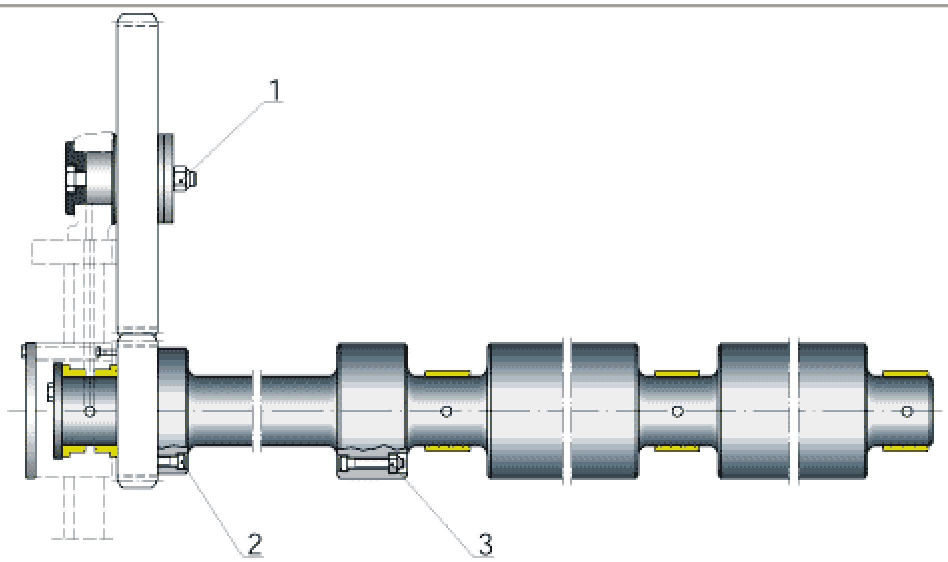

figure: 07-10 J: Balancing shafts (4R22, 4R22/26)

Pos.	Screw connection	Torque (Nm)
1.	Hexagon nut, M16.	200±10
2.	Drive gear wheel fastening screw.	120±10
3.	Balancing shafts, flange connection screws.	120±10

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	25	2.5
M10	17	8	50	5.0
M12	19	10	85	8.5
M16	24	14	200	20.0
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 a degreasing fluid and let dry completely before applying locking fluid.

07.3 Hydraulically Tightened Connections

07.3.1 Tightening pressures for hydraulically tightened connections

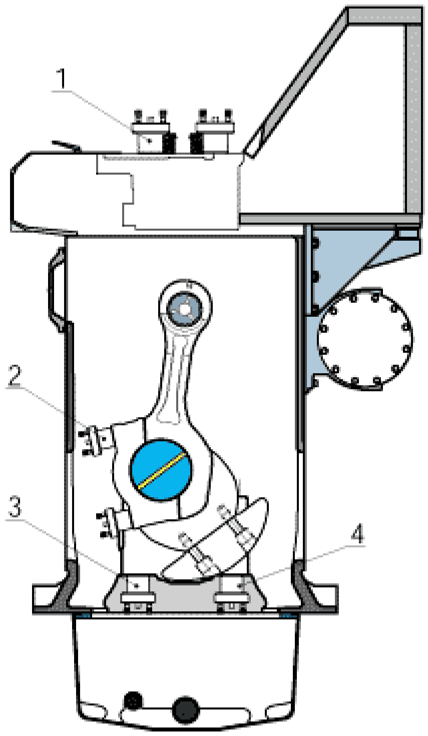

figure: 07-11 Hydraulically tightened connections

Pos.	Screw connection	Max. hydr. pressure (bar)		Tightening torques of studs (Nm)	Hydraulic cylinder number
		tightening	loosening		
1.	Cylinder head screws, M42.	500	520	200	861020
2.	Connecting rod screws, M30x2. -In-line engines -V-engines **Note!** Tighten the nuts in steps.	200..0..555 200..0..555	565 565	85 85	861032 861033/861011
3.	Main bearing screws, M42.	540	560	200	861020/861021
4.	Shield bearing screws, M24.	285	295	50	[861030]

Caution!

The screws will be overloaded if the maximum hydraulic pressure is exceeded.

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 hydraulic tool set

The hydraulic tool set consists of a high pressure hand pump with 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 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.

1 **Connect the hydraulic pump** and cylinder according to Fig [07-12]B. Fill the filling bottle (delivered with the pump) with oil, viscosity about 2°E at 20°C.

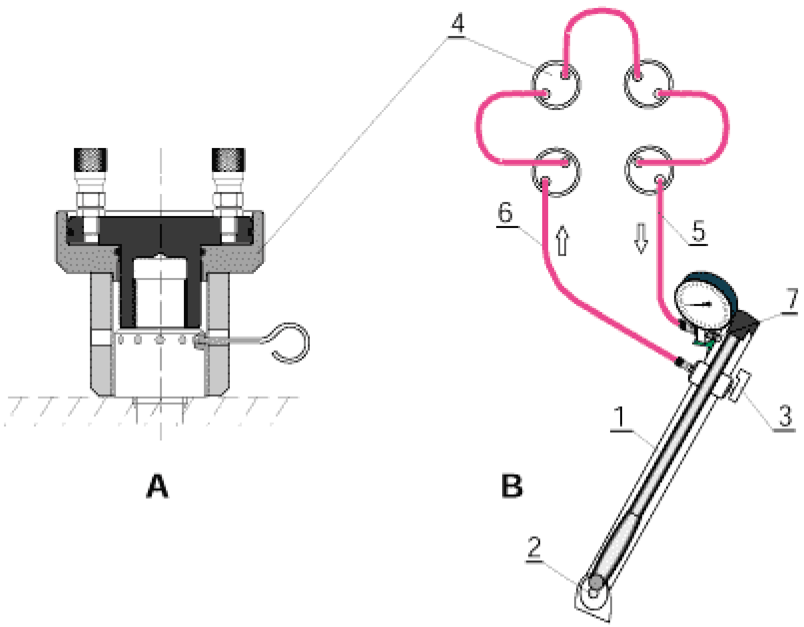

figure: 07-12 Hydraulic cylinder

2 **Open the release valve** (3) and press the pistons of the cylinders (4) to expel oil possibly occurring in the cylinders back to the pump container.

3 **Lift the pump above the cylinders** and keep it in the position where the plastic plug (2) is topmost. Remove the plug and filling screw located inside the plug.

4 **Press the spout** of the filling bottle into the filling hole and squeeze the bottle to make the oil enter. Let air flow into the bottle, and fill the pump container completely with oil.

5 **Replace the filling screw** and plastic plug.

6 **Vent the complete hydraulic set** by closing the valve (3), open the air vent screw (7) and pump until air void oil flows out. Close the screw (7).

7 **If a large oil amount escapes** when venting, refill the container.

The system is provided with bayonet couplings including non-return valves which means that venting is necessary when filling the container, only. The non-return valves are opened by the pins located in the centre of the male and female parts. If these pins get worn, replace the couplings. Risk of blocking system.
If, exceptionally, it is necessary to operate the with couplings not completely intact, it is advisable to open the air vent screw to assure that the passage is open to all cylinders before tightening the connection.

07.3.3 Dismantling hydraulically tightened screw connections

1 **Attach distance sleeves and hydraulic cylinders** according to [Fig 07-12]A. Screw on cylinders by hand.

2 **Connect the hoses** to the pump and cylinders according to Fig [Fig 07-12]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 of the nuts by hand.**

07.3.4 Reassembling hydraulically tightened screw connections

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 clockwise direction until close contact to face. Use the pin intended for this purpose and tighten the nut as much as possible without breaking the pin. Keep 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 the limited angle but approximately the same angle for all nuts of the same kind.

Note

Before the engine has started, ensure that all screw connections that have been opened are properly tightened and locked, if necessary.

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 according to [Fig 07-13].
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 recommendable to be careful when operating at the end of the stroke.

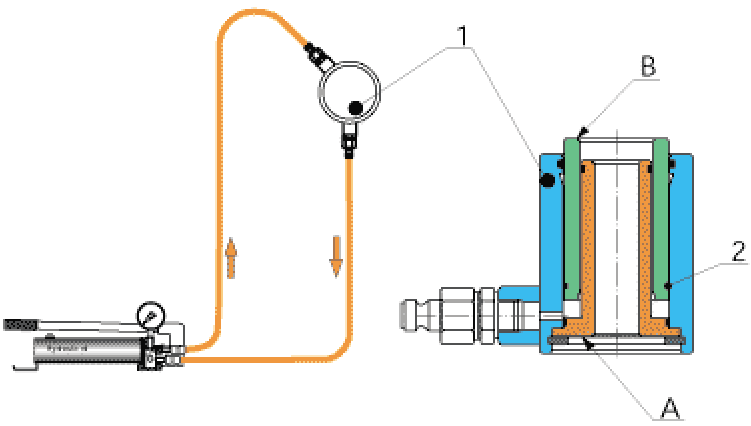

figure: 07-13 Hydraulic extractor cylinder

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

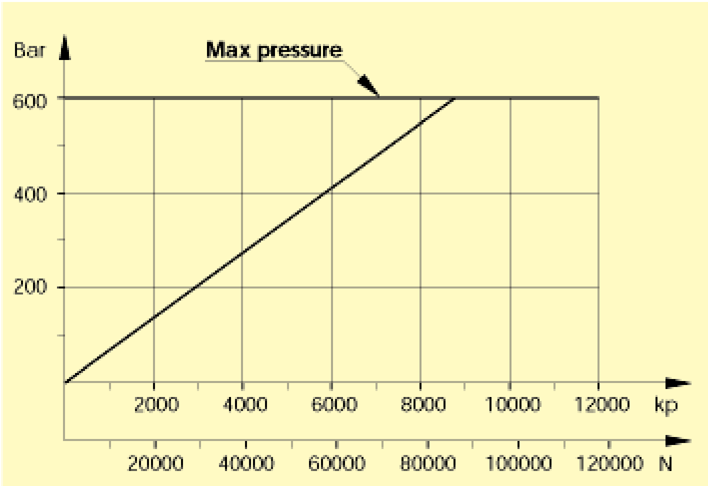

figure: 07-14 Relation between pressure and force for hydraulic extractor

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)	V-engines: The turning device is connected. In-line engines: The cover on flywheel protection is open. **NOTE!** Engine cannot be started when turning device is connected. However, before starting, always check that turning device is removed.	[11.1][21.1]
b)	Starting air pressure too low, shut-off valve on starting air inlet pipe closed.	[21.1][21.5]
c)	Jamming of starting valve in cylinder head.	[21.4]
d)	Jamming of starting air distributor piston.	[21.3]
e)	Starting air solenoid valve faulty.	[21.2]
f)	Inlet or exhaust valve jamming when open. "Negative" valve clearance (strong blowing noise).	[12]
g)	Starting automation outside engine faulty.	[03.1.2][23]
h)	4R22: Starting motor faulty.	[21.6]
2.	**Crankshaft rotates but engine fails to fire**	
a)	Too low speed (1b).	
b)	Automatic shut-down device is not in start position.	[23]
c)	Load limit of control shaft or of governor is set at too low a value.	[22]
d)	Overspeed trip device has tripped.	[22.5][22.6]
e)	Starting fuel limiter wrongly adjusted.	[22.3.5][22.7]
f)	Some part of fuel control mechanism jamming and prevents fuel admission.	[22]
g)	Fuel and injection system not vented, pipe connections between injection pumps and valves not tightened.	[17.3]
h)	Fuel filter clogged.	[17.7][17.1]
i)	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.	[17.7][17.1]
j)	Very low air and engine temperatures (preheat circulating water!)in connection with fuel of low ignition quality.	[02.1]
k)	Fuel insufficiently preheated or precirculated.	[02.1][Fig 02-1]
l)	Too low compression pressure (1f).	
m)	Faulty governor.	
3.	**Engine fires irregularly, some cylinders do not fire at all**	
a)	Jamming valves, inadequate fuel supply, too low temperatures.	1f, 2f, g, h, k, l,

		4d
b)	Injection pump control rack wrongly adjusted.	[22.3]
c)	Injection pump control sleeve does not mesh properly with rack(may cause overspeed if set in direction towards increased fuel quantity).	[16.3]
d)	Injection pump faulty (plunger or tappet sticking; delivery valve spring broken, delivery valve sticking).	[16]
e)	Injection valve faulty; nozzle holes clogged.	[16]
f)	Piston rings ruined; too low compression pressure.	[11.2]
g)	8...16-cylinder engines. It may be troublesome to make these fire on all cylinders when idling, due to the small quantity of fuel required. **In normal operation this is acceptable.** In special cases, in engines which have to idle continuously for longer periods (several hours), for some reason, it is advisable to adjust the rack positions carefully (reduce rack position somewhat on those cylinders having the highest exhaust gas temperatures, increase somewhat on those cylinders not firing). This adjustment should be done in small steps and the difference between rack positions of various cylinders should not exceed 1 mm.	

4.	**Engine speed not stable**	
a)	Governor adjustment faulty (normally too low compensation).	[22]
b)	See point 2f.	
c)	Fuel feed pressure too low.	[01.3]
d)	Water in preheated fuel (vapor lock in injection pumps).	
e)	Loading automation (e.g. controllable pitch propeller) outside engine faulty.	[23]

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, [07.3.1] pos. 2
b)	Valve spring or injection pump tappet spring broken.	[12][16]
c)	Inlet or exhaust valve jamming when open.	
d)	Too large valve clearances.	[06.1][12.4]
e)	One or more cylinders badly overloaded (3b, c).	
f)	Injection pump or valve tappet guide block loose.	[16.3][07.1]E [07.1]F
g)	Initial phase of piston seizure.	
h)	Insufficient preheating of engine in combination with fuel of low ignition quality.	
j)	Fuel injection timing wrong.	

6.	**Dark exhaust gases**	
a)	Late injection (wrongly set camshaft drive).	[06.1][16.3.3][13.3]
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] [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).	[03.3.5][11.2.3]
b)	Blue- whitish exhaust gases may occasionally occur when engine has been idling for a lengthy time or at low ambient temperature, or for a short time after starting.	
c)	Gray whitish exhaust gases due to water leakage from exhaust boiler, turbocharger.	

8.	**Exhaust gas temperature of all cylinders abnormally high**	
a)	Engine badly overloaded (check injection pump rack positions).	Test Records
b)	See point 6c.	
e)	Exhaust pipe pressure after turbine high.	[04.4][04.5][15]

9.	**Exhaust gas temperature of one cylinder above normal**	Test Records
a)	Faulty exhaust gas thermometer.	[23][03.3.1]
b)	Exhaust valve. - jamming when open - "negative" valve clearance - sealing surface blown by (burned)	
c)	Faulty injection valve. - opening pressure much too low - sticking of nozzle needle when open - broken spring - nozzle cracked	[06.1] [16.11]
d)	Late injection.	[06.1][16.3]
e)	Fuel supply insufficient (filter clogged).	
f)	Injection pump faulty , fuel rack sticking in high.	

10.	**Exhaust gas temperature of one cylinder below normal**	
a)	Faulty exhaust gas thermometer.	[23][03.3.1]
b)	See points 2f, h, 3b, c, d, e.	
c)	Leaky injection pipe or pipe fittings.	[16.4]
d)	When idling, see point 3g.	[03.3.1]

11.	**Exhaust gas temperatures very unequal**	
a)	See points 9a, c, e.	
b)	Too low fuel feed pressure: too small flow through injection pumps (see points 2h, i). May cause great load differences between cylinders although injection pump rack positions are the same. **Dangerous!** Causes high thermal overload in individual cylinders.	[01.3]
c)	See points 1f, 6b.	
d)	When idling, see point 3g.	
e)	Exhaust pipe or turbine nozzle ring partly clogged.	

f)	Apply to 8- and 16-cylinder engines. The difference in exhaust gas temperatures of the two cylinders next to the turbocharger is normally 50-120°C.	
12.	**Lubricating oil pressure lacking or too low**	[01.3]
a)	Faulty pressure gauge, gauge pipe clogged.	[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 badly diluted with diesel oil, viscosity of oil too low.	[02.2.1][02.2.3]
g)	Lubricating oil pipes inside engine loose or broken.	[18]
13.	**Too high lubricating oil pressure**	
a)	See points 12a and c.	
14.	**Too high lubricating oil temperature**	[01.3]
a)	Faulty thermometer.	
b)	Insufficient cooling water flow through oil cooler (faulty pump, air in system, valve closed), too high raw water temperature.	[19.1] [01.3]
c)	Oil cooler clogged, deposits on tubes.	[18.5]
d)	Faulty thermostat valve.	[18.7]
15.	**Abnormally high cooling water outlet temperature, difference between cooling water inlet and outlet temperatures too large**	[01.3]
a)	One of thermometers faulty.	
b)	Circulating water cooler clogged, deposits on tubes.	[19]
c)	Insufficient flow of cooling water through engine (circulating water pump faulty), **air in system, valves closed**.	[19] [03.3.1]
d)	Thermostat valve faulty.	[19.4]
16.	**Water in lubricating oil**	[02.2.3][03.3.1]
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]
17.	**Water in charge air receiver** **(escapes through drain pipe in air cooler housing)**	[15]
a)	Leaky air coolers.	[15]
b)	Condensation (too low charge air cooling water temperature).	[03.3.1][Fig 03-1]
18.	**Engine looses speed at constant or increased load**	
a)	Engine overloaded, a further increase of fuel supply is prevented by the mechanical load limiter.	[22.1] [Fig 22-6] pos. 13
b)	See points 2c, f, g, **h, i.**	

c)	See points 4c,d, 5g, 19d.	
19.	**Engine stops**	
a)	Shortage of fuel, see points 2h, i.	
b)	Overspeed trip device has tripped.	[22.5][22.6]
c)	Automatic stop device has tripped.	[23.1.4]
d)	Faulty governor or governor drive.	[22]
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)	Faulty stop automation. Stop by means of stop lever.	[23.1.4]
c)	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 maximum 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 Emergency operation

08.2.1 Operation with defective air cooler(s)

If the water tubes of an air cooler are defective, the cooling water may enter the cylinders. If water or water mist flows out of the drain pipe at the bottom of the cooler housing, check whether it is raw water or condensate. If condensate, reduce cooling (see chapter 03, [Fig 03-1]). If raw water, stop the engine as soon as possible and fit a spare cooler.
If no spare cooler is available, the following can be done as an emergency solution:

1 **Dismantle the cooler for repair** and blank off the opening in the charge air cooler housing. Shut off water supply and return pipes. Repair the cooler, e.g. by plugging the leaking tubes.

2 **If there is not time enough to remove the defective cooler** and repair it, shut off water supply and return pipes.

Note!

This will influence on the water flow to the tube oil cooler and the tube oil cooler temperature will increase

3 **Operating with a partially plugged, shut-down or removed air cooler.** Engine output must be limited so that the normal full load exhaust temperatures are not exceeded.

The turbocharger may surge before the admissible exhaust temperatures are reached. In such a case, engine load must be reduced further to avoid continuous surging.

08.2.2 Operation with defective turbocharger(s)

A defective turbocharger is to be treated in accordance with the service instructions given in the turbocharger instruction book (blocking of rotor

etc.).
If one turbocharger on a V-engine is defective and must be blocked, the other charger should be blocked too. The air connection between the charger and the air coolers should be removed and the engine will operated as a naturally aspirated engine.
When operating the engine without turbochargers, the engine output must be limited so that the normal full load exhaust temperatures are not exceeded.
Available load from the engine with blocked turbocharger (s) is about 20 % of full load.

08.2.3 Operation with defective cams

If the camshaft piece with damaged cams cannot be removed and replaced by a new one, the engine can be kept running by the following measures:

A) Injection pump cams:

Slight damage:
Set injection pump control rod into zero position and lock it by a wire around the pump.

Bad damage:
Remove fuel injection pump. See chapter [16].

Attention!

Concerning **torsional vibrations and other vibrations,** see chapter 08., section [08.2.5].

When operating with a shut-off injection pump over a long period the valve push rods of the inlet and outlet valves are to be removed, and the indicator valve on the respective cylinder is to be opened once an hour to allow any accumulated oil to escape.

Caution!

Oil mist escaping from the indicator valve may cause a fire.

With one cylinder out of operation, reduce load to prevent exhaust temperature of the remaining cylinders from exceeding normal full load temperatures.

B) Valve cams

Stop fuel injection to the cylinder concerned, see chapter [16]. Remove the valve push rods and cam followers of the cylinder. Replace the tubes covering the push rods.

Attention!

Concerning **torsional vibrations and other vibrations,** see chapter 08., section [08.2.5].

With one cylinder out of operation, reduce load to prevent exhaust temperatures of the remaining cylinders from exceeding full load temperatures.

08.2.4 Operation with removed piston and connecting rod

If damage on piston, connecting rod or big end bearing cannot be repaired, the following can be done to allow emergency operation:

1 **Remove the piston and the connecting rod.**

2 **Cover lubricating oil bore in crank pin** with a suitable hose clip, and secure.

3 **Fit completely assembled cylinder head** but omit valve push rods.

4 **Prevent starting air entry to the cylinder head** by removing pilot air pipe.

5 **Shut down injection pump** (chapter [16]).

Attention!

Concerning torsional vibrations and other vibrations, see chapter 08., section [08.2.5].

With one cylinder out of operation, reduce load to prevent exhaust temperature of the remaining cylinders from exceeding normal full load temperatures.
If the turbocharger(s) surge, reduce load further to avoid continuous surging.
Operation with piston and connecting rod of one or more cylinders removed should be performed only in absolute emergency conditions when there are no other means of proceeding under own power.

08.2.5 Torsional vibrations and other vibrations

When running the engine with one cylinder, or more, out of operation, the balance of the engine is disturbed, and severe, or even dangerous, vibrations may occur. The vibration conditions are in practice dependent on the type of the installation.
As a general advice when there are cylinders out of order:

- reduce load as much as possible,
- keep the speed in a favourable range (completely depending on the type of installation,
- if one or several pistons are removed, lowest possible speed should be used.

10.1 General description

10.1.1 Engine block and bearings

The engine block is cast in one piece of cast iron. The distributing duct for the cooling water as well as the air receiver are incorporated in the engine block. The main bearing caps are arranged hanging and support the crankshaft in interchangeable precision type bearing shells. The upper bearing shell is guided in the oil groove by a lug at each end. The lower shell has a lug at one end to be axially located. The periphery of the shells is longer than that of the bearing bore and thus provides for the fixation of the shells. The first main bearing, seen from the driving end, is provided with four thrust washers in order to guide the crankshaft axially. An extra, so-called shield bearing, may be mounted next to the flywheel, when needed (depending on installation).
The camshaft bearing bushes are in housings directly machined in the block, see chapter [14].

10.1.2 Cylinder liners

The engine block embodies the cylinder liners, made of special cast iron and honed to an optimal finish. At the top flange the liners are sealed against the block metallically, and at the lower part by two O-rings.

10.1.3 Covers

The crankcase covers and the covers of the camshaft openings are provided with rubber profile gaskets. Some of the crankcase covers include a spring-loaded safety valve which releases the overpressure in case of a crankcase explosion. The crankcase is provided with an air vent pipe including a non-return valve. The air vent pipe should be conducted away from the engine. A cover incorporating the oil filling hole is located at the driving end of the engine.

10.1.4 Oil sump

The light, welded oil sump is attached to the engine block from below and is sealed off by a rubber sealing. Suction pipes to the lubricating oil pump and separator, as well as the main lubricating oil distributing pipe for crankshaft bearings, are incorporated in the oil sump.
An oil dipstick is located in one of the crankcase covers. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level near the maximum mark and never allow the level to go below the minimum mark. The limits apply to the oil level in a running engine. One side of the dipstick is graduated in centimetre. This scale can be used when checking the lubricating oil consumption.

10.2 Main bearings and thrust washers

10.2.1 Dismantling of main bearings

1 **Remove the crankcase cover** closest to the bearing in question.

2 **Remove the oil pipe** to the main bearing cap in question.

3 **Unscrew the main bearing cap side screw** about one turn by using the wrench combination X-4, [Fig 10-1]. To facilitate the later lowering of the bearing cap unscrew the neighbouring side screws also, see step 9, below.

4 **Lift the distance sleeves (1) in position,** [Fig 10-1] and insert the pins (2) into the slots of the sleeves to fix the sleeves. And screw on the hydraulic cylinders (3).

1. Distance sleeve (861031)
2. Pin (861025)
3. Hydraulic cylinder (861020)
4. Distance sleeve (861022)
5. Pin (861141)
6. Hydraulic cylinder (861030)

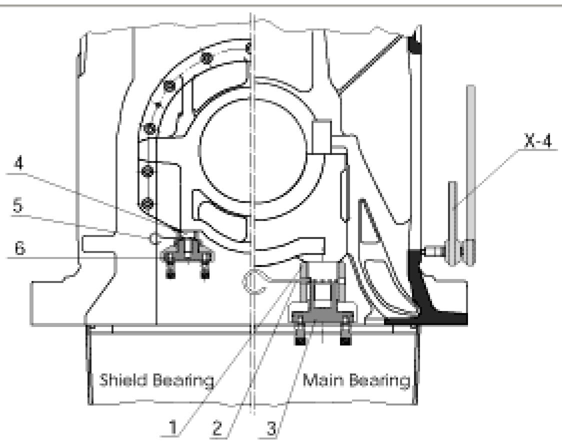

figure: 10-1 Hydraulic tool for main and shield bearing

Note!

For V-engines, equipped with torsional vibration damper Hasse & Wrede ASK 1728, two extra distance sleeves are delivered. These two sleeves are to be used on the main bearing closest to the torsional vibration damper only. The sleeves are marked 3V86B56.

5 **Connect the hoses** and proceed with opening of main bearing screw nuts. For further instruction see chapter 07., section [07.3].

6 **Remove the nuts and apply the main bearing cap lifting tool** 832003, [Fig 10-2]A. Remove the side screws and lower the cap by means of the lifting tool until the handle rests on the bottom edge of the crankcase opening. The lower bearing shell can now be removed out of the cap.

If the main bearing cap is to be removed, shift angle position of the handle by inserting the locking pins into the other pair of holes. In doing so it is possible to further lower the main bearing cap until it is free from the bolts and can be dismantled, [Fig 10-2]B.

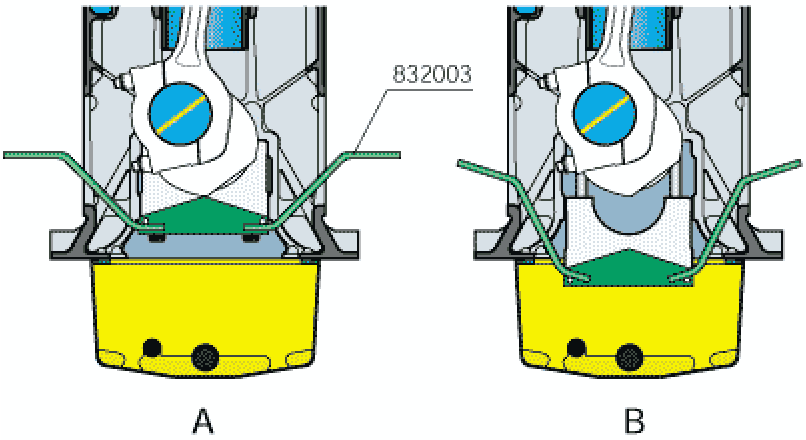

figure: 10-2 Lifting tool for main bearing cap

7 **To dismantle the upper bearing shell,** insert the turning tool 851001 (in-line engine) or 851002 (V-engine) into the crankshaft journal radial oil hole. Turn the crankshaft carefully until the bearing shell has been turned 180° and remove it, [Fig 10-3].

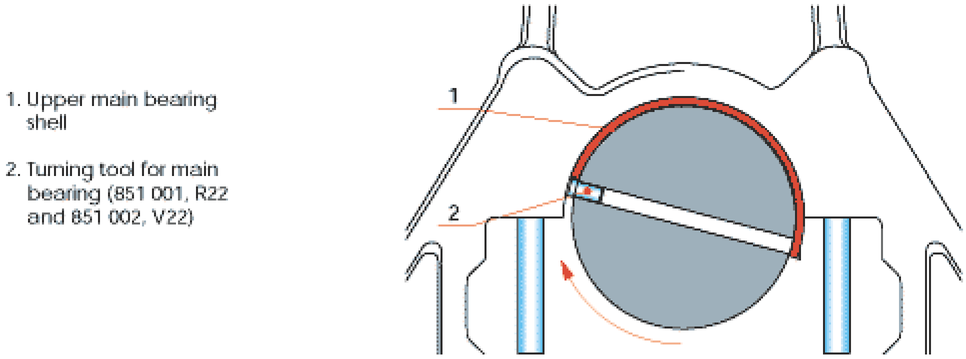

figure: 10-3 Use of turning tool for bearing shell

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

2 **The thrust washers can be removed** from the main bearing cap when it is in lowered position.

To remove the upper halves of the thrust washers, insert the turning tool 851005 (in-line engine) or 851006 (V-engine) into the bearing journal radial oil hole. Turn the crankshaft carefully 180° and remove the washers.

10.2.2 Inspection of main bearings

Wash the bearing shells and check for wear, scoring and other damage. Mark the new bearings with the same bearing numbers as the replaced shells. The thrust washers should be changed in pairs to ensure that the flanges of the axial bearing surfaces are of equal thickness.

No scraping or other fitting of bearing shells, caps or bores is allowed. Burrs or dirt should be locally removed only.

The bearing journals should be inspected for surface finish. Damaged journals (rough surface, scratches, marks of shocks) should be polished. If after a longer period of running, considerably uneven wear appears, see section [06.2]. pos. 11, the crankshaft may be reground and reassembled together with thicker bearing shells.

10.2.3 Installing main bearings

1 **Clean the main bearing bore, caps, shells and crankshaft journal** very carefully.

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

3 **Lubricate the upper shell bearing surface** (not the rear side).

4 **Place the edge of the shell** in the slot between the crankshaft and the bearing bore and push it in by hand as far as possible.

5 **Place the turning tool** 851001 (in-line engine) or 851002 (V-engine) in the crankshaft journal radial oil hole and turn the crankshaft carefully until the bearing shell has been turned into position, [Fig 10-3]. Take care that the bearing shell guiding flap enters the groove without being damaged.

6 **Remove the turning tool.**

7 **Lubricate the lower shell bearing surface** (not the rear side) and place it in the bearing cap. Check that the bearing shells are installed correctly. Raise the cap by means of lifting tool 832003, [Fig 10-2], until the lubricated side screws can be screwed into the threads of the bearing cap by hand.

8 **Remove the lifting tool.**

9 **Lubricate the nuts** and screw on by hand.

10 **Tighten the side screws,** at the **rear side** only, to 300 Nm torque.

11 **Put the distance sleeves (1), [Fig 10-1], in place** and keep them in position by inserting the pins (2) into the holes of the nuts through the sleeve slots. Screw on the cylinders and connect the hoses. Pump pressure to the stated value.

12 **When re-installing the thrust main bearing,** force the crankshaft axially towards the free end.

13 **When re-installing the upper main bearing** with the thrust washer, proceed as follows: Remove the tape from the oil holes. Place the turning tool 851005 (in-line engine) or 851006 (V-engine) in the oil hole. Oil the crankshaft, bearing (not the rear side) and thrust washers. Place them on the crankshaft and turn the crankshaft 180° until the bearings are in the correct position, then turn the crankshaft backwards and remove the turning tool.

Mounting of the lower bearing half: Oil the bearings and thrust washers and mount them in the main bearing cap. Mount the cap as described in point [11].
Note!

The thrust washers are marked according to [Fig 10-4] (operating side of the engine)

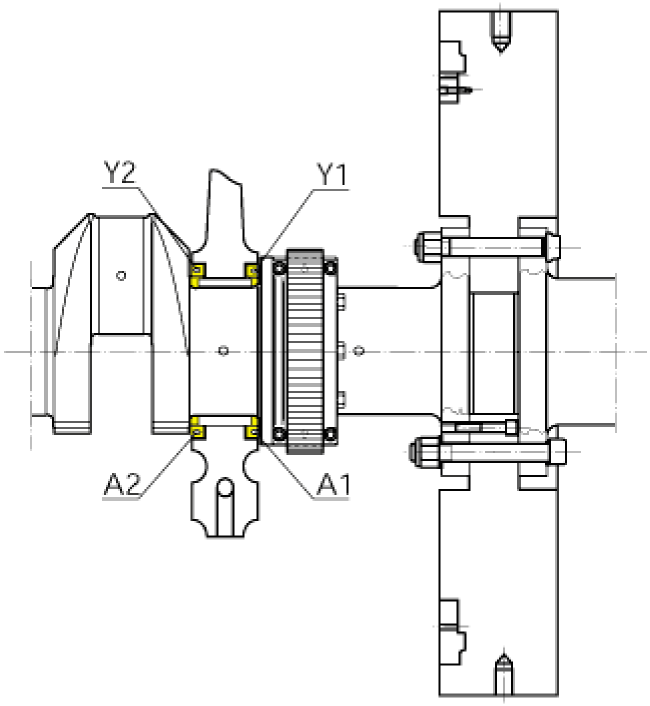

figure: 10-4 Marking of the thrust washers of the crankshaft

3 **Tighten the nuts by the pin (2)** until face-to-face contact. The pressure should be kept constant all the time.

4 **Release pressure** by slowly opening the valve on the pump. Remove the hoses, unscrew the cylinders and take off the distance sleeves and pins.

5 **Tighten the side screws** by using the tool combination Fig 05-15A and [Fig 10-1] to the value stated in chapter 07., section [07.1].

6 **Before starting the engine** after a bearing inspection, check the crankshaft axial clearance, see chapter [11].

10.3 Shield bearing

10.3.1 Dismantling

If the engine is equipped with an extra main bearing (i.e. a shield bearing) between the main thrust bearing and the flywheel, the inspection may proceed as follows:

1 **Remove the end cover.**

2 **Unscrew the four screws** fastening the bottom of the bearing housing to the engine block.

3 **Remove the guiding pins.**

4 **Loosen the nuts** of the two vertical screws by the hydraulic tool. For further instructions see section [07.3].

5 **Lower the bearing cap** so that it rests against the edge of the oil sump. (If the cap is to be removed from the engine, loosen the studs.)

6 **Remove the upper shell** by turning in clockwise direction using the tool 851004 placed in the crankshaft journal radial oil hole, [Fig 10-3].

7 **Remove the turning tool.** Cover the oil hole with tape.

8 **Check the bearing** in the same way as normal main bearings, section [10.2.2].

10.3.2 Assembling

1 **Remove the tape** from the oil hole.

2 **Lubricate the upper bearing shell surface** and crankshaft journal.

3 **Insert the bearing shell** end without lug in the clearance between the journal and bearing bore grooved edge. Push in the shell by hand as far as possible.

4 **Place the turning tool** 851004 in the crankshaft journal radial oil hole and turn carefully in counter-clockwise direction until the edge of the bearing shell levels with the bearing housing mating face. Check that the flap at the bearing edge is not damaged.

5 **Remove the turning tool,** [Fig 10-3].

6 **Lubricate the lower bearing shell surface** and place the bearing shell in the bearing cap.

7 **Raise the bearing cap** until the bearing shell edges level and tighten the nuts by hand.

8 **Knock the two dowel pins** from above to get the lower bearing house centered.

9 **Put the distance sleeves in place,** insert the pins in the slots.

10 **Screw on the hydraulic cylinders** and proceed with tightening of screw nuts, see also section [07.3].

11 **Tighten the four fastening screws to torque** according to section [07.1], by means of tool combination in [Fig 10-1].

10.4 Cylinder liner

10.4.1 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 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 should 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) Cleaning of the cylinder liner water side

The water side of the cylinder liner can be cleaned of deposits with a wire brush.

10.4.2 Removing cylinder liner

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

2 **Assemble the removing device** [836001], [Fig 10-5].

3 **Loosen the cylinder liner** by tensioning the nut (2) of the pull screw (1), [Fig 10-5].

4 **Withdraw the cylinder liner carefully.**

1. Screw (4V83G29)
2. Nut (4V83G31)

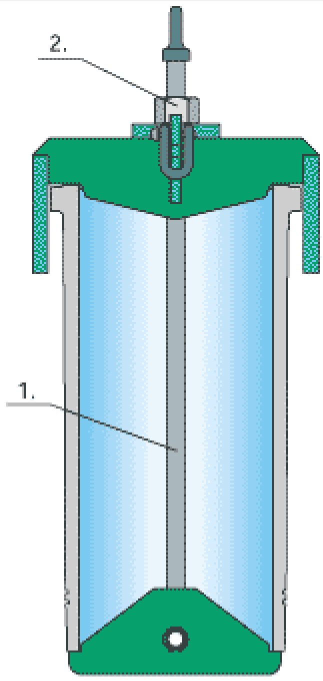

figure: 10-5 Removing and lifting of cylinder liner

10.4.3 Mounting of cylinder liner

If more than one cylinder liner have been removed, check that the liners are installed in the same cylinders as before the overhaul.
The liners are marked with the cylinder numbers to the top of the liner.

1 **Check that all guide and contact faces** (upper level) of the engine block are perfectly clean and intact, as well as the corresponding surfaces of the cylinder liner.

Caution!

Check that the contraction edge diameter is 273 mm, see [Fig 10-6].

2 **Check that the two O-ring grooves are clean** and fit the new O-rings. Also check the contraction edge diameter according to, [Fig 10-6].

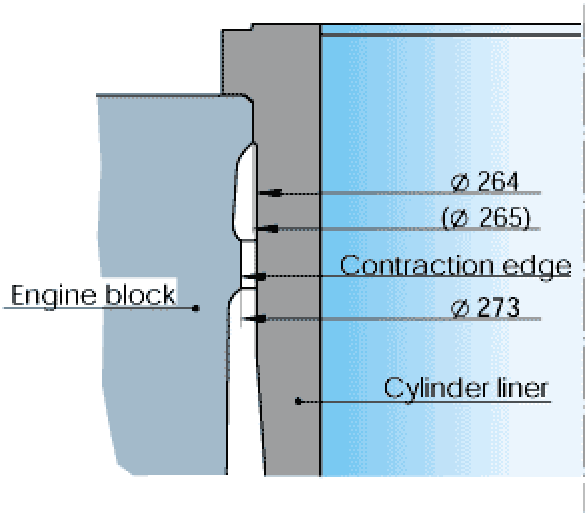

figure: 10-6 Machining of engine block for new type of cylinder liner

3 **Lubricate the O-rings** and sealing faces with Molykote Paste G or soft soap.

4 **Mount the lifting device.**

5 **Lower the liner** carefully into the bore of the block. When the tool touches the engine block, align the liner so that the scribing mark on the liner flange points to the driving end, lower by loosening the nut (2) and press the liner in position by hand. Give the liner a few blows with a rubber or plastic hammer, if necessary.

6 **Check the bore of the liner,** especially straight in front of the O-rings (390 mm from the upper edge of the liner); see section [06.2] pos. 10. The out-of-roundness of a replaced liner must not exceed 0.03 mm.

7 **Mount the piston with the connecting rod.**

8 **Mount the cylinder head,** and refill the cooling water system.

9 **Check the O-ring seals** from the crankcase side while circulating cooling water. Circulate water through the engine under high pressure (1.25 x nominal pressure), if possible (separate cooling water pump).

11.1 Crankshaft

11.1.1 Description

The crankshaft is forged in one piece. The first main bearing, seen from the driving end, is provided with thrust washers and guides the crankshaft axially. On V-engines all crank webs are provided with counterweights; on in-line engines counterweights are used when necessary. Each counterweight is fastened with hexagon tension screws. In 4-cylinder engines, the counterweights are part of the crankshaft, see also section [11.3].

At the driving end of the crankshaft, there is a shrunk-on oil ring or V-sealing ring, preventing oil and gas leakage, and a split gear. At the free end of the shaft there is, if necessary, a tuning mass or a vibration damper as well as a gear for driving of the pumps.

The flywheel is fastened to the crankshaft by four assembly screws, partly, and partly by the screws of the power take off shaft. Normally, these screws are provided with clearance holes and compress the flanges, the flywheel being in between. The power is conveyed by the frictional force between the flanges. The engine can be equipped with a power take off at the free end of the engine, when necessary.

The flywheel position indicator is equipped with a nonius scale for reading of the engine crank angles, at an accuracy of 1°, on the graduation of the flywheel. See chapter 00., section [00.3], for reading of flywheel position.

The turning device for V-engines normally consists of a gear to be coupled to the square pin of the ratchet. The rotational direction for turning can be reversed by alternating the ratch position of the ratchet. A warning light on the instrument panel of the engine will switch on when the turning device is connected. **In line engines** are normally turned by means of a lever to be inserted in the flywheel hole.

Note!

Remove the turning device always before starting the engine.

11.1.2 Crankshaft alignment

When the cylinder block and the generator have been aligned, always check the axial clearance.

1 **Turn the crank of the first cylinder** near the bottom dead center.

2 **Apply the crankshaft indicator** between the two crank webs into the center marks provided for this purpose.

3 **The clearance** between the micrometer and connecting rod should be as small as possible.

4 **Set the micrometer** at zero.

5 **Read the various deviations** when turning the crank to the rear side, top dead center, operating side etc. Record the readings in the "Crankshaft Alignment" -form.

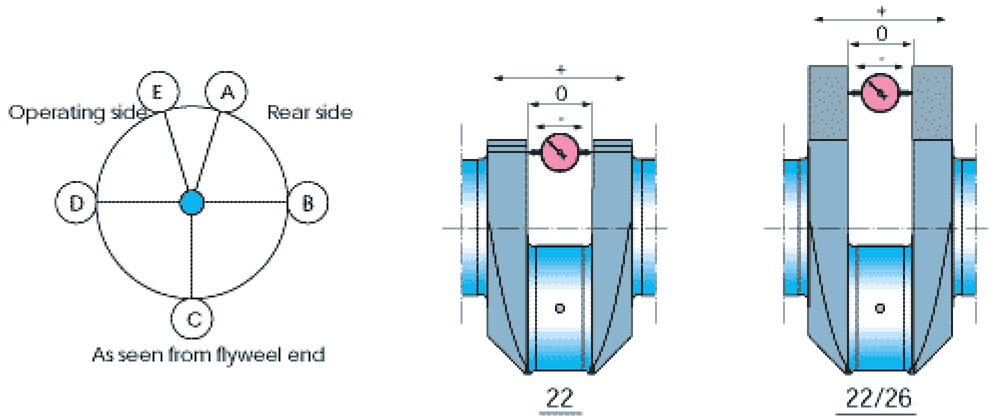

figure: 11-1 Dial indicator position and reading

Note!

During the alignment procedure the crankshaft should be turned in the direction of rotation, only.

6 **Repeat this procedure** with the other cylinders.

7 **The difference between two diametral readings** of the same crank must not exceed following values (in mm):

	22	22/26
- After installing and re-aligning	0.04	0.08
- Re-aligment is recommended, if difference is more than	0.07	0.14
- Re-aligment is absolutely necessary at	0.10	0.20

Note!

Note the difference between the 22 (stroke 240 mm) and 22/26 (stroke 260) engines

Before re-aligning the engine and the driven machinery, check the main bearing shell thickness.

Engines with a torsional elastic coupling

Engines with a torsional elastic coupling connected to the flywheel have a larger difference at the crank web next to the flywheel owing to the crankshaft deflection.

	22	22/26
- After installing and realigning such engines the difference must not exceed	0.06	0.12
- Maximum allowed deviation before re-alignment is absolutely necessary is in this case	0.11	0.22

The crank pin being upwards the reading is negative on this crank web.

When the crank throw for cyl 1 is in the TDC

	22	22/26
- The reading should be	-0.04 - 0	-0.08 - 0
- The recommended value is	-0.02	-0.04

8 **If these values cannot be achieved,** repeat the alignment.

Note!

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

11.1.3 Control of the the axial clearance

Check the crankshaft axial clearance by using a dial micrometer.

1 **Run the engine prelubricating pump** for a few minutes to lubricate the bearings.

2 **Stop the pump** and apply the dial micrometer to the face of the flywheel, for instance.

3 **Set the micrometer at zero.**

4 **Move the crankshaft** in the opposite direction and read the axial clearance on the micrometer.

The axial clearance should be kept within the limits stated in chapter 06., section [06.2] pos. 10.

When installing and realigning, check also the radial clearance around the periphery between the crankshaft flange and the tripartite driving end cover.

11.2 Connecting rod and piston

11.2.1 Description

The connecting rod is drop forged and precision serrated in the mating face. The big end bearing is a trimetal bearing of the same design as the main bearings. Lubricating oil is fed through the main bearings and bores in the crankshaft.

The gudgeon pin bearing has a larger bearing surface on the lower side where the bearing load is higher. Lubricating oil is led through bores in the connecting rod from the big end bearing. The connecting rod is axially guided by the piston through the top part of the gudgeon pin bearing.

The gudgeon pin is hollow and is provided with radial holes to convey lubricating oil from the connecting rod to the piston. The pin ends are covered to prevent oil from escaping. The gudgeon pin is axially fixed in the piston by means of oval retainer rings.
The piston is made of nodular iron and is cooled with the engine lubricating oil conveyed through the gudgeon pin into an annular space, from which the oil is allowed to flow to the engine oil sump. The skirt of the piston is lubricated with oil from bores drilled to the gudgeon pin bearing. The two top ring grooves are hardened.
Note!

Always handle the piston with care.

The piston ring combination includes three compression rings, the two top rings of which are chromium-plated, and one spring loaded, chromium-plated oil scraper ring.

11.2.2 Removing of the connecting rod and piston

1 **Remove the cylinder head** (chapter [12]). Scrape off any carbon around the upper portion of the cylinder liner. It is advisable to cover the piston top with cloth or paper pressed tightly against the wall to collect carbon or other dirt which has come loose.

2 **Clean the threaded hole on the top of the piston** with the tap M12, and screw on the lifting tool [832002] by using the hexagon screw M12x80.

3 **Remove the crankcase cover** from the operating side.

4 **In-line engine:** Turn the crankshaft about 95° from the TDC towards the operating side of the cylinder in question.

V-engine, A-bank: Turn the crankshaft about 95° from the TDC towards the A-bank of the cylinder in question.

V-engine, B-bank: Turn the crankshaft about 95° from the TDC towards the B-bank of the cylinder in question.

5 **Lift the distance sleeves,** 861033 for in-line engines and 861026 for V-engines, on to the connecting rod screws, [Fig 11-2].

6 **Screw on the hydraulic tools;** for in-line engines the hydraulic tool 861027 with the distance piece 861032, for V-engines the hydraulic tool 861027.

7 **Connect the hoses,** and proceed with opening of connecting rod nuts. Note the position of the slots.

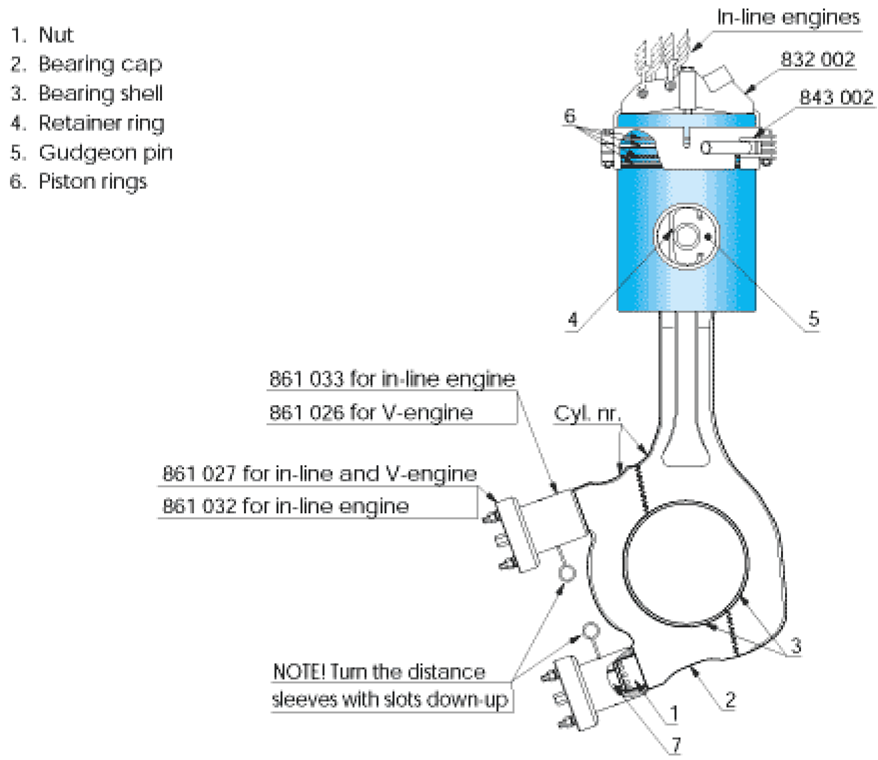

figure: 11-2 Removing piston and H-profile connecting rod

8 **Release the pressure** and remove the hydraulic tool.

9 **Screw off the nuts (1)** and remove the connecting rod screws by the stud tool 803011.

10 **Lift the big end bearing cap (2)** together with the bearing shell out of the engine.

11 **Lift the piston a little** to remove the upper big end bearing shell (3), this applies only to in-line engines.

On V-engines, mount the protecting rails 835003 and 835004 in position above the connecting rod serration.

12 **When lifting the piston,** take care not to damage the crank pin and the cylinder liner wall.

13 **Cover the crank pin oil holes with tape.**

14 **If the connecting rod is to be withdrawn from the piston,** remove the retainer ring (4) from the gudgeon pin hole in the piston, on the side where the gudgeon pin drawing number is, by using the retainer ring pliers [843004].

Note!

Never compress the retainer ring more than barely to be able to remove it from the groove.

Push out the gudgeon pin (5) from the opposite side. If the piston temperature is lower than +18 - 19°C the gudgeon pin may stick but will be easily removed when heating the piston to about 30°C.

15 **To remove the piston rings (6),** use the piston ring pliers [843003]. The design of these pliers prevents from overstressing the rings. However, the piston rings should not be removed unless the rings and grooves require cleaning, measuring etc. If the piston rings are to be reinstalled, note how they are turned.

Every time when removing the piston, careful records should be made.

11.2.3 Maintenance of the piston and connecting rod

1 **Clean all the parts carefully.** When removing burned carbon deposits from the pistons particular care should be taken not to damage the piston material. Never use emery cloth.

The cleaning is facilitated if coked parts are soaked in kerosene or fuel. An efficient carbon solvent - e.g. ARDROX No. 668 or similar - should preferably be used to facilitate the cleaning and to protect the pistons against mechanical damage. When using chemical cleaning agents, take care not to clean the piston skirt with such agents; the phosphate/graphite overlay may be damaged. Measure the height of the piston ring grooves, see chapter 06., section [06.2], pos. 11.
In case of excessive fouling or sticking, the piston rings should be removed from the pistons and checked.
Check the rings for wear by inserting them into a new cylinder liner and measuring the ring gaps at the joint. Also check the clearance of the rings in their grooves, see chapter 06., section [06.2], pos. 11.
Especially the two chromium-plated topmost piston rings should be examined. If the chromium-plating is worn through, the ring should immediately be replaced by a new one.

Note!

If the cylinder liner is new or honed, all rings are to be replaced by new ones.

2 **Check the end plugs of the gudgeon pins.**

3 **Check the gudgeon pin and big end bearing clearances** (chapter 06., section [06.2], pos. 11) at intervals according to chapter [04]. They will easily be checked by measuring the pins and bearing separately (the big end bearing being tightened to full torque). When using a feeler gauge the gauge should be formed of as many thin blades as possible; if using thick blades the overlay plating of the bearing may be damaged.

4 **Check that the serration** of the connecting rod is not damaged.

11.2.4 Installing the connecting rod and piston

1 **Check that the bores** for the skirt lubrication are not blocked.

2 **The gudgeon pins (5)** should always be inserted from the same side of the piston from which they have been removed and should be placed the same way around, see section [11.2.2] pos.[12]. If the piston temperature is lower than +18 - 19°C the gudgeon pin may stick but will move freely if the piston is heated in oil to about 30°C. Oil the pin with lubricating oil before installing, [Fig 11-2].

3 **Never compress the retainer ring (4)** more than barely to be able to fit it in the groove. If the ring is loose in the groove after installation it should be replaced.

4 **When mounting the piston** in the connecting rod, see that the cylinder number has stamped on the piston crown and the connecting rod are on the same side. When changing a piston, mark the new piston with the same number as the replaced one. The arrow on the piston head should point to the camshaft side.

5 **Check the gap clearance** by fitting the rings into a new cylinder liner before installing new piston rings. Check also the vertical clearance in the ring grooves (chapter 06., section [06.2], pos. 11). When installing the rings, use the piston ring pliers. The ring joints should be located 120° in relation to each others.

Old piston rings should always be placed in the same groove and the same way around as when taken out.

6 **Clean the piston,** cylinder liner, connecting rod bearing bore and crank pin carefully.

7 **Wash the big end bearing (3).** When changing bearings, both bearing shells should be marked with the cylinder number in the same way as the replaced one.

8 **Oil the piston and crank pin** with lubricating oil. Place the clamp device 843002 for the piston rings around the piston. Check that the piston rings slide into the grooves without being damaged.

9 **Turn the crankshaft.**

In-line engine: Turn the crankshaft 95° from the TDC towards the operating side of the cylinder in question.
V-engine A-bank: Turn the crankshaft 95° from the TDC towards the A-bank of the cylinder in question.
V-engine B-bank: Turn the crankshaft 95° from the TDC towards the B-bank of the cylinder concerned.
In V-engines, mount the upper bearings shell and the protecting rails 835003 and 835004.

10 **Lower carefully the piston.** Turn the piston and connecting rod so that the side with the cylinder number faces the camshaft.

In-line engine: When the connecting rod is lowered to the vicinity of the crank pin, apply the upper bearing shell in the bearing bore observing that the guiding flap slides into the recess of the connecting rod.

11 **Lubricate the threads** of the big end bearing screws (7) with oil.

12 **Lift the bearing cap (2)** together with the lower bearing shell in place. Attach the connecting rod screws and tighten to stated torque by using the stud tool 803011.

13 **Screw on the nuts (1)** and tighten by hand until the lower joint face of the big end bearing cap contacts that of the connecting rod, starting with the lower nut.

14 **Lift the distance sleeves,** 861033 for the in-line engine and 861026 for the V-engine, on to the connecting rod screws.

15 **Screw on the hydraulic tools;** for the in-line engine the hydraulic tool 861027 with the distance piece 861032 screwed on to the hydraulic piston, for the V-engine the hydraulic tool 861027.

16 **Connect the hoses,** and proceed with tightening of connecting rod nuts.

11.3 Balancing mechanism for 4-cylinder engines

The four-cylinder in-line engine is equipped with two balancing shafts (3) which rotate at a speed twice the crankshaft speed. The shafts are driven by the crankshaft (1) through an intermediate gear (2). Each shaft is pivoted in four pressure lubricated sliding bearings (4), one of which is axially guiding. The counterweights are integrated into the shaft.
Normally, the arrangement needs no maintenance. In connection with overhauls of the engine the sliding bearings can be inspected. In case the transmission has been opened it is absolutely necessary to make sure that the marks of the gears remain in their initial positions.

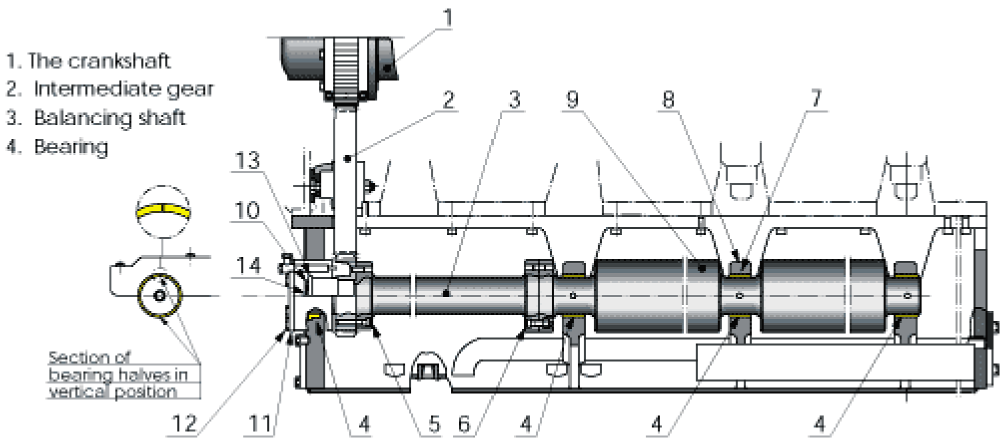

figure: 11-3 4R22, 4R22/26 balancing shaft

The second-order free forces of the 4-cylinder in-line engines are completely counterbalanced by means of an arrangement consisting of two balance shafts with eccentrical masses, rotating in opposite directions in relation to each other. The shafts rotate at a rate of twice the engine speed. The centrifugal forces counteract each others horizontally and counterbalance the free forces of the engine vertically, [Fig 11-3].

11.3.1 Removal of balancing shaft bearing bushes

1 **Turn the engine** into a position where the balancing shaft eccentrics point downwards.

2 **Loosen the screws (6) ,** from the shaft the bearings of which is to be removed.

3 **Loosen the screws (7)**and remove the upper bearing shells (8).

4 **Lift up the balancing shaft (9)**by the crane. The bearings comes out with the shaft and You can take them away.

5 **Move the shaft to the direction of the free end** and let the shaft down

6 **Loosen the fastening screws** (12) of the cover (11).

7 **Remove a locking wire** (14)and loosen the fastening screws (10) of the axial washer (13) at the free end of the shaft.

8 **Remove the shaft piece** (3).

9 **Lift the removing device 834001 inside the bearing** and tighten the nut of the pulling screw.

10 **Connect the hoses** of the hydraulic pump to the hydraulic tool.

11 **Pump pressure** into the hydraulic tool to remove the bearing bush. Pressure must not exceed the value stated in the chapter [07]. If the bearing bush is still sticking when the stated pressure is achieved, it may be necessary to knock at the opposite end of the shaft.

12 **Open the pump valve,** disconnect the hoses of the hydraulic tool and lift out the removing tool and bearing bush.

11.3.2 Installing balancing shaft bearing bushes

1 **Oil the bearing bushes surfaces**lightly with clean engine oil.

2 **Lift the mounting device 834001 with the bearing bush** to the place where the bearing is to be mounted and tighten the nut of the pulling screw.

3 **Connect the hoses** of the hydraulic pump to the hydraulic tool.

4 **Pump pressure** into the hydraulic tool install the bearing bush. Pressure must not exceed the value stated in the chapter [07].

5 **Open the pump valve,** disconnect the hoses of the hydraulic tool and lift out the hydraulic tool.

6 **Re-install the shaft piece** (3), clean the threads of the fastening screws (10) thoroughly and apply Loctite 242 to them.

7 **Put the axial washer (13) to end of the shaft**

8 **Tighten the screws** (10) to the stated torque and put the locking wire (14) to the screws.

9 **Re-install the cover** (11) and tighten the screws (12).

10 **Lift up the balancing shaft (9)** (by the crane) and move it back to direction of the flywheel.

11 **Put the bearings (4) to the shaft,** at the same time as you let it down.Install the bearing bracket.

12 **Clean the threads of the fastening screws (7)** thoroughly and apply Loctite 242 to them.

13 **Tighten the screws**(7) to the stated torque value. Lock with the wire.

14 **Clean the threads of the fastening screws (6)**thoroughly and apply Loctite 242 to them.

15 **Tighten the screws**(6) to the stated torque.

11.3.3 Removal of balancing shaft gear

1 **Turn the engine**into a position where the balancing shaft eccentrics point downwards.

2 **Follow the steps** in section [11.3.1].

3 **Loosen the screws (6)** and remove the shaft pieces (3).

11.3.4 Installing balancing shaft gear

1 **Push the driving gears of the balancing shafts** so that they mesh when the guiding pins are horizontal in relation to the centre line of the engine, [Fig 11-4].

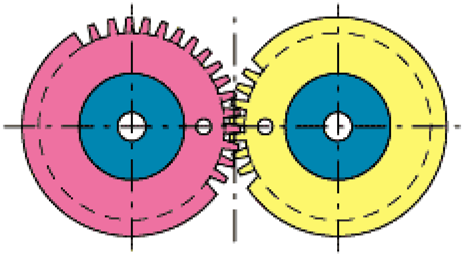

figure: 11-4 4R22 balancing arrangement (Phase 1)

2 **Push the intermediate gear in position** when the crankshaft is turned with cylinder 1 in TDC (top dead centre) and the balancing shafts with the guiding pins upwards, see [Fig 11-5].

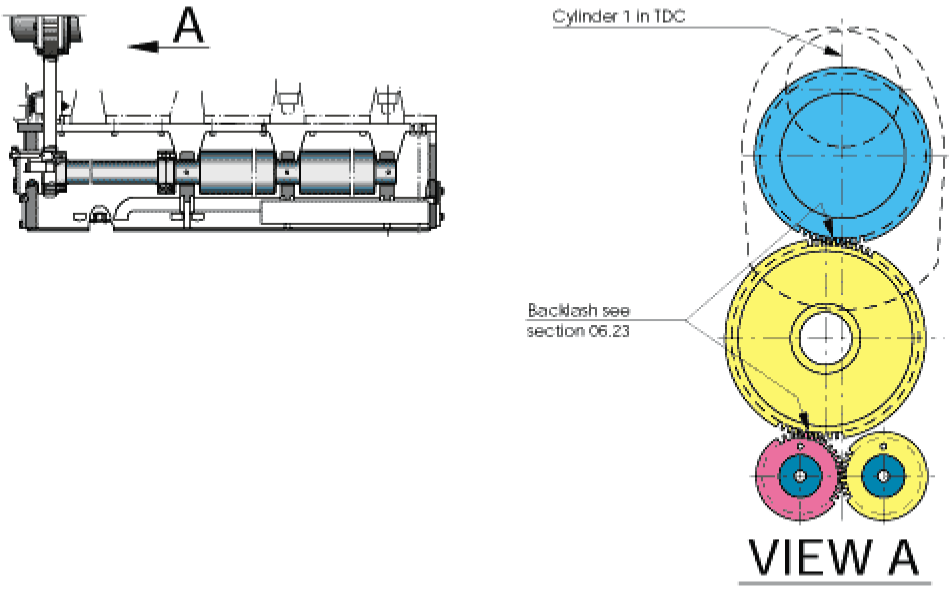

figure: 11-5 4R22 balancing arrangement (Phase 2)

11.4 Balancing mechanism for 8V22 engines

The eight-cylinder V-engine has four balancing wheels rotating at a speed twice the crankshaft speed. Each wheel is driven by the crankshaft through an intermediate gear. The bearing arrangement is similar to the one used in the camshaft intermediate gear. Normally the balancing arrangement needs no maintenance. In case the transmission has been opened, for example in connection with water pump exchange, it is absolutely necessary to make sure that the marks of the gears remain in their initial position. See [Fig 11-6] and [Fig 11-7].

11.4.1 Dismantling (at the free end)

1 **Remove the water pumps,** lube oil pump and the fuel feed pump as well as the pipes connected to the end cover.

2 **Remove the end cover.** Note that the end cover is fastened by 4 screws also from the inner side of the crankcase.

3 **Check the axial clearance,** section [06.2] pos. 23 B.

4 **Remove the screws** (1), (2) and (3).

5 **Remove the flange (4)** and the shaft (5). The whole package counterweights - gear wheel can now be removed.

6 **Check the bearing clearance,** section [06.2] pos. 23 B.

7 **If the bearing clearance exceeds the normal values** or if the bearing is found to be damaged, remove the bearing bushes (6) by using an extractor, see [Fig 11-6] View C.

11.4.2 Assembling (at the free end)

1 **Clean throughly the bearing housing,** i.e. the counterweights, and mount new bearings. The bearings should be cooled down with, for example, liquid air. Note that the longitudinal oil grooves (28) in the bushes shall point towards the centre of gravity of the counterweights (marked with a distinct mark), see [Fig 11-6] View C and [Fig 11-7].

2 **Mount the bush (13) to the shaft (5),**

3 **Apply LOCTITE 275 on the threads of the fixing screw (3) and tighten the screw to the torque of 450 Nm. Put the counterweights,** the shaft and the flange (4) to their places, apply LOCTITE 275 on the threads of the screw (1) and tighten the screw to the torque of 450 Nm.

4 **Measure with a dial indicator** the axial clearance of the bearing bushes in the counterbalance system (see section [06.2] pos. 23 B).

5 **Turn the crankshaft 30° clockwise** from the top dead centre of cylinder no. Al (in this position the crank pin of cylinder 1 points straight upwards).

6 **Re-install the end cover with help of the guiding pins.** Check that the hose seal against the underneath surface of the end cover comes to its place properly and that the under edge of the pump cover comes 0.15 ... 0.55 mm above the under edge of the engine block. Do not forget to fasten the end cover also from the inside of the block (4 screws).

7 **Re-install the water pumps.** Provided the assembly has been carried out correctly the counterweights now point downwards and the crank pin of cyl. 1 straight upwards, see [Fig 11-7].

11.4.3 Checking

1 **Turn the crankshaft 45° clockwise** (from the position when the crank pin of cylinder 1 points straight upwards). The counterweights rotate with a speed twice the speed of the crankshaft. This means that the counterweight on bank A should point straight to the side. The scribing mark on the counterweight is now visible through the hole (14) provided the assembly is correct, see [Fig 11-6] View C and [Fig 11-7].

2 **Turn the crankshaft further 90° clockwise.** The scribing mark of the counterweight on bank B should now be visible through the hole (14)**,** otherwise the assembly is to be repeated.

3 **Check the backlash of the gear wheel (12)** and the backlash of the water pump gear wheel through the holes in the cover (see section [06.2] pos. 19 and 23 b).

4 **Re-install the lube oil pump,** pipes and before start check that the bearings get lube oil.

Note!

When dismantling a water pump(s) it will affect the counterbalance system as it gets its driving force via the gear wheels of the water pumps.It is most convenient to turn the crankshaft 30° clockwise from the top dead centre of cylinder 1 (to the position when crank pin no. 1 points straight upwards and the counterweights point straight downwards). In this position the water pump(s) can be removed and installed without affection to the counterbalance system.

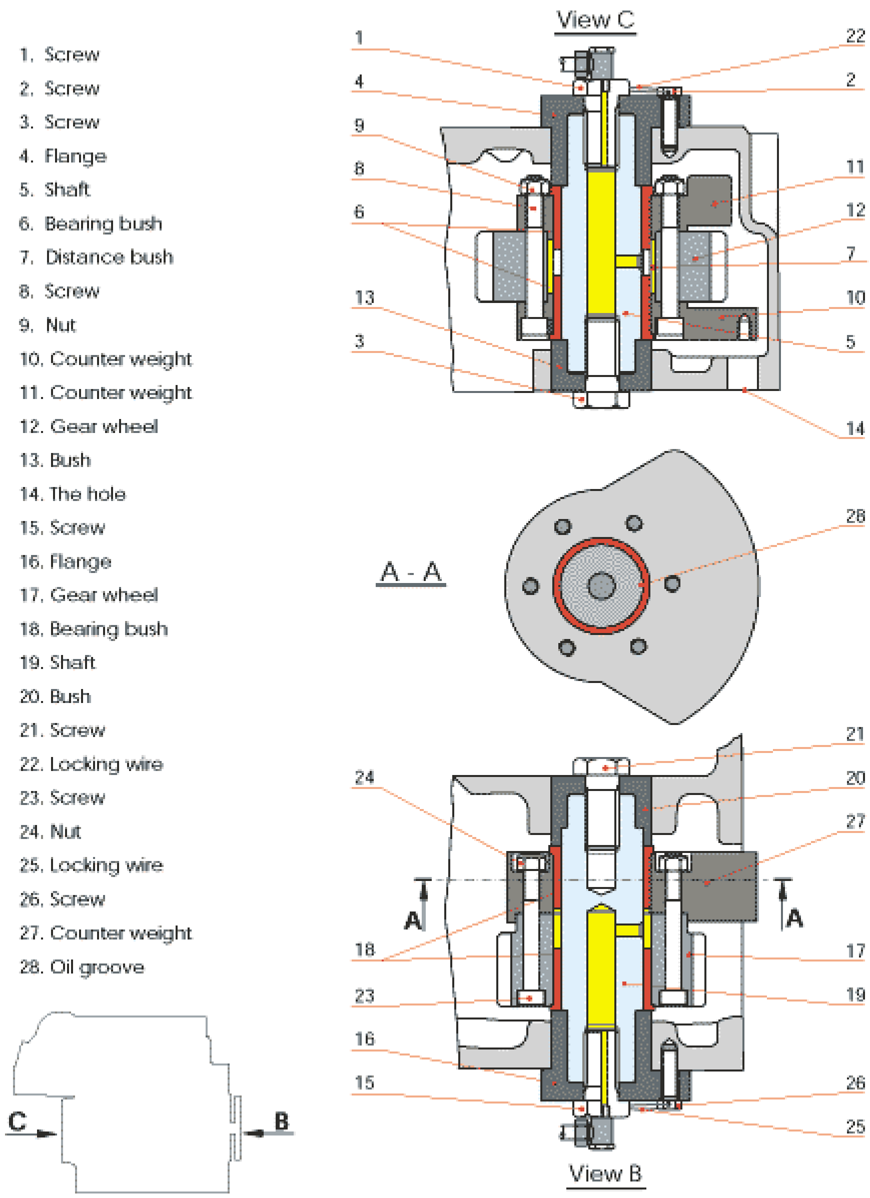

figure: 11-6 Balancing mechanism for 8V22

11.4.4 Dismantling (at the flywheel end)

1 **Check the axial clearance,** section [06.2] pos. 23 B.

2 **Unscrew the screw (15)** and remove the flange (16).

3 **Unscrew the screw (21)** and remove the shaft (19). The whole package counterweights - gear wheel can now be removed.

4 **Check the bearing clearance,** section [06.2] pos. 23 B.

5 **If the bearing clearance exceeds the normal values** or if the bearing is found to be damaged, remove the bearing bushes (18) by using an extractor, see [Fig 11-7] View B.

11.4.5 Assembling

1 **Clean throughly the bearing housing,** i.e. the counterweight and gear wheel and mount new bearings. The bearings should be cooled down with, for example, liquid air. Note that the longitudinal oil grooves (28) in the bushes shall point towards the centre of gravity of the counterweights (marked with a distinct mark).

2 **Mount the bush (20) to the shaft (19),** apply LOCTITE 275 on the threads of the fixing screw (21) and tighten the screw to the torque of 450 Nm.

3 **Turn the crankshaft 30° clockwise** from the top dead centre of cylinder 1 (in this position the crank pin of cylinder 1 points straight upwards), see [Fig 11-7].

4 **Put the counterweight,** the shaft (19) and the flange (16) to their places, apply LOCTITE 275 on the threads of the screw

(15) and tighten the screw to the torque of 450 Nm.

5 **Measure with a dial indicator** the axial clearance of the bearing bushes in the counterbalance system (see section [06.2] pos. 23 B).

Note!

The counterweights shall point straight downwards when the crank pin of cylinder 1 points straight upwards.

6 **Before start** check that the bearings get lube oil.

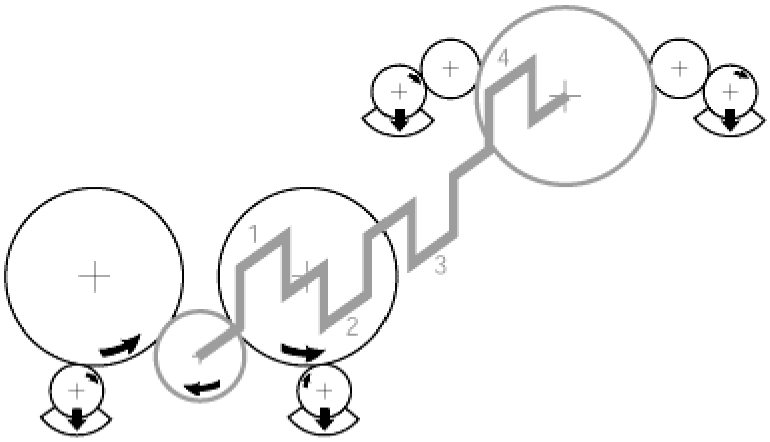

figure: 11-7 Diagram for 8V22 balancing system

12 Cylinder Head with Valves

version : 12-9601-00

12.1 General description

The cylinder heads are cast of special quality grey iron. Each head includes two inlet valves (10), two exhaust valves (9), a centrally located fuel injection valve (4), a starting valve (13) and an indicator valve (12).The cylinder heads are individually tightened to the engine block with four studs and hydraulically tightened nuts. A metallic gasket is sealing between the cylinder liner and the cylinder head.
V-engines have starting valves only on A-bank cylinders. On B-bank cylinders is the starting valve replaced with a dummy.
The inlet and exhaust valves are designed with hard-faced seat surfaces and chromium-plated stems and they tight against shrunk-in seat rings in the cylinder head. The exhaust valves are equipped with valve rotators (6). Also inlet valves can at request be delivered with valve rotators. The exhaust valve seats (8) are water-cooled.

1. Bearing bracket
2. Rocker arm
3. Yoke for valves
4. Injection valve
5. Cylinder head
6. Rotocap
7. Connection piece
8. Exhaust valve seat
9. Exhaust valve
10. Inlet valve
11. Inlet valve seat
12. Indicator valve
13. Starting valve
14. Push rod
15. Water pipe

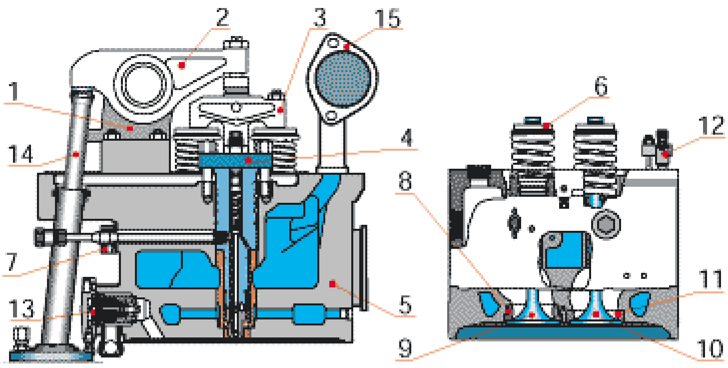

figure: 12-1 Cylinder head

The four screw and box-cone design is a traditional and well proven design for cylinder heads. The benefits of four screws is not only the ease of maintenance but it also allows the design of large and correctly designed channels for combustion air and exhaust gases. In a heavy fuel engine the correct material temperatures are a crucial factor to ensure long lifetime of the components being in contact with combustion gases. Efficient cooling and a rigid design is best achieved with the "double deck" design in which the flame plate is relatively thin and the mechanical load is transferred to the strong intermediate deck. The most sensitive areas of the cylinder head are cooled by drilled cooling channels optimized to distribute the water flow evenly around valves and the centrally located fuel injector.
The injection valve is described in chapter [16].

12.1.1 Functions

The flame plate of the cylinder head is a part of the combustion chamber. During the combustion, the flame plate is exposed to high pressures and high temperatures. The air flow is governed by two inlet valves in the flame plate. In a similar way, the exhaust gas is led from the cylinder through the cylinder head exhaust channel and to the exhaust manifold. The gas flow is governed by two exhaust valves.
The multi-orifice injection valve (4), as well as injection valve sleeve, is centrally mounted in the cylinder head. The injection valve sleeve holds the injection valve in position and separates the injection valve from the cooling water.
Each cylinder head is individually cooled by a water flow entering the cylinder head from the cylinder jacket through one single bore. There are drilled cooling passages to the exhaust valve seats. The cooling water is collected to a single flow after passing the flame plate and the seat rings.
The valve mechanism is lubricated from the lubricating oil system. The oil is led through a pipe from the valve tappet guide block to the rocker arm bracket (1). All other flows in the cylinder head are through drillings.
The controlled leaks of the injection valve is returned through the protection pipe.
The fuel pipe is also provided with protection against hazardous leaks from the high pressure connection stud.

12.2 Removing and mounting of the cylinder head

12.2.1 Removing of the cylinder head

1 **Drain cooling water.** Remove the cooling water outlet pipe.

2 **Remove the cylinder head cover,** the panel covering the injection pumps and exhaust insulation panel over the exhaust gas connection to the cylinder head.

3 **Remove the exhaust pipe fastening screws.**

4 **Remove the injection pipe.**

5 **Loosen the oil pipe and the starting air pipe.**

6 **Remove the rocker arm bracket (1)** and the push rods (14) as well as the caps of the cylinder head screws. Pull up the sleeve on the leakage pipe. Remove the screw on the splash shield.

7 **Lift the distance sleeves and hydraulic cylinders** 861020 in place and proceed with opening of cylinder head nuts.

8 **Remove the cylinder head nuts.**

9 **Apply the lifting tool** 832005.

10 **Lift off the cylinder head.**

11 **Cover the cylinder opening** with a slab of wood or similar.

12 **Apply the caps to protect the screw threads.**

12.2.2 Installing the cylinder head

1 **Check the sealing rings** of the water, charge air and starting air connections and of the push rod protecting pipes, check the cylinder head gaskets. Clean and oil all sealing surfaces. Put the exhaust pipe sealing ring in place. If necessary, press it slightly to make it stick in the groove.

2 **Apply the lifting tool** 832005 to the cylinder head.

3 **Lift the head above the cylinder** and lower it carefully. When lowering the head, take care that the starting air connection pipe and the air pipe slide into the seals without force.

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

5 **Lift the hydraulic cylinders 861020 in place.** Screw on the cylinders, connect the hoses and proceed with tightening of the cylinder head screws.

6 **Apply the protecting caps** to the cylinder head screws.

7 **Fit the yokes.** The yokes must be fitted on the correct yoke guides.

Note the marks on the yokes: EX = exhaust valves; IN = inlet valves.

Check that all studs of the rocker arm bracket fastening are fully countersunk in the cylinder head before the rocker arm is mounted. If the studs are not fully screwed in, loosen them and apply LOCTITE 270 on the threads. Then screw in the studs completely in the cylinder head.

8 **Mount the push rod protecting pipes** and fit the push rods and the rocker arm bracket. Tighten the nuts to the torque stated in chapter 07., section [07.1].

9 **Connect the exhaust, oil, injection and starting air pipes** and fit the water outlet pipe.

10 **Adjust the valve clearances.**

11 **Mount the cylinder head cover,** injection pump panel and exhaust insulation panel.

12 **Before starting,** fill the engine circulating water system and turn the engine some revolutions the indicator valves being open.

12.2.3 General maintenance of the cylinder head

General maintenance of the cylinder head includes a thorough visual check, including water cooling spaces. Possible scale formation in cooling spaces can disturb the cooling effect and therefore it has to be cleaned, see chapter [02].
Combustion spaces must be inspected carefully for possible wear. Valve seats and the injection valve sleeve should be inspected for possible water leakage and replaced if necessary.
Valve guides should be checked and replaced if worn. O-rings must be replaced with new ones at every overhaul.
Sealing surfaces between the cylinder head and cylinder liner should be inspected and reconditioned if necessary.

12.2.4 Adjusting valve clearance and yoke

1 **Turn the engine to the TDC at ignition** for the cylinder concerned. See section [00.3].

2 **Loosen the locking nuts** of the adjusting screws on the rocker arm as well as on the yoke. Unscrew the adjusting screws to provide sample clearance.

3 **Press the fixed end of the yoke against the valve stem** by pressing down the adjustable end. Screw down the adjusting screw until it touches the valve end and note the position of the spanner. 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.

4 **Turn the adjusting screw** counter-clockwise to the middle position and lock the counter nut of the adjusting screw.

5 **Insert a feeler gauge** corresponding to the valve clearance (see chapter [06]) between the pressure surface of the yoke and the shoe of the rocker arm. Tighten the adjusting screw until the feeler gauge can be somewhat moved to and fro. Tighten the locking nut while fixing the adjusting screw. Check that the clearance has not changed while tightening.

1. Adjusting screw for rocker arm
2. Counter nut
3. Adjusting screw for valve yoke
4. Counter nut

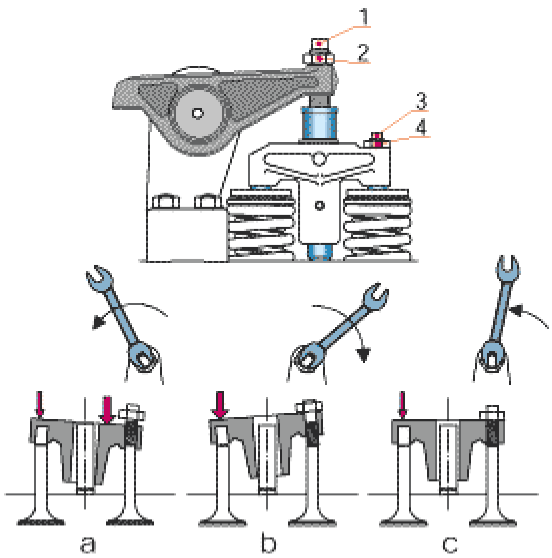

figure: 12-2 Adjusting valve clearance

12.3 Inlet and exhaust valves and seat rings

12.3.1 General description

The cylinder head has four valves fitted, two inlet valves and two exhaust valves. All the valves are made of surface-treated heat resistant steel. The valves move in cast iron guides, which are press fitted in the cylinder head and can be replaced. The valve guides have an O-ring (sealing against the valve stem), which is located at the top of the guide bore.
The valves are provided with one valve spring per valve and valve rotating devices or valve spring retainers.
Valve seat rings are fitted in the cylinder head for both inlet and exhaust valves. The exhaust valve seat rings are cooled and hence provided with two O-rings.

12.3.2 Dismantling the valves

1 **Fit the tool assembly** 846010 according to [Fig 12-3].

2 **Depress the springs** by turning the device clockwise.

3 **Knock at the center** of the valve discs, one at a time, whereby the cotters come loose and can be removed.

4 **Unload the tool.** The spring retainers and the springs can now be removed.

5 **Check that the valves move** easily in the guides.

Caution!

Note in which guide each valve was situated before removing them.

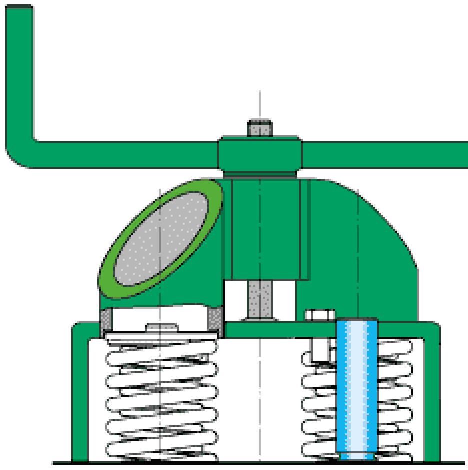

figure: 12-3 Tool assembly for dismantling valves

12.3.3 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 the sketch [Fig 12-4]. The measure "Y" should be more than 5 mm (nominal 6 mm) and measure "Z" should be less than 2 mm. If the measures exceed these limits the valve must be replaced.

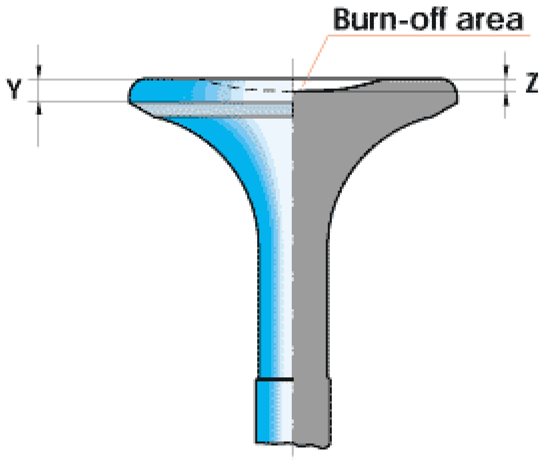

figure: 12-4 Control of the burning off on valve

3 **Check the sealing faces** at the valves and the sealing rings. For this purpose it is recommended to apply a thin layer of fine lapping compound to the valve seat and rub the valve slightly against the seat a few times by hand. If the sealing faces are bright or if there is a coherent sealing face grinding is not recommended. If there is slight pitting, only, lapping is recommended. If the pitting extends over nearly the entire sealing face or if imperfect sealing is observed the valve and the seat should be reground.

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.

4 **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.

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

1 **Fit the turning tool 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.

12.3.5 Machine grinding

If there is deep pitting or other damage, the valve and seat should be ground by machine:

Note!

The valve should be cooled by water during the grinding.

1 **Seat face of the valve.** The seat angle of the exhaust valve is 30° and the angle of the inlet valve is 20°, both with a tolerance of -0.5° to achieve contact to the seat at the periphery. Minimum allowable edge thickness of the valve is 5.2 mm; after that the valve must be replaced by a new one.

2 **Seat ring for the inlet valve.** The seat angle of the inlet valve seat ring is 20° with a tolerance of +0.15°. The seat can be ground until the outer seat diameter is 74 mm; after that the ring must be replaced by a new one.

3 **Seat ring for the exhaust valve.** The seat angle of the exhaust valve seat ring is 30° with a tolerance of +0.20°. The seat can be ground until the outer seat diameter is 73 mm.

Note!

After grinding a light lapping is recommended to provide contact between valve and seat.

12.3.6 Change of the seat ring

12.3.6.1 Removal of the old ring

The seat rings can be changed when the valves are removed.
The exhaust seat ring can most conveniently be removed hydraulically by using tool 837024 and inlet seat ring by using tool [837019], which can be ordered from engine manufacturer. In case the special tool is not available a flat bar or a scrapped valve can be used.

1 **Fit a scrapped valve to the seat** and weld it to the seat by electric beam welding.

Also a flat bar of the dimensions 10x30 mm can be used.

2 **Press or knock** out the ring through the valve guide with an arbor.

12.3.7 Fitting a new inlet valve seat ring

1 **Check the bore diameter** in the cylinder head, see section [06.2], pos. 12 in this manual.

2 **The ring can be assembled** by freezing in with liquid air of -190°C, the cylinder head temperature being minimum 20°C, or by pressing in with a guided arbor. Always make sure that the ring contacts the bottom of the bore.

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

12.3.8 Fitting a new exhaust valve seat ring

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

2 **For fitting an exhaust valve seat ring** the tool [834002] is required.

3 **Check the bore diameters** in the cylinder head.

4 **Cool the seat ring** in a thermostat controlled freeze box to -15 - 30°C.

Note!

The seal rings will be damaged at lower temperatures.

5 **Put the new seal ring** on the seat ring and apply Loctite 272 on the bores in the cylinder head and on the corresponding surfaces of the seat ring.

6 **Put the seat ring** into the guiding bush and press in the seat with the guided arbor.

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

8 **Keep the cylinder head temperature** at minimum 20°C for six hours to harden the locking fluid.

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

Note!

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

12.3.9 Reassembling of the engine valves

1 **Check the valve springs** for cracks and wear marks on the coils. If any, replace the springs by new ones.

2 **Put the 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 **Check that the exhaust valve rotators turn smoothly** by hand. If the movement between upper and lower part of the rotator is not smooth and free, exchange the complete rotator.

6 **Put on the valve springs** and spring discs and compress the springs with the tool set. Fit the valve cotters and unload the springs. Check that the valve cotters fit properly.

12.4 Indicator valve

12.4.1 Operation and maintenance of the indicator valve

The inside construction of the indicator valve is such that the pressure in the cylinder tightens it. Consequently the force needed to close the valve is relatively low. The valve has a left-handed screw and is opened and closed respectively as follows, [Fig 12-5]. Use the T-handle wrench [808001] to open and close the indicator valve.

1 **When starting the engine** the indicator valves should be closed using only so weak a force that the sealing surfaces go together. The pressure of the cylinder will push them tightly together.

2 **When stopping the engine,** the indicator valves should be opened only half a turn. Then the tightening caused by a temperature decrease cannot have an effect.

3 **When opening the indicator valve**for measuring the cylinder pressure, tightening to open position by force must be avoided.

4 **When closing the indicator valve** after measuring the cylinder pressure, only a weak torque is needed. A so called "finger torque" is usually enough.

5 **Add a high temperature lubricant** (up to 1000°C) to the valve stem threads when you feel that it is not moving easily.

Use the right T-handle wrench to open and close the indicator valve.

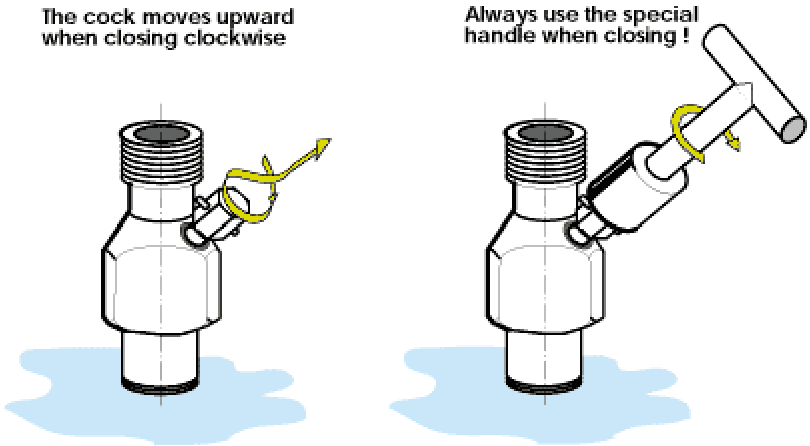

figure: 12-5 Open and close indicator valve

13.1 General description

The camshaft is driven by the crankshaft (1), [Fig 13-1], through a gearing. The gear (2) on the crankshaft is split and fixed to a flange on the crankshaft with axial screws (4). These screws as well as the fastening screws of the gear are locked with Loctite 242. A pair of intermediate wheels (5) and (6) are pivoted on a bearing journal.

The camshaft driving gear (18) is guided to the camshaft bearing journal with a pin (22) and fastened by means of a flange connection between the bearing piece (20) and the camshaft extension (25). The camshaft extension supports also a worm gear (23) for the speed governor drive and the overspeed trip (in the V-engine on the A-bank). An oil jet provides for lubrication and cooling of the gears.

The camshaft rotates with half of the engine speed in the same direction as the engine.

13.2 Intermediate gears and camshaft gear

The intermediate gear wheels are case hardened. The wheels have a common shaft and are fixed to each other by a screw connection. The lubricating for the bearings is arranged through drilling's in the shaft from a distributing pipe.

The basic adjustment of valve injection is done with the intermediate gearwheel pair. The timing can be adjusted if the gear wheels are rotated in relation to each other. Basic adjustment are marked on the gear wheels.

Note!

The valves and the pistons will come in contact with each other if the valve timing is set wrong, which will cause serious damages to the engine.

13.2.1 Maintenance of camshaft gearing

Whenever the opportunity occurs, check the condition of the gears. Measure tooth backlash and bearing clearances, see section [06.2]. An early detection of any tooth damage can prevent serious damage.

13.2.2 Basic adjustment of valve timing

The basic adjustment of the valve and injection timing is done by changing the relative position between the intermediate wheels (5) and (6). If the position is changed, the position of the camshaft is changed in relation to the crankshaft.

Note!

The relative position between the two wheels is adjusted at the factory and should not be changed unless it is absolutely necessary.

1 **Remove the cover** (30).

2 **Loosen the fastening nuts** (7), by rotating the crankshaft (1).

3 **After loosen the last fastening screw** turn the crankshaft as much as necessary. The bigger intermediate gear wheel should then rotate while the smaller intermediate gear wheel should stand still.

4 **Tighten the nuts** (7) for the intermediate gear wheels to stated torque when the desired movement is reached and turn the crankshaft as much as it is necessary.

5 **Check the valve timing** of one cylinder and the fuel injection timing.

6 **Mount the cover (30).**

13.2.3 Removing of camshaft driving gear

Note!

The pair of intermediate gears should not be disassembled unless necessary because the two wheels are adjusted between each other to give correct cam positions on each cylinder bank. Before removing the gearing, check the tooth and bearing clearances at intervals according to chapter [04].

1 **Remove the camshaft cover,** the gear covers and the governor (all necessary covers and pipes).

2 **Unscrew the screws** (28), and remove the cover.

3 **Remove the locking wire** and unscrew the screws (29). Withdraw the overspeed trip device and the overspeed trip housing.

4 **Unscrew the screws** (19) of the flange connection and withdraw the camshaft extension (25).

5 **Unscrew the screws** (21) of the camshaft driving gear. Remove the camshaft gear (18).

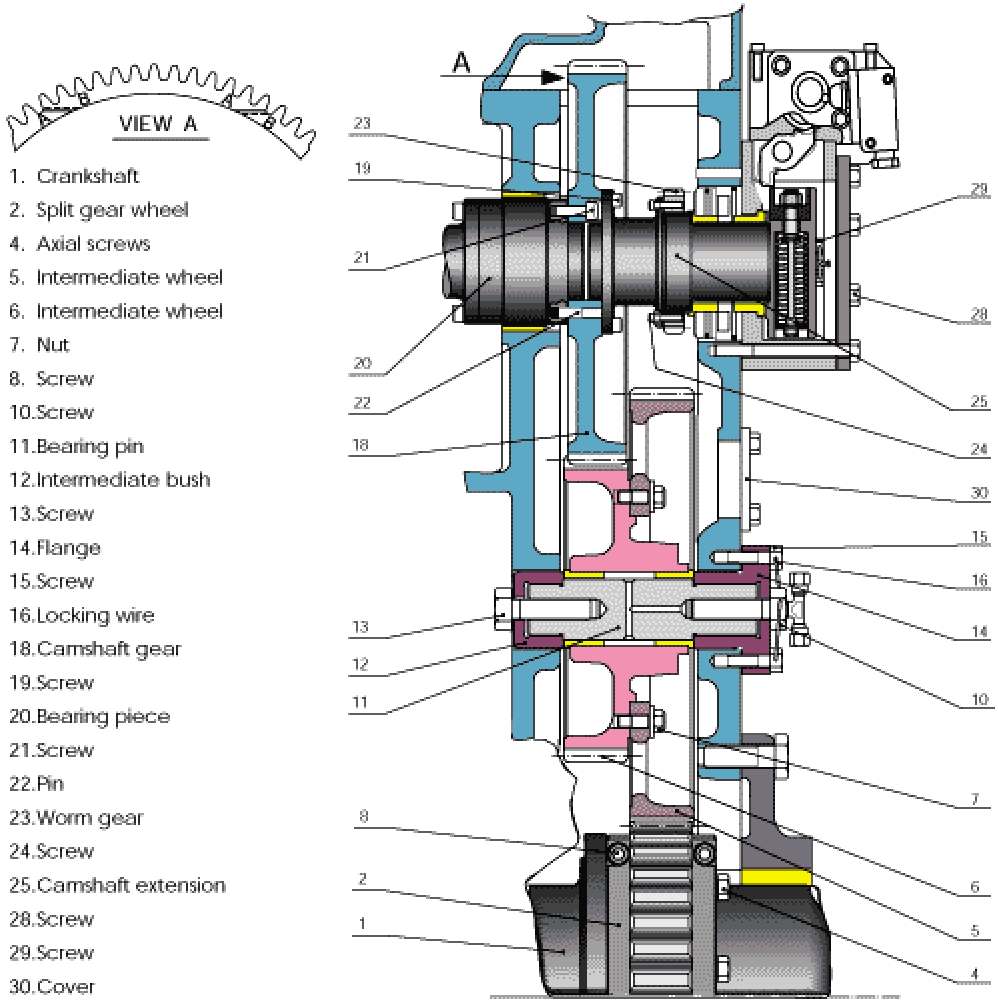

figure: 13-1 Camshaft driving gear

6 **Loosen the screws** (10) and (15) (2 pcs) in the order mentioned. Remove the flange (14). Put a hexagon socket wrench on the hexagon end of the bearing pin and a ring spanner on screw (13) and loosen screw (13) by turning the bearing pin.

7 **Turn the crankshaft** until the flywheel hole (diameter 60 mm) at the inside of the rim is in front of the intermediate wheel bearing pin (Not 22/26 engines).

8 **Press out the bearing pin.** (11)

9 **The intermediate wheel** can now be lifted out, for instance by means of a rope sling. Remove screw (13) and intermediate bush (12).

13.2.4 Mounting of the driving camshaft gear

1 **Turn the crankshaft as follows:**

a) In-line engines: Turn the crankshaft to the TDC for cylinder No 1.
b) V-engines, the camshaft gearings of both cylinder banks removed: Turn the crankshaft to the TDC for cylinder No A1.
c) V-engines, the gearing of the A-bank installed, the gearing of the B-bank removed: Turn the crankshaft to the TDC at ignition for cylinder No A1. Then turn 60° to the TDC for cylinder No B1 (55° for 16V22).
d) V-engines, the gearing of the B-bank installed, the gearing of the A-bank removed: Turn the crankshaft to the TDC at ignition for cylinder No B1. Then turn to the TDC for cylinder No A1.
In connection with turning, place the bearing pin in the hole of the flywheel rim which is nearest to "Cyl. 1 TDC".

2 **Place the intermediate bush** (12) in its bore and lower the completely assembled intermediate wheel for instance by means of a rope sling. (By using a mirror, check that the marked tooth of the intermediate wheel meshes properly with the marked tooth gap on the split gear (2). See [Fig 13-1] and [Fig 13-2].

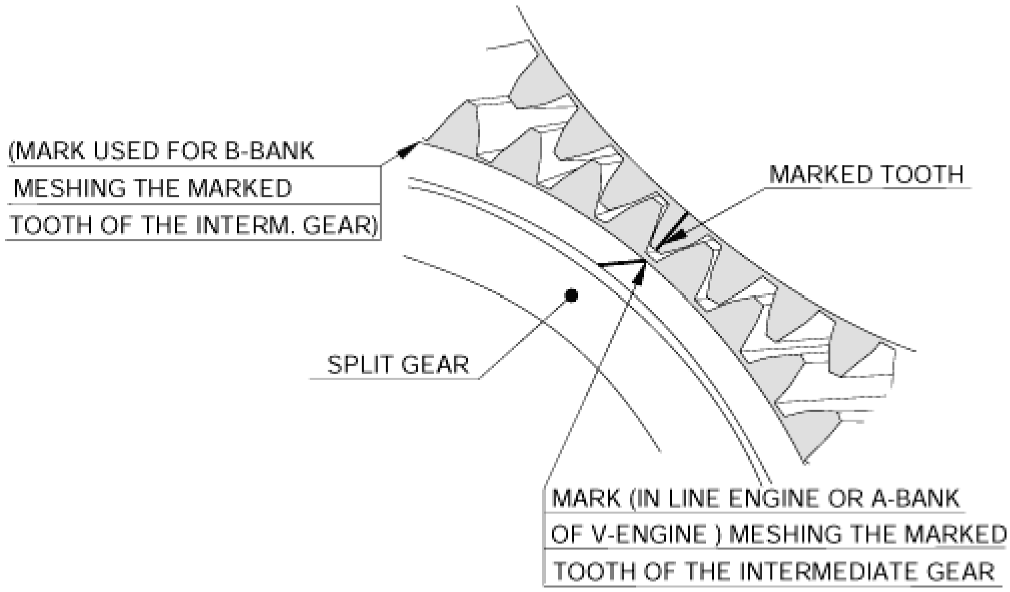

figure: 13-2 View inside the engine

3 **Place the bearing pin** (11) into the intermediate gear and the bush (12).

4 **Coat the screw** (13) with Loctite 242 (screw it in by hand).

5 **Fit the flange** (14) together with a new O-ring and tighten the screw (15). First tighten the screw (10) and then the screw (13). Tightening torque, see section [07].

6 **Measure the axial clearance** of the intermediate wheel bearing and the backlash between the wheels (2) and (5). See section [06.2] pos. 13.

7 **Apply locking wire** between the screws (10) and (15).

8 **The camshaft driving gear** is meshed in and is installed so that the mark matches the surface of the engine block, see [Fig 13-1]; view A. On the driving gear there are marks for the A-bank as well as for the B-bank. The guiding pin (22) indicates the fixing of the camshaft and the gear in relation to each other. Tighten the screws (21) to torque according to section [07.1]. These screws are treated with locking compound and may be refused twice before the locking effect is lost, in case they are only slightly cleaned with rags.

9 **Install the overspeed trip** and the extension piece (25).

10 **Measure the backlash** between the wheels (6) and (18). See section [06.2] pos. 13.

11 **Install the adjacent components.** For covers not having gaskets, use non-drying sealing compound.

12 **Check the firing sequence** of the V-engine cylinder banks, see section [01.1].

13 **Check the valve timing** of one cylinder, at least (see section [06]). If any details of the gearing have been changed, the injection pump delivery start should be checked according to section [16.4].

14 **Mount all the covers.**

Note!

Check the valve timing before the engine is started.

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 [13.2.2], the split gear wheel (2) can be removed from the crankshaft, [Fig 13-1].

1 **Remove the end cover half.**

2 **Loosen the fastening screws** (8).

3 **Unscrew the axial screws** (4).

4 **Unscrew the fastening screws** (8) 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 **Apply Loctite 242 on the threads** of the screws (4) and (8).

3 **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 (4) and (8) by hand.

4 **Tighten the axial screws** (4) to a torque of 10 Nm and check that contact is established between the gear wheel and the crankshaft flange.

5 **Tighten the fastening screws** (8) to a torque of 40 Nm. The screws closer to the crankshaft flange are to be tightened at first.

6 **Tighten the fastening screws** (8) to stated torque, see section [07.1]. The screws closer to the crankshaft flange are to be tightened at first.

7 **Tighten the axial screws** (4) to the stated torque, see section [07.1].

8 **Check the base tangent length.** W is measured across (W1 and W2) and perpendicular (W3 and W4) (to joint 7 teeth). Maximum Deviation = 0.02 mm.

9 **Check the gear wheel roundness.** Place a cylindrical pin (ø10 mm) in the tooth gap as shown in [Fig 13-3]. Turn the engine and use a dial indicator to get an indication for the diameters (D1, D2 and D3). The maximum permissible difference between the measured values is 0.03 mm.

10 **Mount the end cover half.**

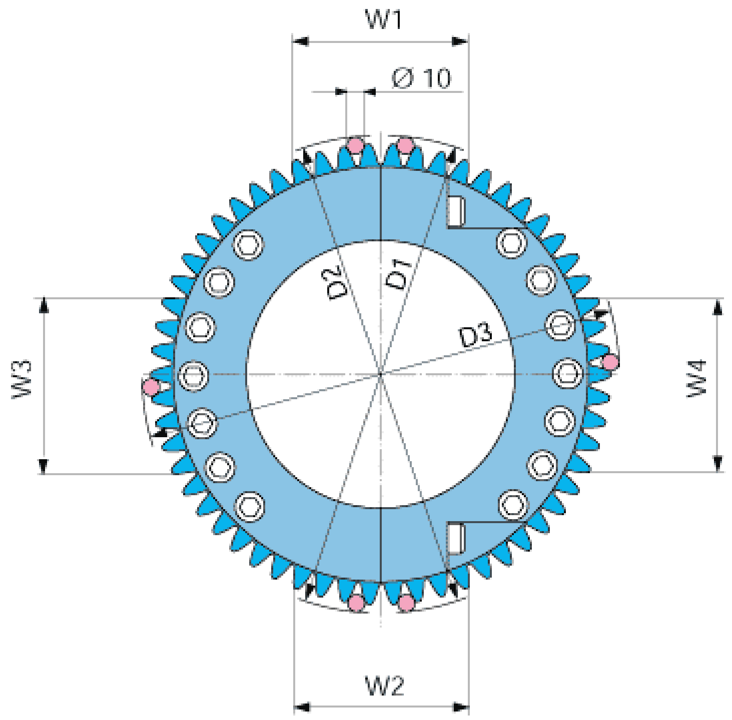

figure: 13-3 Measuring split gear wheel

14.1 Valve mechanism

14.1.1 Description of valve mechanism

The valve mechanism operates the inlet and outlet valves at the required timing. The valve mechanism consists of valve tappets (11) of the piston type moving in a common guide block casing (7), tubular push rods (4) with ball joints, drop forged rocker arms (3) pivoted in a rocker arm bearing bracket (13) and a yoke (14) guided by a yoke pin in the cylinder head, ([Fig 14-1]).

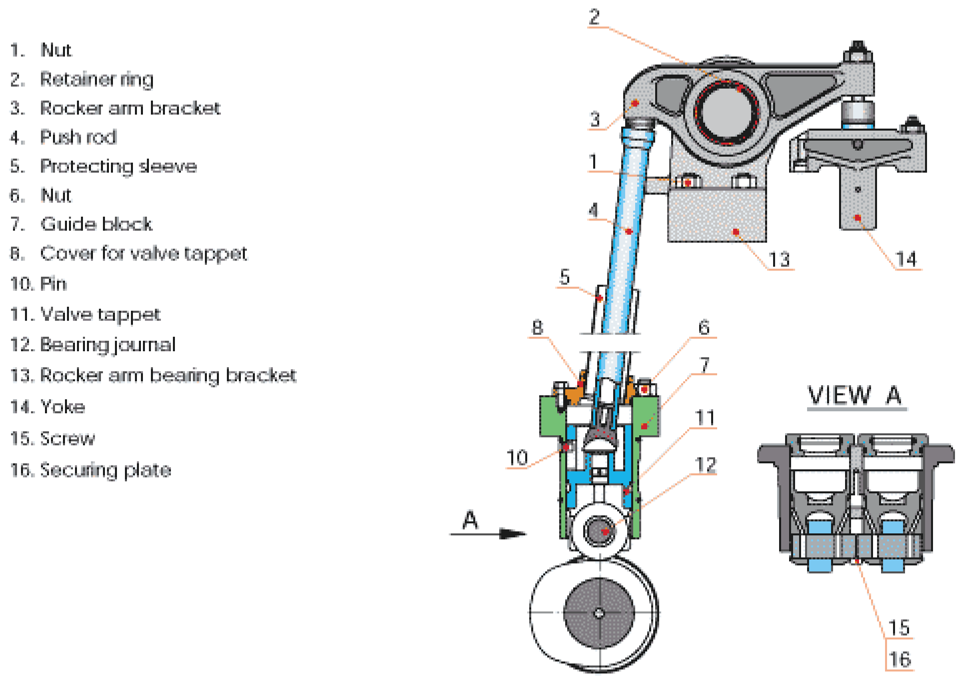

figure: 14-1 Valve mechanism

14.1.2 Function

The movement of the valve tappets is governed by the cam profile. The valve tappets transfer the movement through push rods to the rocker arms. The rocker arms operate the inlet and exhaust valves through a yoke.
The bracket for the rocker arms is made of nodular cast iron and is fastened to the cylinder head by four screws. The steel journal is press fitted in the bracket.
The rocker arms act on the valve yokes, which are guided by an eccentrically placed yoke pin. To compensate for heat expansion a clearance must exist between the rocker arm and yoke. All adjustments are made on a cold engine, and this work procedure is explained in chapter [12].
Each valve yoke operates two valves simultaneously.
The valve mechanism is lubricated from the main flow with pipe connections. All flows in the cylinder head are through drillings. Oil to the valve yokes passes through the rocker arm bracket. Oil which is passed to the yoke tappet is lubricating the tappet and by splashing through the bores also lubricates the valve rotators. Oil is returned to the crankcase in a free flow through the protecting sleeves for the push rod.

14.1.3 Maintenance of valve mechanism

Normally, the valve mechanism needs no maintenance, but inspection and adjustment of the components and check for wear should be done at intervals according to section [04]. Data are stated in chapter [06]. The valve clearance adjustments are described in section [12.4].
Components, which have been working together for a long time and thus have worn somewhat in relation to each other should be installed in the same place to avoid unnecessary wear.

14.1.3.1 Dismantling and assembling the rocker arm bearing bracket

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 and the injection pump are on the base circle of the cam.

3 **Remove the rocker arm bearing bracket (13)** from the cylinder head by loosening the nuts (1), see [Fig 14-1].

4 **The rocker arms** can be dismantled by removing the locking ring (2) with the pliers [843001].

5 **When cleaning** the rocker arm bearing bracket and the bearing pin, pay special attention to the oil holes.

6 **Inspect and measure** the details for wear (section [06.2]).

7 **Oil the details** with lubricating oil before reassembling.

8 **Measure the axial clearance** of the rocker arms after assembling, minimum 0.15 mm, see chapter [06].

14.1.3.2 Dismantling and assembling the valve tappets

1 **Remove the rocker arm bracket** (13) first.

2 **Remove the push rods** (4) and the protecting sleeves (5)

3 **Unscrew the nuts** (6) and remove the guide block (7) from the engine.

4 **Remove the cover** (8) and the guiding pin (10) to clean and measure the guide block bores. Change the O-rings of the cover if they are damaged or hard.

5 **Remove the screws (15)** and remove the securing plate (16).

6 **The valve tappets** (11) can now be withdrawn. Mark the components so that they can be refitted in the same position.

7 **The tappet rollers,** bushes and pins are separated by pushing out the pin (12).

14.1.3.3 Inspection of valve mechanism parts

1 **When cleaning the components,** pay special attention to the angular holes in the tappet and the pin.

2 **Inspect and measure** the components for damage and wear, section [06.2].

3 **When reassembling,** it is advisable to lubricate the components with clean lubricating oil.

4 **When fitting the securing plate** (16), use undamaged corners of the sheet to lock the screws (15). Take care that there are - or are caused - no metal parts which may come loose.

5 **Before fitting the guide block,** check the flange gasket and replace it by a new one, if necessary.

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 with case hardened sliding surface.
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 overspeed trip device (7) and a helical gear (8) for driving of the speed governor. At the free end the camshaft has an extension (5) with a cam for operating the starting air distributor (not valid for 4-cylinder engines with starting motor).
In a B-bank on the V-engine the camshaft has only an axial bearing situated at the driving end.

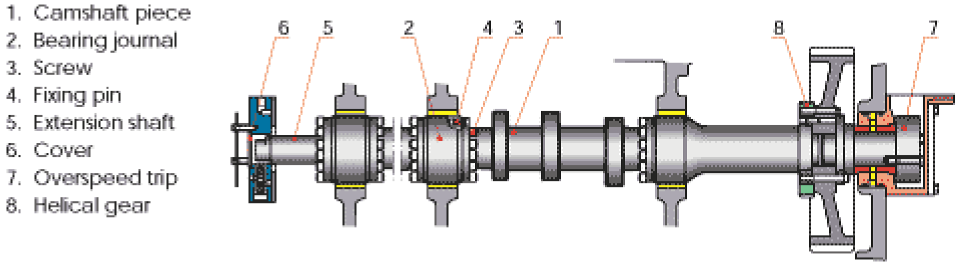

figure: 14-2 Camshaft

14.2.2 Removing of camshaft piece

1 **Remove the camshaft cover,** the injection pump and the guide blocks from the cylinder concerned.

2 **Unscrew the flange connection screws** (3) from both ends of the camshaft piece by using the tool combination in Fig 05-15B.

3 **Remove the cover** (6) from the starting air distributor and 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 free end side rocker arm bearing bracket(s) has to be removed if the crankshaft is turned, otherwise there will be contact between valve and piston.

14.2.3 Mounting of camshaft piece

1 **Clean and degrease** the flange connection surfaces and the threaded holes.

2 **Fit the fixing pins** (4) and retainer rings with 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 compress the camshaft.

4 **Fit the flange connection screws** dry and tighten by using the tool combination in Fig 05-15B. The flange connection screws are treated with locking compound and can be used three times if carefully cleaned.

5 **Check the valve tappets** and rollers carefully. Even slightly damaged tappet rollers have to be changed.

6 **Mount the cover** (6) of the starting air distributor, the guide blocks, injection pumps etc.

7 **Check the valve clearance** and fuel delivery start of the injection pumps on all cylinders towards the free end.

14.3 Camshaft bearings

14.3.1 Inspection of the camshaft bearing

When the camshaft bearing journal has been removed, the inner diameter of the bearing bush can be measured in situ by using a ball anvil micrometer screw. The wear limit is stated in section [06.2] pos. 10. 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 from the starting air distributor.**

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

4 **Move the part of the camshaft** located towards the free end of the engine maximum 20 mm in the direction of the free end by using a suitable lever.

Caution!

Before moving the camshaft axially, unload the pressure of the cams by removing the rocker arm brackets and injection pumps.

5 **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.

14.3.2 Removing of the camshaft bearing bush

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

2 **Remove the camshaft bearing journal.**

3 **Assemble the removing device** 834001 according to [Fig 14-3]. When end bearing is removed, insert the guide sleeve (part of 834001) the thicker part being directed towards the middle of the engine.

Caution!

Before moving the camshaft axially, unload the pressure of the cams by removing the rocker arm brackets and injection pumps.

4 **Tighten the hydraulic cylinder** by light tensioning of the pull screw.

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

6 **Pump pressure to the hydraulic tool** to withdraw the bearing bush. **The pressure must not exceed 600 bar.** If the bearing bush does not move when this pressure is achieved, a light knock at the end flange of the tool may be necessary.

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

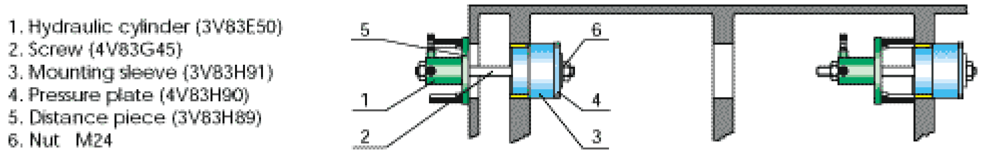

figure: 14-3 Removing of camshaft bearing bush

14.3.3 Mounting of the camshaft bearing bush

1 **Lubricate the new bearing bush** lightly with clean engine oil at the outer surface and put it on the guide sleeve.

2 **Assemble the mounting device** 834001 according to [Fig 14-4]. If an end bearing is mounted, insert the guide sleeve so the thinner part is directed towards the middle of the engine. Position the mark on the bearing bush against that on the engine block.

3 **Tighten the hydraulic cylinder** by light tensioning of the pull screw.

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

5 **Pump pressure to the hydraulic tool** to the bearing bush. **The pressure must not exceed 600 bar.**

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

7 **Lubricate the bearing bush running surface** and fit the cam shaft bearing journal.

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

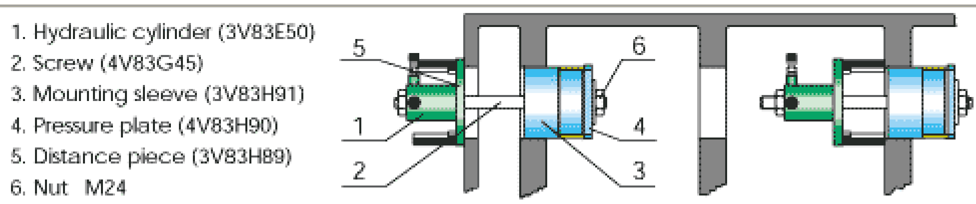

figure: 14-4 Mounting of camshaft bearing bush

15.1 Turbocharger

15.1.1 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. 12 and 16 cylinder V-engines have two identical cooler inserts in a common housing.
The turbocharger is cooled with water and connected to the engine cooling system. The turbocharger has a lubricating oil system of its own.
The air outlet casing is connected to the air duct and the exhaust pipes to the gas inlet casing through metal bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions.

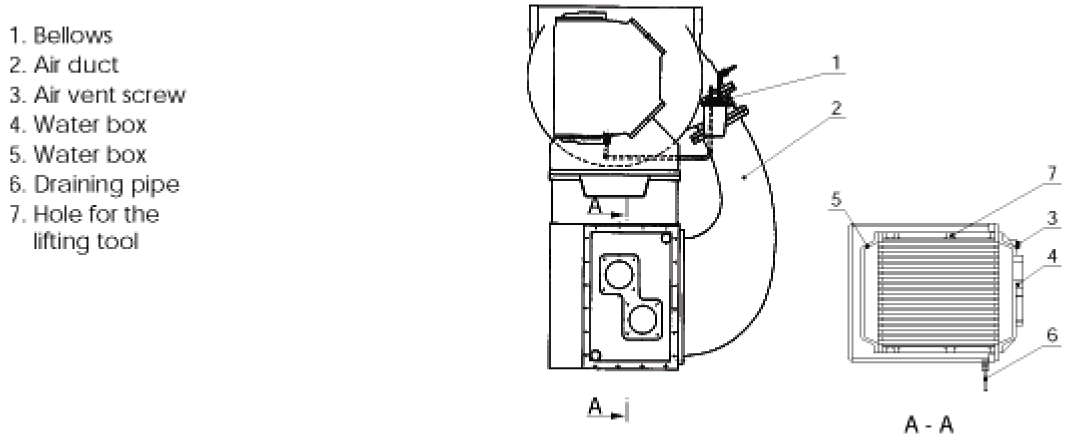

figure: 15-1 Turbocharger and air cooler

Turbochargers for engines running on heavy fuel (22HF and 22HE) are equipped with cleaning devices for washing by water of the compressor and the turbine.
Turbochargers for engines running on marine diesel fuel (22MD) are equipped with cleaning devices for washing by water of the compressor.

15.1.2 Turbocharger maintenance

Normal overhauls can be carried out without removing the turbo-charger from the engine.
When dismantling, remove the connection pipes for water. Loosen the exhaust inlet and outlet pipes.
When reassembling, take care that all seals are intact. High temperature resistant lubricants are used for exhaust pipe screws.
Maintenance of the turbocharger is carried out according to section [15.1.3] and to the instructions of the turbocharger manufacturer. It is recommended to use the service net of the engine manufacturer or the turbocharger manufacturer.

15.1.3 Water cleaning of turbine during operation (applies to engines running on heavy fuel)

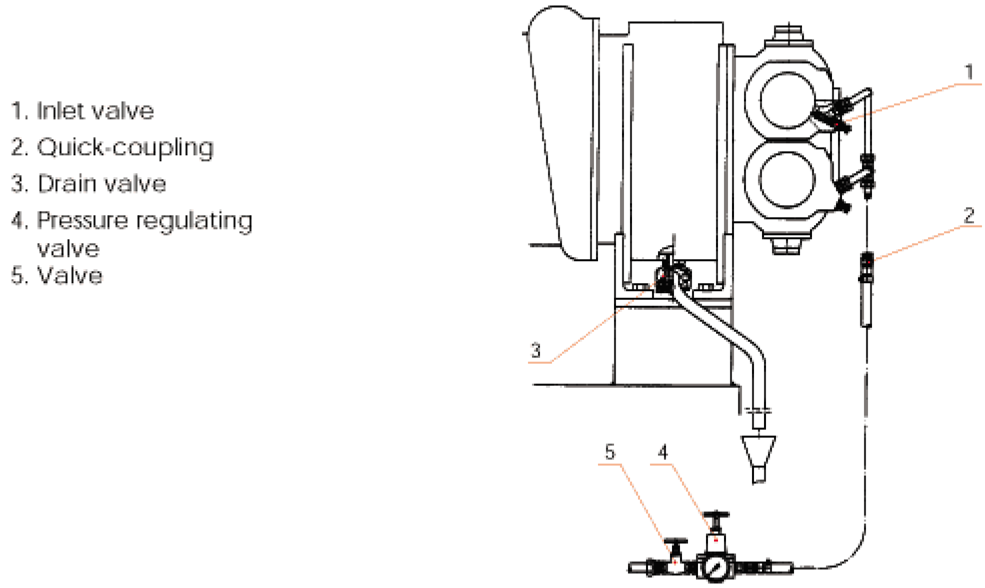

figure: 15-2 Water cleaning of turbine

15.1.3.1 Principles of the cleaning method

As practical experiences show, the dirt deposits on the turbine side can be reduced by periodic cleaning (washing) during operation.
The principle is to employ water-droplet action to clean the guard, turbine nozzle and turbine blades of combustion products while the engine is

running at reduced power, by a combination of scouring action and partial dissolving of the deposits.
Under no circumstances the turbine should be allowed to run long enough to become very heavily coated with deposits.
A fouled turbine can be recognized by abnormal exhaust gas tem-perature, charger speed and charge air pressure. In some case it can lead to compressor surging. The bearings of the turbocharger are also sensitive to the imbalance caused by the deposits.
The water supply is conveyed to an injector (1) with fixed size orifice, fitted into each branch of the engine exhaust gas pipe. Turbochargers, which have one gas inlet, are provided with two injectors on the same pipe. The injectors are connected to a quick-coupling (2).

15.1.3.2 Cleaning intervals

The optimum period between cleaning operations will obviously vary from one installation to another, and will depend on the type of fuel used as well as on running conditions. Under "average" conditions, with engines running on residual fuels, experience shows that cleaning intervals of about 200 hours are satisfactory.

15.1.3.3 Water flow rates

The necessary water flow is basically dependent on the volume of gas and its temperature. The flow should be adjusted so that about 50 to 70% of the water is evaporated and escapes through the exhaust gases, while the remaining water is drained through the tap in the exhaust casing.
Recommended water flow rates:

Water cleaning of turbine		
Turbocharger size	∆p (bar)	Water flow (l/min)
VTR 161	1	2.0 - 3.0
VTR 201	1	3.0 - 4.5
VTR 251	1	4.5-7

Additives or solvents must not be used in the cleaning water. The use of salt water is out of question.

15.1.3.4 Cleaning procedure:

1 **Record blower charge air pressure,** cylinder exhaust gas tem-peratures, charger speed, for later use to assess efficacy of cleaning.

2 **Reduce engine load to between 10 and 20% of full load rating.**

3 **Open the valves (1),** and check that they are not clogged.

4 **Connect the water hose.**

5 **Open the drain valve (3)** and check that it is clear of block-age.

6 **Open the valve (5) and valves (1) completely.**

7 **The pressure control valve (4) must be adjusted to a pressure of 1 bar.**

8 **Check the water drains through the drain pipe.**

9 **Cleaning is terminated after about 10 min.** The water supply valve (5) is closed.

10 **After termination of water injection the engine must run for three minutes at constant load** until all parts are dry.

11 **Shut all valves and disconnect the hose** to ensure that no water can possibly enter the exhaust pipes except during the cleaning periods.

12 **Resume normal engine operation at higher output** and, as soon as possible, repeat the readings taken under step 1. for comparative purposes.

Water washing of the compressor side during operation, see
enclosed separate manual for the turbocharger.

15.2 Charge air cooler

15.2.1 Maintenance of charge air cooler

Condensate from the air is drained through a small pipe (6) at the bottom of the cooler housing, after the insert. Exa-mine 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 condi-tions with very high humidity) the cooler insert may be leak and must be dismantled and pressure tested.

At longer stops, the cooler should be either completely filled or completely emptied, as a half-filled cooler increases the risk of corrosion. If there is a risk of sinking water level in the system when the engine is stopped, drain the cooler completely. Open the air vent screw (3) to avoid vacuum when draining.
Clean and pressure test the cooler at intervals according to section [04] or if the receiver temperature cannot be held within stipulated values at full load.
Always when cleaning, check for corrosion.

15.2.2 Cleaning cooler insert

A) Remove the cooling water pipes. Loosen the cooler insert flange screws and withdraw the insert until the thread or the hole (7) for the lifting tool is visible. If necessary, use the screws in the two threaded extractor holes in the flange.
B) Apply the lifting tool and lift off the insert.
C) Clean the air side with a degreasing liquid and blow pressure air or steam through the insert. See also section [18.5.3].
D) Remove the water boxed (4) and (5) to make the water side accessible.
E) Clean the water side according to the instructions for oil cooler in section [18.5.4].
F) Check the gaskets.
G) Reassemble the cooler insert and mount it on the engine. Check tightness when starting up.

15.1 Turbocharger

15.1.1 General description

The turbocharger utilizes the energy of the engine exhaust gas to feed more air to the engine, thereby offering advantages such as boosted engine power output and thriftier fuel consumption.
The exhaust gas discharged from the cylinders of the engine are led through the exhaust manifold into the turbocharger and are accelerated in the turbine housing before the passing of the turbine wheel. The turbine rotates at a high speed and turns the compressor wheel mounted on the same shaft as the turbine wheel. The compressor takes air, often through a filter, from the engine surroundings and compresses it to a higher pressure. A higher pressure results in a higher density of the air which means that a larger amount of air is forced into the cylinder and correspondingly a larger amount of fuel can be burnt. This increases the effective pressure during the combustion and thus increases the output.
During the compression of the air in the turbocharger, the air is heated up mainly due to the compression and partly due to losses in the compression work in the compressor. The hot and compressed air flows through an air cooler. When the air is cooled, the density of the air is further increased.
The turbocharger can be divided into two basic sections: The turbine wheel that is driven by the exhaust gas and the compressor wheel which forces intake air through the air cooler and into the cylinder. The turbine wheel is of the axial turbine type, i.e. the gas passes axially through the turbine. The shaft connecting the turbine wheel to the compressor wheel is supported by two roller bearings, one in each end of the shaft. The compressor is of radial type.
The gas inlet and outlet housings of the turbocharger are cooled with water from the HT-cooling water circuit of the engine. The water flows through the turbocharger bracket and is divided into two streams before it goes into the turbocharger, both to the gas inlet casing and to the gas outlet casing. After the turbocharger the flows are joined to a common venting pipe, from which air is evacuated. The water flows further down to the HT-thermostatic valve. The flow is regulated by a fixed orifice at the outlet from the casings. Normally these orifices should not be changed.
The turbocharger rotor is provided with roller bearings for low friction. The bearings are lubricated an internal lubricating oil system in the turbocharger. See chapter 02., section [02.2.5] for approved lubricating oils.
The air outlet housing of the turbocharger is connected to the air duct (2) of the engine through a piece of metal bellows (1), which allows thermal expansion of the air duct, see [Fig 15-1].

Caution!

The surfaces of the turbocharger and the air duct are hot.

The exhaust pipes from the engine are also connected to the turbocharger through metal expansion bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions.
The turbocharger is equipped with cleaning devices for cleaning of both the compressor and the turbine by water injection.
The turbocharger is supported by a bracket, which is fastened to the engine block at the free end of the engine with screws.

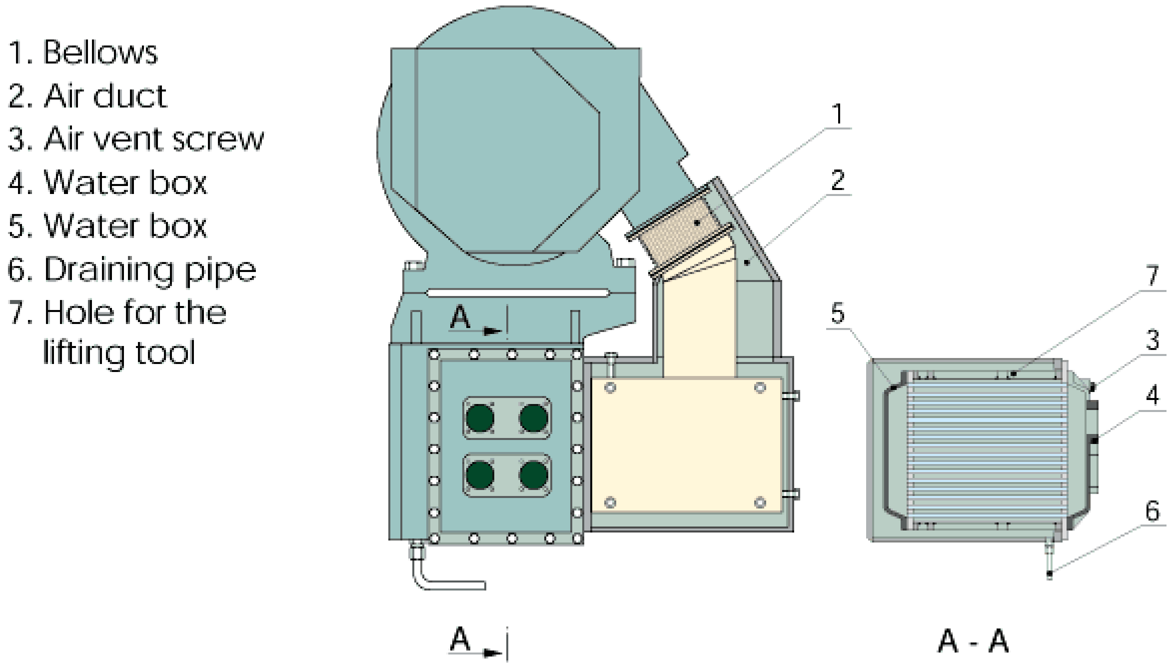

figure: 15-1 Turbocharger and air cooler

15.1.2 Turbocharger maintenance

Maintenance of the turbocharger is carried out according to the instructions of the turbocharger manufacturer. It is recommended to use the service net of the engine manufacturer or the turbocharger manufacturer.

Normal overhauls can be carried out without removing the turbocharger from the engine. When dismantling, remove the protecting covers and the connection pipes for water. Loosen the exhaust inlet and outlet pipes.

When reassembling, take care that all seals are intact. High temperature resistant lubricants are used for exhaust pipe screws.

15.1.3 Water cleaning of turbine

During operation, especially when running on heavy fuel, impurities in the exhaust gases sticks to the turbine wheel and other components in the turbocharger exhaust side. A dirty turbine causes higher temperatures of the exhaust gas and higher stresses of the bearings due to imbalance.

Practical experiences show that the deposits on the turbine side can be reduced by periodic cleaning (washing) during operation and the overhaul periods can be extended.

During long time 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 has probably been 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 [15.1.4]. 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, while the remaining water drains from the exhaust casing through the valve. It is important that all of the water does not evaporate, since the cleaning effect is based upon the water solubility of the deposits and the mechanical effect of the striking water drops. 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 flow is controlled by regulating the pressure to a suitable level by a pressure regulating valve (4). Before the cleaning is started, the exhaust gas pressure before the turbocharger should be measured by means of the pressure gauge on the pressure regulating valve. The correct adjustment of the pressure regulating valve during the cleaning procedure is the exhaust gas pressure plus Δp in the table below.

Water cleaning of turbine		
Turbocharger size	Δp (bar)	Water flow (l/min)
VTR 184	0.8-1.3	6.0 - 7.5
VTR 214	1.4-2.2	8.0 - 10.0

During cleaning, the exhaust housing is drained through the valve (3), see [Fig 15-2].

Additives or solvents must not be used in the cleaning water. The use of salt water is out of question.

1. Inlet valve
2. Quick-coupling
3. Drain valve
4. Pressure regulating valve
5. Valve

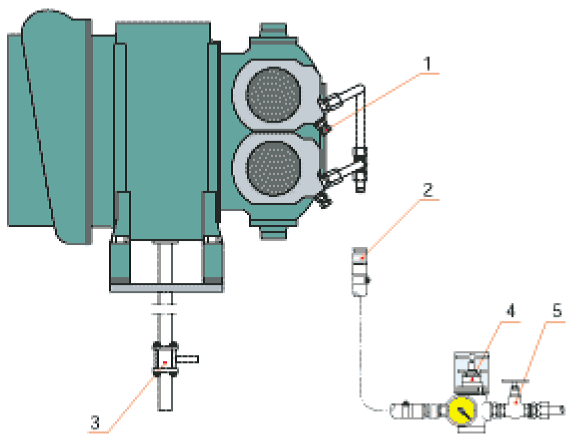

figure: 15-2 Water cleaning of turbine

15.1.4 Cleaning procedure of turbine

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** to about 35 kW/cyl at nominal speed (between 20 and 40 % of full load rating) or reduce speed to between 550 and 600 RPM with fixed propeller. Run the engine for five minutes on this load before the washing is started. **Maximum allowed exhaust gas temperature after cylinder is 380°C!**

Note!

The charge air pressure should be higher than 0.2 bar. Otherwise there is a risk that the cleaning water flows into the bearing casing of the turbocharger.

3 **Open valves (1),** and check that they are not clogged.

4 **Measure the exhaust gas pressure.**

5 **Connect water hose.**

6 **Open drain valve (3)** and check that it is clear of blockage.

7 **Open valve** (5) slowly within 30 seconds and increase the water flow until about 0.1 l/min flows off through the drain opening of the gas outlet casing. Adjust the pressure control valve to an over pressure Δp according to the table above increased with the exhaust gas pressure measured before the turbocharger.

The best cleaning effect is achieved if one inlet at a time is opened and washed.

8 **The washing time** is about 10 minutes. A measure for the washing time is also the cleanliness and clarity of the drained water. If the drained water is still dirty after 10 minutes washing, finish the cleaning procedure but **repeat it after one to two hour of normal operation.**

9 **After termination of water injection** the engine must run for three minutes at 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 minutes 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 load (20 - 40 % of full rated load).

15.1.5 Cleaning procedure of compressor

The compressor can be cleaned during operation by injecting water. The method is suitable, provided contamination is not too far advanced. If the deposit is very heavy and hard, the compressor must be cleaned mechanically.
The injected water does not act as a solvent, the cleaning effect is achieved by the physical impact of the drops on the deposit. It is therefore advisable to use clean water containing no additives either in the form of solvents or softening agents, which could be precipitated in the compressor and form a deposit.
Regular cleaning of the compressor prevents or delays the formation of deposit, but it does not eliminate the need for normal overhauls, for which the turbocharger has to be completely dismantled.
An inlet pipe, through which water can be injected into the compressor, is integrated in the air inlet casing and in the compressor casing.
The water must be injected while the engine is running and at the highest possible load, i. e. at a high compressor speed.
For an efficient washing it is important to inject all the water required within 4 - 10 seconds. This water quantity is 0.3 dm^3
For injection the measuring cup on the turbocharger bracket should be used, the latter being pressurized (e.g. by charge-air). Under no circumstances may the injection nozzle be connected to the water main flow through tap or a large tank, because this would allow an uncontrolled quantity of water to enter the turbocharger and the diesel engine.

Note!

Clean the compressor (air side) of the turbocharger at as high load as possible (full rated load).

The cleaning device for the compressor is used as follow:

1 **Record blower charge air pressure,** cylinder exhaust gas temperatures, charger speed, for later use to assess efficiency of the cleaning.

2 **Loosen knob (3) and remove cover (1).**

3 **Fill the cup with water up to 1 cm below the rim.**

4 **Re-fit cover (1) and tight screw knob (3).**

5 **Press button (2).** The button opens a valve which admits compressed air from the compressor through pipe (4). This forces the water through a passage and through the pipe (5) to the compressor.

6 **Repeat the readings** taken in step 1 above for comparative purposes. The success of injection can be recognized by the change in charge air pressure and in the exhaust gas temperature, [Fig 15-3].

Note!

If injection is not successful, it must not be repeated before ten minutes.

After injection, the engine should be run loaded for at least five minutes.

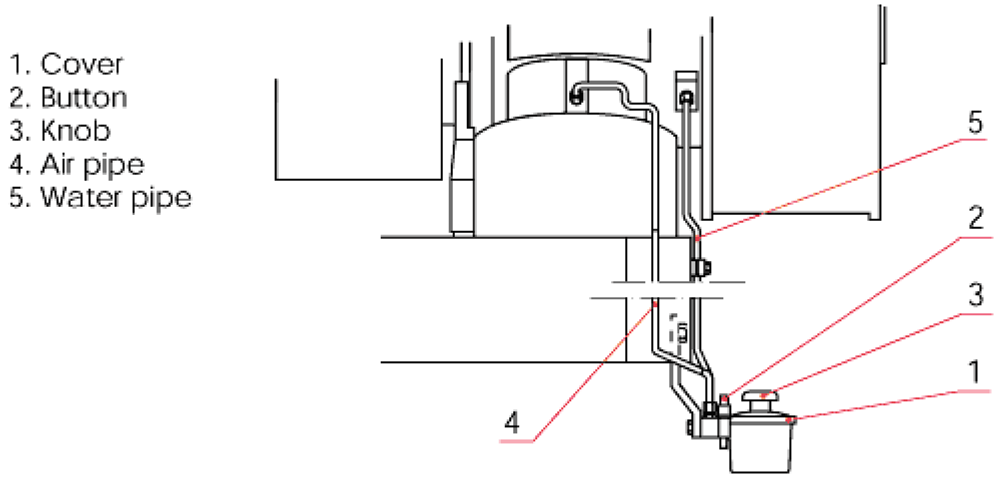

figure: 15-3 Water cleaning of compressor

15.1.6 Operation with damaged turbocharger

In case of a serious breakdown of the turbocharger, and if the situation do not allow the immediate repair or exchange of the turbocharger, the engine can temporarily be operated up to about 20 % of the nominal output of the engine with the turbocharger rotor removed.
For removing of the rotor, see instructions in the turbocharger manual.
It is to be noticed that the blocking of the rotor is not recommended as the engine will suffer less with the rotor completely removed.

Caution!

As the turbocharger is out of function the thermal load on the engine components will increase. Therefore the exhaust gas temperatures must be carefully watched during operation with removed rotor.

The exhaust gas temperatures after the cylinder heads must not exceed 500°C. If the engine is operated for longer periods with exhaust temperatures close to 500°C with the rotor removed there is a risk of piston seizure. This is due to the hot temperatures internally the piston (cooling gallery) causing the lubricating oil forming deposits in the cooling gallery. This will result in a poorer cooling effect with more thermal expansion of the piston, one of which in turn can lead to piston seizure.
During operation also closely follow that the lube oil temperature is kept at the level of normal operation.
Also other engine components will be exposed to the higher thermal loading.
After the turbocharger rotor has been removed in accordance with the instructions in the turbocharger manual, proceed in the following way:

1 **Remove the air duct (2)** shown in [Fig 15-1].

2 **Make sure** that the air entry into the charge air cooler housing is clean and that no foreign particles can enter the air inlet passage.

3 **When the engine is loaded** follow carefully the exhaust gas temperatures do not exceed 500°C. It is to be noted that the exhaust gas temperatures will increase by time and that the operator should first let the temperatures be stabilized at a certain load before the load is increased to the maximum allowable. The maximum allowable load is in any case 20 % of the nominal output of the engine.

The engine shall not be operated without the turbocharger in function for more than 100 hours. If the engine has been in operation with high thermal load it is recommended the engine supplier is contacted in order to clarify the need for exchange of components and/or inspections.

Note!

Both the turbochargers on a V-engine must be removed or blanked if one of them fails.

15.2 Charge air cooler

15.2.1 General maintenance

1 **Condensate from the air is drained** through a small pipe (6), [Fig 15-1] at the bottom of the cooler housing, after the insert. 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 emptied, as a half-filled cooler increases the risk of corrosion. If there is a risk of sinking water level in the system when the engine is stopped, drain the cooler completely. Open the air vent screw (3) to avoid vacuum when draining, [Fig 15-1].

3 **Clean and pressure test the cooler** at intervals according to section [04]. or if the receiver temperature cannot be held within stipulated values at full load.

4 **Always when cleaning,** check for corrosion.

15.2.2 Cleaning cooler insert

Cleaning of the water and air side heat exchange surfaces is imperative for a long and trouble free operation of the engine and must be done at regular intervals.

1 **Remove the cooling water pipes.** Loosen the cooler insert flange screws and withdraw the insert until the thread or the hole (7) for the lifting tool is visible. If necessary, use the screws in the two threaded extractor holes in the flange, [Fig 15-1].

2 **Apply the lifting tool** and lift off the insert.

3 **Clean the air side of the cooler** by immersing it in a chemical cleaning bath for at least 24 hours. We recommend that the detergent is circulated for the best cleaning effect. When cleaning is completed, the cooler should be flushed by applying a powerful water jet.

Note!

If the water jet attacks the cooling tubes vertically, i.e. in parallel to the fins, a pressure of 120 bar is suitable to be applied at a distance of two meters from the fin surface.

Caution!

Wrong use of water jet may cause damage to the fins, which results in an increased pressure drop over the air cooler.

4 **Clean the water side** by detaching the headers (4) and (5), see [Fig 15-1], from the cooler bundle and immersing the tube bundle into a chemical cleaning bath for at least 24 hours. Upon completion, follow the recommendations given for the air side.

5 **Check the gaskets** before reassembling the headers.

6 **Mount the cooler on the engine.**

7 **Vent the cooler** and check the tightness when starting up.

15.1 Turbocharger

15.1.1 General description

The turbocharger utilizes the energy of the engine exhaust gas to feed more air to the engine, thereby offering advantages such as boosted engine power output and thriftier fuel consumption.

The exhaust gas discharged from the cylinders of the engine are led through the exhaust manifold into the turbocharger and are accelerated in the turbine housing before the passing of the turbine wheel. The turbine rotates at a high speed and turns the compressor wheel mounted on the same shaft as the turbine wheel. The compressor takes air, often through a filter, from the engine surroundings and compresses it to a higher pressure. A higher pressure results in a higher density of the air which means that a larger amount of air is forced into the cylinder and correspondingly a larger amount of fuel can be burnt. This increases the effective pressure during the combustion and thus increases the output.

During the compression of the air in the turbocharger, the air is heated up mainly due to the compression and partly due to losses in the compression work in the compressor. The hot and compressed air flows through an air cooler. When the air is cooled, the density of the air is further increased.

The turbocharger can be divided into two basic sections: The turbine wheel that is driven by the exhaust gas and the compressor wheel which forces intake air through the air cooler and into the cylinder. The turbine wheel is of the axial turbine type, i.e. the gas passes axially through the turbine. The shaft connecting the turbine wheel to the compressor wheel is supported by two roller bearings, one in each end of the shaft. The compressor is of radial type.

The gas inlet and outlet housings of the turbocharger are cooled with water from the HT-cooling water circuit of the engine. The water flows through the turbocharger bracket and is divided into two streams before it goes into the turbocharger, both to the gas inlet casing and to the gas outlet casing. After the turbocharger the flows are joined to a common venting pipe, from which air is evacuated. The water flows further down to the HT-thermostatic valve. The flow is regulated by a fixed orifice at the outlet from the casings. Normally these orifices should not be changed.

The turbocharger rotor is provided with roller bearings for low friction. The bearings are lubricated an internal lubricating oil system in the turbocharger. See chapter 02., section [02.2.5] for approved lubricating oils.

The air outlet housing of the turbocharger is connected to the air duct (2) of the engine through a piece of metal bellows (1), which allows thermal expansion of the air duct, see [Fig 15-1].

Caution!

The surfaces of the turbocharger and the air duct are hot.

The exhaust pipes from the engine are also connected to the turbocharger through metal expansion bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions.

The turbocharger is equipped with cleaning devices for cleaning of both the compressor and the turbine by water injection.

The turbocharger is supported by a bracket, which is fastened to the engine block at the free end of the engine with screws.

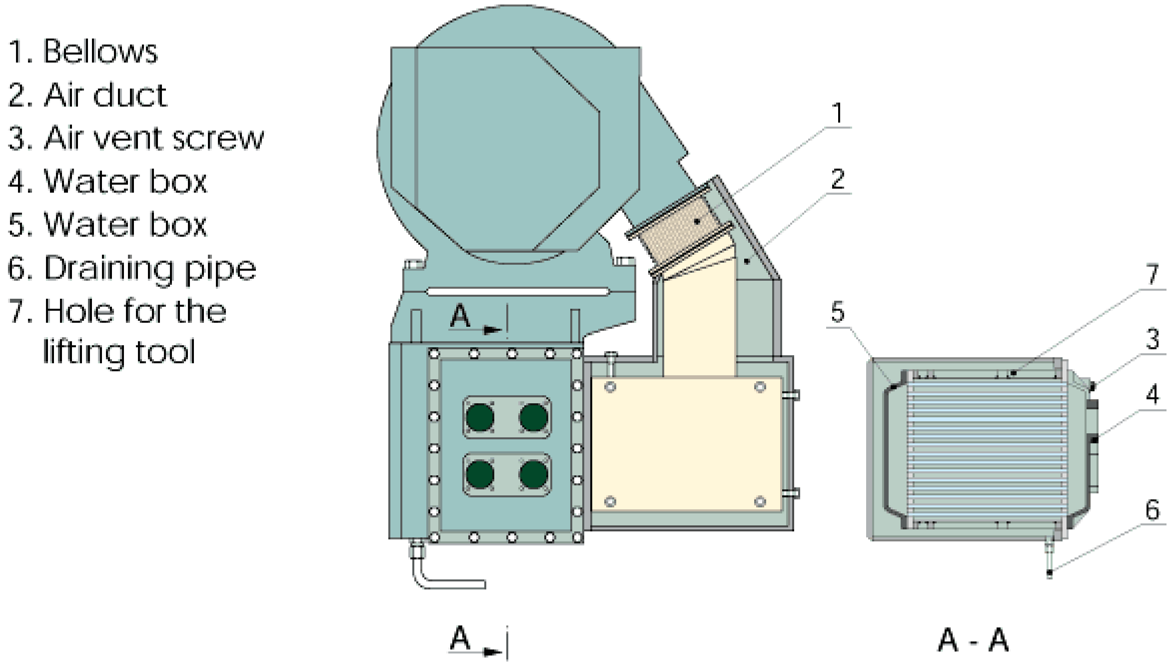

figure: 15-1 Turbocharger and air cooler

15.1.2 Turbocharger maintenance

Maintenance of the turbocharger is carried out according to the instructions of the turbocharger manufacturer. It is recommended to use the service net of the engine manufacturer or the turbocharger manufacturer.
Normal overhauls can be carried out without removing the turbocharger from the engine. When dismantling, remove the protecting covers and the connection pipes for water. Loosen the exhaust inlet and outlet pipes.
When reassembling, take care that all seals are intact. High temperature resistant lubricants are used for exhaust pipe screws.

15.1.3 Water cleaning of turbine

During operation, especially when running on heavy fuel, impurities in the exhaust gases sticks to the turbine wheel and other components in the turbocharger exhaust side. A dirty turbine causes higher temperatures of the exhaust gas and higher stresses of the bearings due to imbalance.
Practical experiences show that the deposits on the turbine side can be reduced by periodic cleaning (washing) during operation and the overhaul periods can be extended.
During long time 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 has probably been 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 [15.1.4]. 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, while the remaining water drains from the exhaust casing through the valve. It is important that all of the water does not evaporate, since the cleaning effect is based upon the water solubility of the deposits and the mechanical effect of the striking water drops. 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 flow is controlled by regulating the pressure to a suitable level by a pressure regulating valve (4). Before the cleaning is started, the exhaust gas pressure before the turbocharger should be measured by means of the pressure gauge on the pressure regulating valve. The correct adjustment of the pressure regulating valve during the cleaning procedure is the exhaust gas pressure plus Δp in the table below.

Water cleaning of turbine		
Turbocharger size	Δp (bar)	Water flow (l/min)
NR15/R, NR20	1	2.0 - 3.0
NR20/R	1	3.0 - 4.5

During cleaning, the exhaust housing is drained through the valve (3), see [Fig 15-2].

Additives or solvents must not be used in the cleaning water. The use of salt water is out of question.

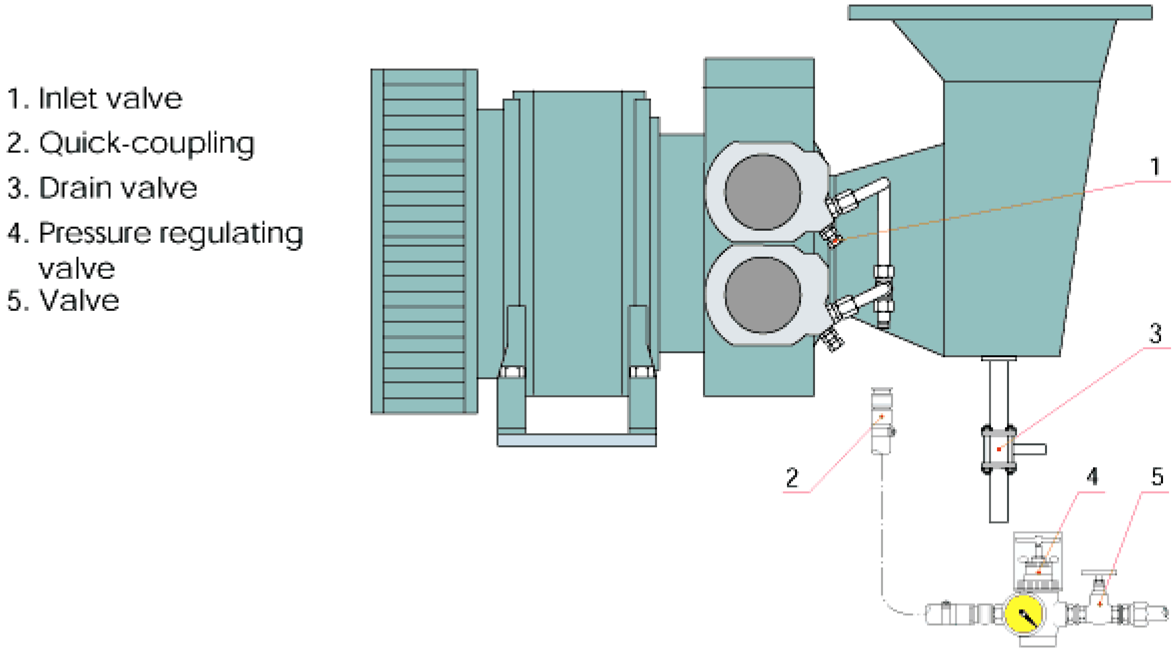

figure: 15-2 Water cleaning of turbine

15.1.4 Cleaning procedure of turbine

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** to about 35 kW/cyl at nominal speed (between 20 and 40 % of full load rating) or reduce speed to between 550 and 600 RPM with fixed propeller. Run the engine for five minutes on this load before the washing is started. **Maximum allowed exhaust gas temperature after cylinder is 380°C!**

Note!

The charge air pressure should be higher than 0.2 bar. Otherwise there is a risk that the cleaning water flows into the bearing casing of the turbocharger.

3 **Open valves (1),** and check that they are not clogged.

4 **Measure the exhaust gas pressure.**

5 **Connect water hose.**

6 **Open drain valve (3)** and check that it is clear of blockage.

7 **Open valve** (5) slowly within 30 seconds and increase the water flow until about 0.1 l/min flows off through the drain opening of the gas outlet casing. Adjust the pressure control valve to an over pressure Δp according to the table above increased with the exhaust gas pressure measured before the turbocharger.

The best cleaning effect is achieved if one inlet at a time is opened and washed.

8 **The washing time** is about 10 minutes. A measure for the washing time is also the cleanliness and clarity of the drained water. If the drained water is still dirty after 10 minutes washing, finish the cleaning procedure but **repeat it after one to two hour of normal operation.**

9 **After termination of water injection** the engine must run for three minutes at 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 minutes 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 load (20 - 40 % of full rated load).

15.1.5 Cleaning procedure of compressor

The compressor can be cleaned during operation by injecting water. The method is suitable, provided contamination is not too far advanced. If the deposit is very heavy and hard, the compressor must be cleaned mechanically.

The injected water does not act as a solvent, the cleaning effect is achieved by the physical impact of the drops on the deposit. It is therefore advisable to use clean water containing no additives either in the form of solvents or softening agents, which could be precipitated in the compressor and form a deposit.

Regular cleaning of the compressor prevents or delays the formation of deposit, but it does not eliminate the need for normal overhauls, for which the turbocharger has to be completely dismantled.

An inlet pipe, through which water can be injected into the compressor, is integrated in the air inlet casing and in the compressor casing.

The water must be injected while the engine is running and at the highest possible load, i. e. at a high compressor speed.

For an efficient washing it is important to inject all the water required within 4 - 10 seconds. This water quantity is 0.3 dm^3

For injection the measuring cup on the turbocharger bracket should be used, the latter being pressurized (e.g. by charge-air). Under no circumstances may the injection nozzle be connected to the water main flow through tap or a large tank, because this would allow an uncontrolled quantity of water to enter the turbocharger and the diesel engine.

Note!

Clean the compressor (air side) of the turbocharger at as high load as possible (full rated load).

The cleaning device for the compressor is used as follow:

1 **Record blower charge air pressure,** cylinder exhaust gas temperatures, charger speed, for later use to assess efficiency of the cleaning.

2 **Loosen knob (3) and remove cover (1).**

3 **Fill the cup with water up to 1 cm below the rim.**

4 **Re-fit cover (1) and tight screw knob (3).**

5 **Press button (2).** The button opens a valve which admits compressed air from the compressor through pipe (4). This forces the water through a passage and through the pipe (5) to the compressor.

6 **Repeat the readings** taken in step 1 above for comparative purposes. The success of injection can be recognized by the change in charge air pressure and in the exhaust gas temperature, [Fig 15-3].

Note!

If injection is not successful, it must not be repeated before ten minutes.

After injection, the engine should be run loaded for at least five minutes.

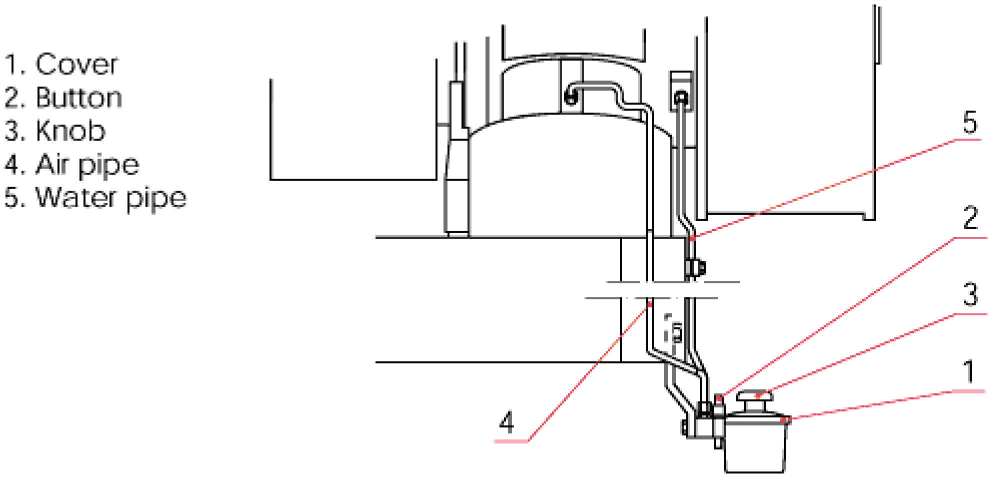

figure: 15-3 Water cleaning of compressor

15.1.6 Operation with damaged turbocharger

In case of a serious breakdown of the turbocharger, and if the situation do not allow the immediate repair or exchange of the turbocharger, the engine can temporarily be operated up to about 20 % of the nominal output of the engine with the turbocharger rotor removed.
For removing of the rotor, see instructions in the turbocharger manual.
It is to be noticed that the blocking of the rotor is not recommended as the engine will suffer less with the rotor completely removed.

Caution!

As the turbocharger is out of function the thermal load on the engine components will increase. Therefore the exhaust gas temperatures must be carefully watched during operation with removed rotor.

The exhaust gas temperatures after the cylinder heads must not exceed 500°C. If the engine is operated for longer periods with exhaust temperatures close to 500°C with the rotor removed there is a risk of piston seizure. This is due to the hot temperatures internally the piston (cooling gallery) causing the lubricating oil forming deposits in the cooling gallery. This will result in a poorer cooling effect with more thermal expansion of the piston, one of which in turn can lead to piston seizure.
During operation also closely follow that the lube oil temperature is kept at the level of normal operation.
Also other engine components will be exposed to the higher thermal loading.
After the turbocharger rotor has been removed in accordance with the instructions in the turbocharger manual, proceed in the following way:

1 **Remove the air duct (2)** shown in [Fig 15-1].

2 **Make sure** that the air entry into the charge air cooler housing is clean and that no foreign particles can enter the air inlet passage.

3 **When the engine is loaded** follow carefully the exhaust gas temperatures do not exceed 500°C. It is to be noted that the exhaust gas temperatures will increase by time and that the operator should first let the temperatures be stabilized at a certain load before the load is increased to the maximum allowable. The maximum allowable load is in any case 20 % of the nominal output of the engine.

The engine shall not be operated without the turbocharger in function for more than 100 hours. If the engine has been in operation with high thermal load it is recommended the engine supplier is contacted in order to clarify the need for exchange of components and/or inspections.

Note!

Both the turbochargers on a V-engine must be removed or blanked if one of them fails.

15.2 Charge air cooler

15.2.1 General maintenance

1 **Condensate from the air is drained** through a small pipe (6), [Fig 15-1] at the bottom of the cooler housing, after the insert. 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 emptied, as a half-filled cooler increases the risk of corrosion. If there is a risk of sinking water level in the system when the engine is stopped, drain the cooler completely. Open the air vent screw (3) to avoid vacuum when draining, [Fig 15-1].

3 **Clean and pressure test the cooler** at intervals according to section 04. or if the receiver temperature cannot be held within stipulated values at full load.

4 **Always when cleaning,** check for corrosion.

15.2.2 Cleaning cooler insert

Cleaning of the water and air side heat exchange surfaces is imperative for a long and trouble free operation of the engine and must be done at regular intervals.

1 **Remove the cooling water pipes.** Loosen the cooler insert flange screws and withdraw the insert until the thread or the hole (7) for the lifting tool is visible. If necessary, use the screws in the two threaded extractor holes in the flange, [Fig 15-1].

2 **Apply the lifting tool** and lift off the insert.

3 **Clean the air side of the cooler** by immersing it in a chemical cleaning bath for at least 24 hours. We recommend that the detergent is circulated for the best cleaning effect. When cleaning is completed, the cooler should be flushed by applying a powerful water jet.

Note!

If the water jet attacks the cooling tubes vertically, i.e. in parallel to the fins, a pressure of 120 bar is suitable to be applied at a distance of two meters from the fin surface.

Caution!

Wrong use of water jet may cause damage to the fins, which results in an increased pressure drop over the air cooler.

4 **Clean the water side** by detaching the headers (4) and (5), see [Fig 15-1], from the cooler bundle and immersing the tube bundle into a chemical cleaning bath for at least 24 hours. Upon completion, follow the recommendations given for the air side.

5 **Check the gaskets** before reassembling the headers.

6 **Mount the cooler on the engine.**

7 **Vent the cooler** and check the tightness when starting up.

16.1 General description

This chapter deals with the high pressure side of the fuel system including injection pump, high pressure pipe and injection valve.
The injection pumps are one-cylinder pumps with built-in roller tappets. The element is pressure lubricated and the drain fuel is led to a pipe system with atmospheric pressure outside the pump.
The injection pumps can be provided with an individual emergency stop cylinder coupled to an electro-pneumatic overspeed protecting system.
The high pressure line consists of a high pressure pipe and a high pressure connection piece, screwed sideways into the nozzle holder.
The injection valve consists of a nozzle holder and a multiorifice nozzle.

16.2 Injection pump

16.2.1 Function

The injection pump pressurizes fuel to the injection nozzle. It has a regulating mechanism for increasing or decreasing the fuel feed quantity according to the engine load and speed. The pumps are governed by the governor.
The plunger, pushed up by the camshaft via the roller tappet and pulled back by the spring acting on the roller tappet, reciprocate in the element on a predetermined stroke to feed fuel under pressure.
The plunger also controls the injected amount by adjusting the helix edge position relative to the discharge port. The plunger has an obliquely cut groove (lead) on its side. When the plunger is at the lowest position or bottom dead centre, fuel flows through the inlet port into the element bore. Rotation of the camshaft moves the plunger up. When the top edge of the plunger step is lined up with the ports, application of pressure to fuel begins. As the plunger moves up further, and the helix of the plunger meets with the ports, the high pressure fuel flows through the lead to the ports and the pressure feed of fuel is completed.
The plunger stroke during which the fuel is fed under pressure is called the effective stroke.
According to the engine load, the amount of fuel injected is increased or reduced by turning the plunger a certain angle to change the helix position where the ports are closed on the up stroke and hence increasing or reducing the effective stroke. The fuel rack is connected to the regulating mechanism of the governor. If the fuel rack is moved, the control sleeve in mesh with the rack is turned. Since the control sleeve acts on the plunger, the plunger turns with the control sleeve, thus the effective stroke changes and the injected fuel amount increases or decreases.
The element is of a mono-block design with integrated fuel delivery valve and constant pressure valve. The ports are of a special design to prevent cavitation.
The delivery valve, provided in the top of the element, performs the function of discharging the pressurized fuel to the injection pipe. The fuel compressed to a high pressure by the plunger forces the delivery valve to pop up. Once the effective stroke of the plunger ends, the delivery valve is brought back to its original position by the spring and blocks the fuel path, thereby preventing counter flow of the fuel.
After the effective stroke, the fuel is drawn back through the constant pressure valve from the high pressure injection pipe to instantly lower the residual pressure between the delivery valve and the nozzle. This draw-back effect improves the termination of an injection on the nozzle and prevents after injection dripping.

16.2.2 General description

The injection pump body consists of a cast housing provided with flanges for fastening against the engine block. The tappet with roller is located at the bottom of the housing. The roller rolls against the injection cam of the camshaft under the pressure of a spring (17). Between the tappet and the plunger there is a disc (28) against which the plunger end is pressed.
The pump element, of the mono-element type, is included in the top part of the housing and consists of a plunger (8) and a cylinder (7) which are matched between themselves and should be treated as a unit. The upper part, i.e. the fuel side, is sealed from below by O-rings (24). The element cylinder is pressure lubricated, which prevents fuel from penetrating downwards and mixing with lubricating oil.
The fuel delivery control, i.e. the rotary motion of the plunger, is actuated by a control rack through a control sleeve (14).
The delivery valves are located in the upper part of the element and in the head piece. The sealing element cylinder-head piece is metallic, see [Fig 16-1].

16.3 Maintenance of injection pump

Most maintenance operations can be done without removing the injection pump from the engine. It is recommendable that the engine will be run 5 minutes with light fuel before stopped for overhaul of injection pump. During maintenance utmost cleanliness must be observed.

16.3.1 Removal of injection pump

It is recommended that the engine run a 5 minutes with light fuel before it is stopped for overhaul of injection pump.

1 **Shut fuel supply** to the engine before removing the injection pump.

2 **Remove the fuel feed pipe elbows,** high pressure injection pipe and leak fuel pipe. Cover immediately all openings with tape or plugs to prevent dirt from entering the system.

3 **Remove the fastening screw (52)** for the cover (35) of the fuel injection equipment.

4 **Remove the pneumatic shutdown cylinder (53)** and the pipe from the distributing pipe.

5. Delivery valve + spring
6. Discharge valve + spring
7. Element cylinder
8. Plunger
9. Screw
14. Control sleeve
16. Upper spring sleeve
17. Spring
21. Fixing screw
24. O-ring
28. Pressure plate
35. Head piece
42. Venting plug
52. Screw
53. Shutdown cylinder
54. Nut

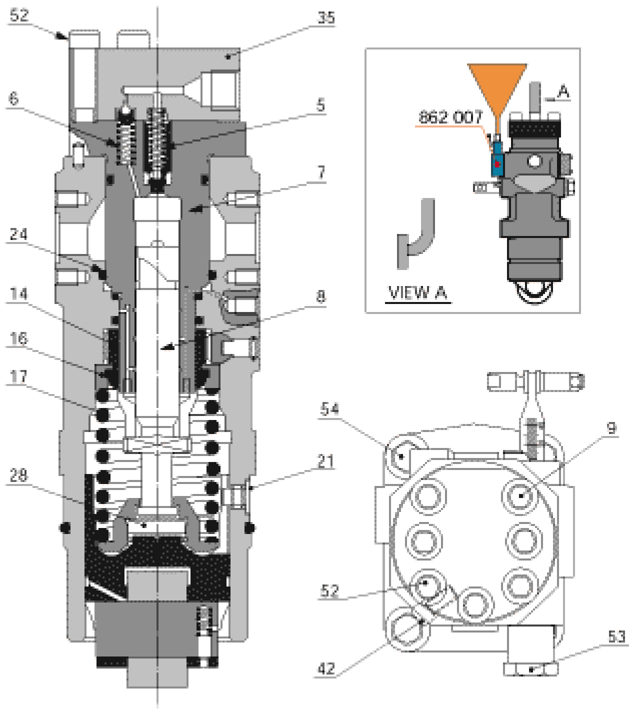

figure: 16-1 Injection pump

5 **Disengage the connection piece** from the fuel control rack by removing the nut and pulling the screw aside. Put the nut on its place at once to avoid loosing any part.

6 **Turn the crankshaft** so that the pump tappet roller rests upon the base circle of the fuel cam.

7 **Loosen the flange nuts (54)** with the tool [806005] and lift off the pump. Cover the oil supply inlet hole and the pump bore in the engine block.

8 **Clean the pump externally.**

16.3.2 Mounting of injection pump

1 **The pump is assumed to be assembled** and cleaned and the surface and bore of the engine block to be cleaned.

2 **Check the O-ring** of the pump body, grease and enter it into the groove. Check that the fuel cam is not in the lifting position.

3 **Put the pump into place** and tighten the flange nuts to torque.

4 **Connect the connection piece** between the control shaft and fuel control rack with the screw and nut.

Note!

Center the joint by applying force between the fuel control rack and connection piece, see chapter [22]. Check that the joint moves easily.

5 **Remove the protecting tape** or plugs and connect the fuel feed pipes and leak fuel pipe.

6 **Reinstall the injection pipe.** Tighten the injection pipe cap nuts to torque according to chapter [07] with the tool [806009].

7 **Open the fuel supply** to the engine and vent the fuel filter and injection pumps according to the instructions in chapter [17]. The injection pump is provided with a venting plug (42), see [Fig 16-1].

8 **Check the fuel rack positions** according to chapter 22, section [22.3.1].

16.3.3 Control of fuel delivery commencement

For normal adjustment of injection timing the prelift can be measured mechanically by a special tool but the beginning of the effective pump

stroke is determined by an indirect method, i.e. by observing when the duct between the low pressure side and the high pressure side of the injection pump is shut by the edge of the element plunger, the so called "flowing position".
Control of fuel delivery start 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 **Fuel supply is arranged** by connecting the funnel [862007] to the pump.

3 **Dismantle the injection pump head piece** (35) and remove the delivery valve (5) including the spring, [Fig 16-1]. Reinstall the head piece.

4 **Connect the pipe elbow** to the head piece.

5 **Set the fuel control rack** at maximum position.

6 **Turn the crankshaft** to a position 22° before TDC at ignition for the cylinder to be checked.

7 **Fill the funnel** with **distillate fuel**. Fuel is now flowing out from the pipe elbow.

8 **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. See chapter [06].

9 **Repeat pos. 2 - 8** on all cylinders to be checked.

10 **Compare the crankshaft positions** with correct values. 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.

11 **Reassemble the fuel delivery and discharge valve.**

Note!

The mechanically measured prelift is recommended for determing the fuel injection timing.

16.3.4 Dismantling of injection pump
Observe utmost cleanliness when working with the injection equipment.
It is supposed that the injection pump is removed from the engine and the outside of the pump carefully cleaned.

1 **It is recommendable** to put the pump in a screw vice to positions convenient for the different operations.

2 **Support the roller tappet** by hand and open the fixing screw (21), [Fig 16-1].

3 **Remove the roller tappet.**

4 **Remove the spring retainer** and element plunger.

5 **Remove the spring** and control sleeve.

6 **Turn the pump** into vertical position.

7 **Open the screws** (52) of the head piece crosswise and in steps of 30°.

8 **Open the screws** (9) of the element cylinder crosswise and in steps of 30° to avoid overloading the last screw.

9 **Remove the delivery valves (5) and (6).**

10 **Take out the element cylinder (7)** by using a soft tool.

Note!

The element cylinder, plunger and delivery valve are matched and they must be kept together during the overhaul.

11 **Remove the erosion plugs.**

12 **Wash the element plunger** and the cylinder in clean fuel or special oil and keep them always together, the plunger being inserted in the cylinder.

Note!

Normally, further dismantling is not necessary. The details must be protected against rust and especially the element plunger running surface should not be unnecessarily handled with bare fingers.

16.3.5 Reassembling injection pump

1 **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.

2 **Renew the seal rings** on the element cylinder and lubricate the rings with lubricating oil.

3 **Reinstall the element cylinder** into the position where the fixing groove corresponds to the fixing pin.

4 **Reinstall the delivery valves** (if control of fuel delivery commencement is necessary, see section [16.3.3]).

5 **Fit the pump head piece** into place and tighten the screws (52), [Fig 16-1] by hand. Fit and tighten the screws (9) by hand.

Note!

The sealing surfaces must be absolutely clean.

6 **Tighten the screws (9) and (52) crosswise to torque** in three steps according to chapter 07., section [07.1] to ensure equal tightening of every screw.

7 **Turn the pump** and fit the control sleeve. Move the fuel rack 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.

8 **Reinstall the upper spring disc** (16) and spring (17).

9 **Assemble the element plunger** with the spring disc and pressure plate (28).

Note the mark on one side of the plunger vane. The marked side of the 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.

10 **Reinstall the tappet assembly.** The guiding groove of the tappet must correspond to the fixing screw (21).

11 **Screw in and tighten the fixing screw (21).**

12 **Check that the fuel rack can be easily moved.**

13 **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 injection line consists of two parts, the high pressure connection piece which is screwed into the nozzle holder, and the injection pipe.
The high pressure connection piece seals with plain metallic surfaces and these surfaces are to be checked before mounting. Always tighten the connection piece to correct torque before mounting the injection pipe; also in case only the injection pipe has been removed, because there is a risk of the connection piece coming loose when removing the pipe.
The injection pipes are delivered complete with connection nuts assembled. Always tighten the connections to correct torque.
If necessary, the engine can be provided with alarm for a broken injection pipe. In that case the injection pipes are enclosed in a pipe, from which a drain pipe goes to a collecting vessel for the leak fuel lines. The vessel is provided with a level switch, which gives alarm at the set level. To prevent the normal leak fuel flow from triggering the alarm the vessel is fitted with a valve. This valve should be adjusted so that the normal leak fuel continuously flows through it. The switch gives alarm only when the flow is abnormal (a broken injection pipe).
When removed, the injection line details have to be protected against dirt and rust.

16.5 Injection valve

16.5.1 General description

The injection valve is centrally located in the cylinder head and includes nozzle holder and nozzle. The fuel enters the nozzle holder sideways through a connection piece screwed into the nozzle holder.

1. Nut
2. Cap nut
3. Nut
4. Nut
5. Connection piece
6. Screw
8. Spring
9. Screw
10. Nut

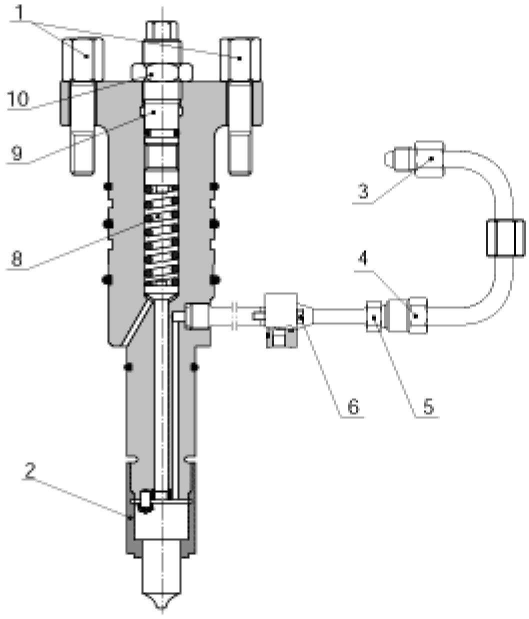

figure: 16-2 Injection valves

16.5.2 Removing injection valve

1 **Remove the cylinder head cover** and the cover of injection pump box.

2 **Remove the high pressure injection pipe** and connection piece.

3 **Remove the fastening nuts** of the injection valve.

4 **Lift out the injection valve.** If much force has to be used there is a risk of the stainless sleeve of the cylinder head coming loose, which, in such a case, must be checked.

5 **Protect the fuel inlet hole** of the injection valve and bore in the cylinder head.

16.5.3 Overhauling injection valve

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, the spring (8) is broken. Clean the outside of the nozzle with a brass wire brush. Don't use steel wire brush.

2 **Release the nozzle spring (8) tension** by opening the counter nut (10) and screwing up the adjusting screw (9), see [Fig 16-2].

3 **Remove the nozzle** from the holder by opening the cap nut (2). Be careful not to drop the nozzle. If there is coke between the nozzle and the nut it may be difficult to remove the nozzle. In such a case, place the nozzle with the nut on a soft support and knock it out by using a piece of pipe, see [Fig 16-3].

Never knock directly on the nozzle tip!

4 **Check the nozzle needle** movement which may vary as follows:

needle completely free

needle free to move within normal lifting range

needle is sticking

The needle must not be removed by force because this often results in complete jamming. Unless it can be easily removed, immerse the nozzle in lubricating oil and heat the oil to 150 - 200°C. Normally, the needle can be removed from a hot nozzle.

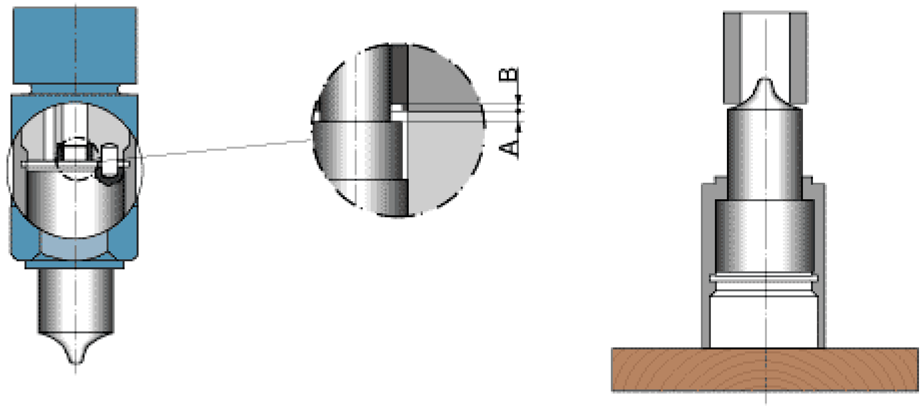

figure: 16-3 Maximum lift of nozzle, removing of nozzle from holder

5 **Clean the details.** If possible, use a chemical carbon dissolving solution. If there is none available, immerse the details in clean fuel oil, white spirit or similar to soak carbon. Then clean the details carefully by the tools [845006]. Do not use steel wire brushes or hard tools! Clean the orifices of the nozzle with needles provided for this purpose. After cleaning, rinse the details to remove carbon residues and dirt particles.

Before inserting the needle 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.

6 **Clean the nozzle holder** and cap nut carefully; if necessary, dismantle the nozzle holder to clean all details. Check the nozzle spring (8).

7 **Check the high pressure sealing faces** of the nozzle holder, i.e. the contact face to the nozzle and the bottom of the fuel inlet hole.

8 **Check maximum lift of the nozzle,** i.e. the sum of measures A and B in [Fig 16-3]. 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] pos. 16, the nozzle should be replaced by a new one.

9 **Reassemble the injection valve.**

10 **Connect the injection valve** to the test pump [864011]. Pump to expel air. Shut the manometer valve and pump rapidly to blow dirt out of the nozzle orifices. Place a dry paper under the nozzle and give the pump a quick blow. Note fuel spray uniformity.

11 **Check the opening pressure:**

open the manometer valve

pump slowly and watch the manometer to note the opening pressure. If the opening pressure is more than 20 bar below the stated value it indicates a broken spring or badly worn parts.

12 **If the spray is uniform,** adjust the opening pressure to stated value and check the spray uniformity once more.

13 **Check the needle seat tightness:**

increase pressure to a value 20 bar below stated opening pressure

keep pressure constant for 10 seconds and check that no fuel drops occur on the nozzle tip. A slight dampness may be acceptable.

14 **Check the needle spindle tightness:**

pump until pressure is 20 bar below stated opening pressure

measure time for a pressure drop of 50 bar. The time must not be below 3 seconds. A time longer than 20 seconds indicates fouled spindle.

15 **If the tests** according to pos. 10 - 14 give satisfactory results the injection valve can be reinstalled in the engine. Otherwise, replace the nozzle by a new one.

16 **If leakage occurs** on the high pressure sealing surfaces the damaged detail should be replaced by a new one or reconditioned.

17 **If nozzles or injection valves** are to be stored they should be treated with corrosion protecting oil.

16.5.4 Mounting of injection valve

1 **Check that the bottom** of the stainless sleeve in the cylinder head is clean. If necessary, clean or lap the surface with the tool [841008]. If lapping is necessary the cylinder head must be lifted off. For lapping, a steel washer and fine lapping compound is used. The injection valve is sealed off metal to metal to the bottom of the stainless sleeve!

2 **Put new O-rings** on the injection valve. Lubricate the injection valve with oil.

3 **Fit the injection valve** into the cylinder head bore but do not tighten the nuts (1), [Fig 16-2].

4 **Put new O-rings** in the sealing flange of the high pressure connection piece (5). Place the flange on the connection piece and screw in the connection by hand, (be sure that the flange screws (6) is loose). Tighten the connection piece (5) to correct torque.

5 **Mount the injection line** and tighten the two cap nuts (3 and 4) to correct torque, see section [07.1].

6 **Tighten the fastening nuts (1)** of the injection valve to correct torque in steps of 10 Nm, see section [07.1].

7 **Fasten the hexagon nuts (6) on the sealing flange** of the high pressure connection.

8 **Reinstall the covers.**

[Fig 16-4]

16.6 Change of beginning of effective pump stroke (delivery start)

1 **Check the delivery start** on one of the cylinders.

2 **In-line engine:** Open the camshaft gear wheel cover and the cover (30), see [Fig 13-1] in chapter [13].

V-engine: Open the camshaft gear wheel cover on one bank as well as the cover (30) on the B-bank or the plug (17) on the A-bank.

3 **Mark the nut** (7) for the camshaft intermediate wheel next to the opening.

4 **Loosen all nuts** (7) on the intermediate wheel, the marked nut last.

5 **The last nut** (7) having been loosened, turn the crankshaft opposite to the direction of rotation the number of crank angle degrees required for an earlier delivery commencement.

Note!

The camshaft must not rotate while turning.

6 **Secure the marked nut** (7) and check the new delivery commencement.

7 **If the desired delivery commencement** has been obtained. Tighten the other nuts (7) to correct torque, see section [07.1].

8 **V-engine:** Repeat the procedure for the other bank.

17.1 General description

The engine is designed for continuous heavy fuel duty. Main engines as well as the auxiliary engines, can be started and stopped on heavy fuel. 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 book. See separate instructions.
The engine is normally equipped with an electrically driven fuel feed pump (9) and a duplex filter (8) to provide correct flow, pressure and filtration irrespective of the number of engines connected to a common external treatment system.

5. Pressure gauge
6. Thermometer
7. Pressure switch
8. Fuel filter
9. Fuel pump
10. Pressure valve
11. Pressure control valve
12. Valve
13. Pressure difference alarm
14. Valve
15. Valve

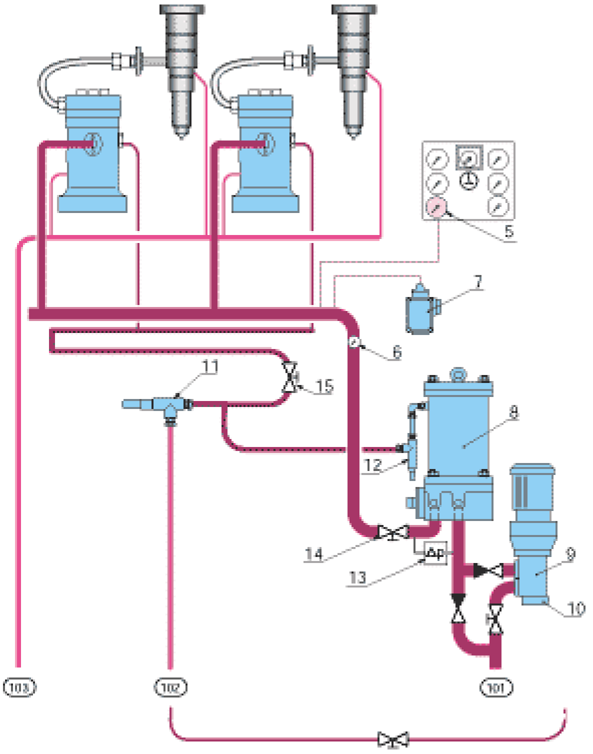

figure: 17-1 Fuel system

The electrically driven 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. Both sides of the duplex filter shall be in operation at the same time to get maximum capacity of the filter cartridges. However it is possible to change cartridges during operation as part of the fuel can then flow through the valves (12) thus by passing the filter. This will happen also when heating up a cold system containing heavy fuel; fuel flows through the valves (12) until the filter and the whole system gradually are heated up.
A pressure gauge (5) on the instrument panel indicates fuel inlet pressure and a local thermometer (6) indicates the inlet temperature. A pressure switch (7) for low fuel pressure is connected to the alarm system.
Fuel leaking from injection pumps and injection valves is collected in a separate enclosed system. Thus this fuel can be reused.
A separate pipe system leading from the top level of the engine block collects waste oil, fuel or water arising when overhauling cylinder heads, for example.
The high pressure system with injection pump and injection valve is described in chapter [16].

17.2 Maintenance

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 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 section [04].
The fuel should always be separated 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. [17.3].
For maintenance of the fuel treatment equipment not mounted on the engine, see separate instructions.

17.3 Venting

Open the air vent screws on the injection pumps (see chapter 16, [Fig 16-1] pos. 42.) If the static pressure from the day tank is not sufficient, the fuel feed pump should be started.
Vent the filter always after changing cartridges in the filter.

If the engine is stopped and the feed pump is not running, the three-way valve of the filter can be directly changed over to both sides in operation and the air can be vented through the air vent screw of the filter. 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 17-2]) 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 gives signal for too low fuel pressure. This may involve the risk of air escaping from the filter to the injection pumps, which may cause the engine to stop.

To avoid air escaping to the injection pump, fill up the filter with clean fuel before changing over.

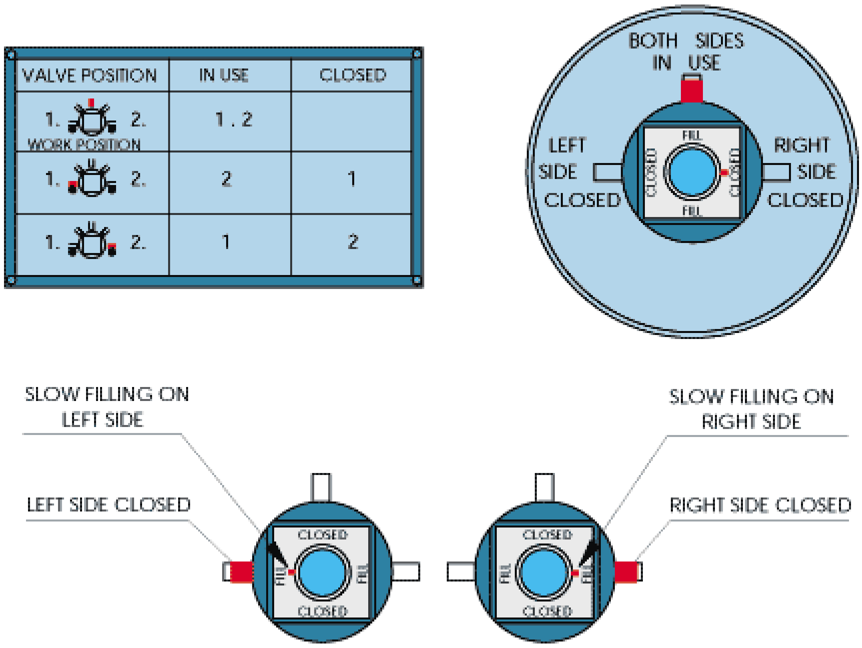

figure: 17-2 Three-way valve positions

17.4 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 17-1]) running.
All pressures mentioned in the instruction 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, counterclockwise to achieve lower pressure.

1 **Adjustment of the valve (10) on the pump:** Raise the pressure in the system slowly by closing the valve (14). Adjust the valve (10) to 10 bar when the nominal pressure is 5 - 7 bar and to 12 bar when the nominal pressure is 8 bar (see chapter 01., section [01.2]). Open the valve (14) 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):** Shut off the valve (15). Check that the recommended operating pressure +2.5 bar is achieved. Check that the valves are equally adjusted by closing one side of the filter, one after the other. When doing so a somewhat higher pressure can be achieved owing to double overflow through the filter. Adjust the valves (12), if necessary.

After adjustment, open the valve (15) completely.

17.5 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 [17.4].
17.6 Fuel filter
17.6.1 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 17-3]A shows the valve in this position. When changing cartridges during operation one side can be closed. [Fig 17-3]B 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.

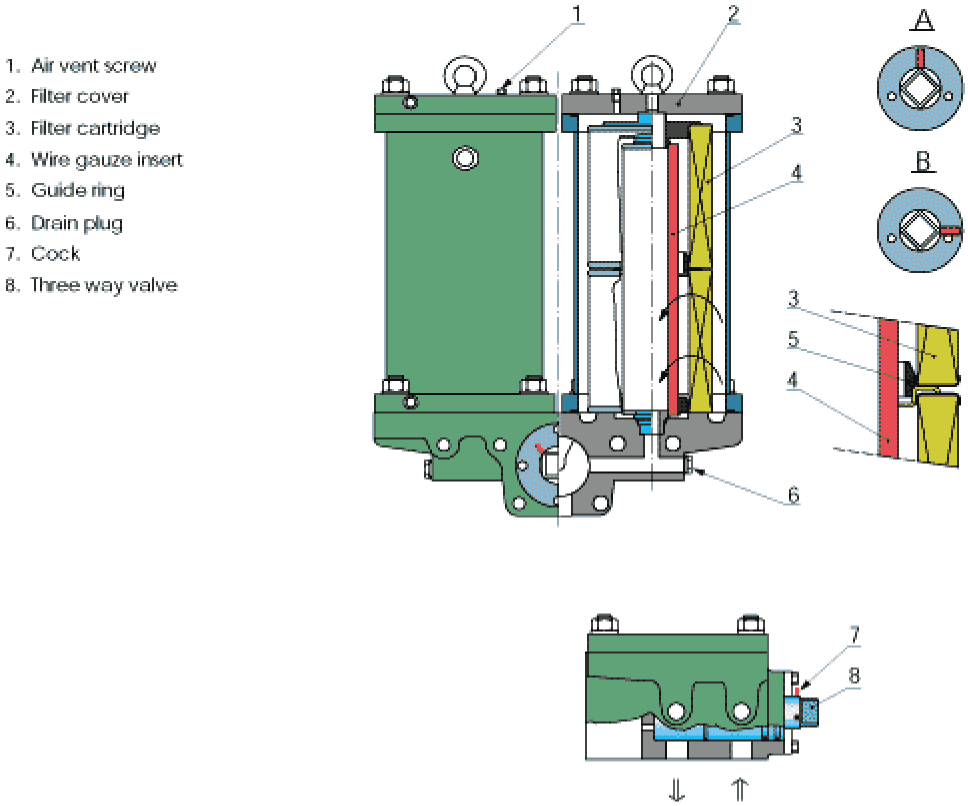

figure: 17-3 Fuel filter

17.6.2 Changing of filter cartridges

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 being 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 working position (both sides of filter in operation). If the filter cannot be filled, change over very slowly, see section [17.3].

11 **Vent the filter** if not completely filled according to pos. 10. See section [17.3].

17.7 Running in fuel oil filter

To ensure a safe start up of a new engine the fuel oil must be cleaned by filtering away dirt and foreign particles. All VASA 22 and VASA 22/26 engines without fuel feed pumps, are equipped with a running in filter according to the [Fig 17-4]. This filter protects the fuel injection equipment of the engine during the initial period of operation. At this time, there is a higher risk of damage from foreign debris in the fuel system. Installations of this kind (fuel feed pump in the external fuel system), generally heavy fuel installations, must be equipped with a fine fuel filter in the external system.

The element of the running in filter has to be removed after the first 100 hours of operation and the running-in filter housing should be left empty. The running in filter housing functions as a damper for pressure peaks in the fuel system when the filter element is left out.

If any kind of maintenance work is necessary on the fuel system, between the engine and the fine fuel filter, it is recommended that the running in filter is used for some (20 - 50) hours afterwards.

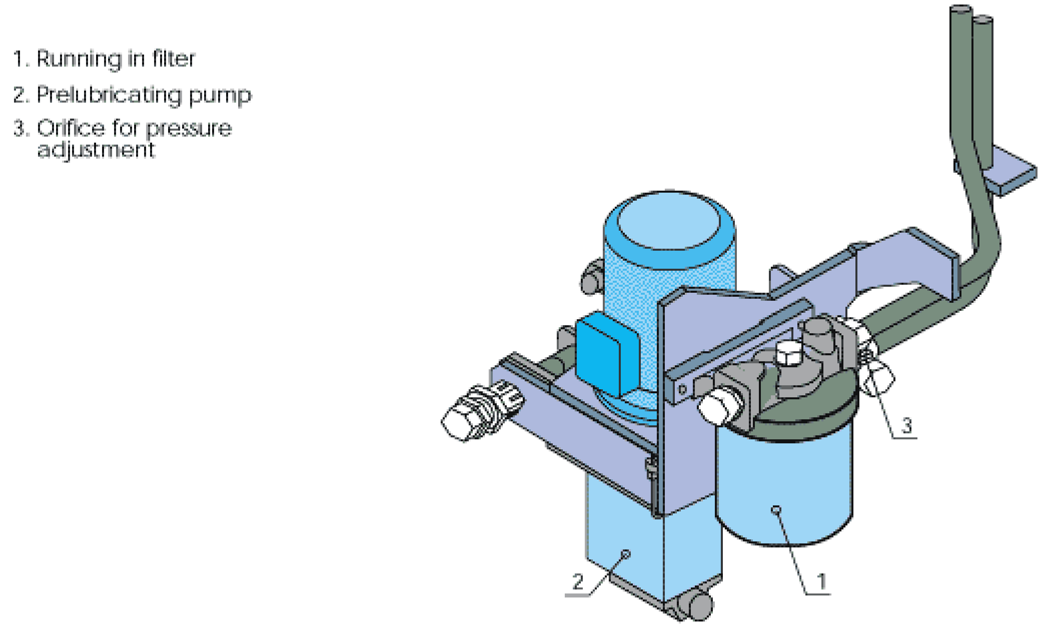

figure: 17-4 Running in filter

18 Lubricating Oil System

version : 18-9601-00

18.1 General design

The engine is provided with a lubricating oil pump (2) directly driven by the pump gear at the free end of the crankshaft. In some installations there is a separately driven standby pump in parallel. The pump sucks oil from the engine oil sump and forces it through the lubricating oil cooler (17) equipped with a thermostat valve (16) controlling the oil temperature, through the lubricating oil main filter(s) (13) to the main distributing pipe (12). From the main distributing pipe the oil flows, via bores in the block, to the main bearings and through bores in the connecting rod further to the gudgeon pin (11) and piston cooling space. Through separate pipes the oil is conveyed to the other lubricating points like camshaft bearing (10), injection pump tappets and valves, rocker arm bearings (9) and valve mechanism gear wheel bearings and oil syringes for lubricating and cooling. Part of the oil flows through a centrifugal filter(s) (5) back to the oil sump. The oil sump may be provided with a level switch connected to the alarm system.
For preheating the lubricating oil of the engine a heat exchanger (18) may be fitted in the lubricating oil pipe after the prelubricating pump. Warm water for preheating the HT-circuit flows through this heat exchanger thereby heating the lubricating oil. At low loads the warm lubricating oil will heat the LT-water via the lubricating oil cooler.
An electrically driven prelubricating pump (4) in parallel to the direct driven pump, pumps the oil through the system when the engine is stand-by and especially before starting. A non-return valve (3) prevents the oil from flowing in the wrong direction during operation. The pressure pipe from the prelubricating pump may be provided with a three-way valve; thus the oil sump can be emptied by means of this pump.
The pressure in the distributing pipe (12) is controlled by a pressure control valve (1) on the pump. The pressure can be adjusted by means of a set screw (17), on the control valve, see ([Fig 18-2]). 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 (7) on the instrument panel shows the lubricating oil pressure before the engine (in the engine distributing pipe). The system includes three pressure switches for low lubricating oil pressure (8), two connected to the automatic alarm system and one to the automatic stop system (see chapter [23]).
The temperature can be checked from thermometers (19) before and after the oil cooler, i.e. the temperature after and before the engine. A temperature switch for high oil temperature is connected to the automatic alarm system (see chapter [23]).
The speed governor and turbochargers of VTR-type have their own oil systems, see separate instruction books. Turbocharger of TCU make are connected to the engine lubricating system.
Connections for a separator are provided on the oil sump at the free end of the engine.
The oil filling opening (14) is located at the driving end and an oil dipstick (15) at the middle of the engine, [Fig 18-1].

1. Pressure control valve
2. Lubricating oil pump
3. Non-return valve
4. Prelubricating oil pump
5. Centrifucal filter
7. Pressure gauge
8. Pressure switch
9. Rocker arm bearings
10. Camshaft bearings
11. Gudgeon pin
12. Distributing pipe
13. Lubricating oil main filter
14. Oil filling opening
15. Oil dipstick
16. Thermostat valve
17. Lubricating oil cooler
18. Heat exchanger
19. Thermometers

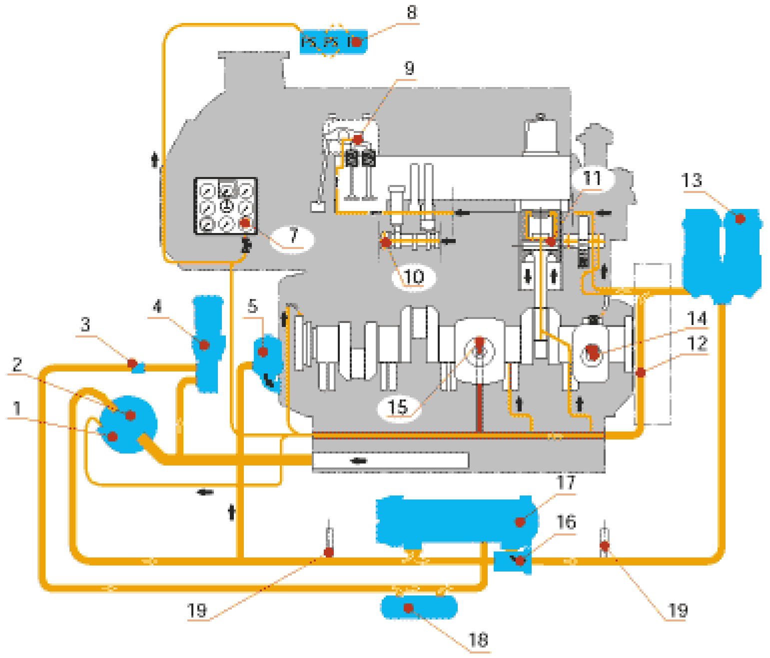

figure: 18-1 Lubricating oil system

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 shows the maximum and minimum limits between which the oil level may vary. Keep the oil level near the maximum mark and never allow the level to go below the minimum mark. The limits apply to the oil level in a running engine. Add maximum 10 % new oil at a time (see section [02.2]). One side of the dipstick is graduated in centimetres. 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]. The oil still being 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(s) and the centrifugal filter(s). Change cartridges in the main filter(s) unless they have been changed recently.
Centrifuging of the oil is recommended, 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.

18.3 Lubricating oil pump

18.3.1 Description

The pump is of the gear type, equipped with a built-on, combined pressure control/safety valve. Five identical bronze bearings are used. No outside lubrication is required. The cover is sealed by an O-ring. ([Fig 18-2]).

18.3.2 Dismantling

1 **Remove and inspect the control valve** according to section [18.4].

2 **Remove the screw (4)** and withdraw the gear (2) by means of the tool 837012.

3 **Withdraw the pump cover** by using two of the fastening screws (1) in the two threaded holes located in the cover, [Fig 18-2].

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 3 mm below the cover and housing level. Be careful so that the bearing lubrication grooves (5) slide into the right position according to [Fig 18-2].

4 **Check the bearing diameter** after mounting. Check the gear wheel axial clearance (see chapter 06., section [06.2] pos. 18).

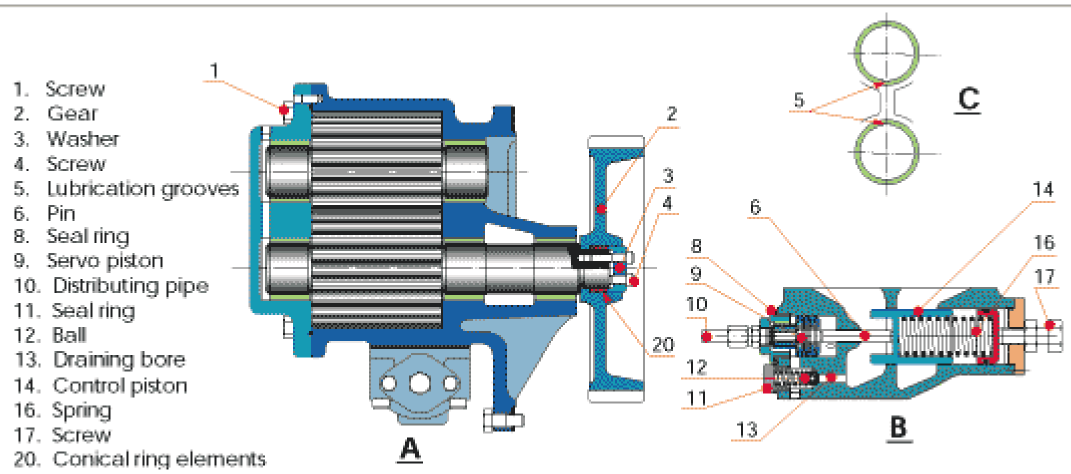

figure: 18-2 Lubricating oil pump

18.3.4 Assembling

1 **Clean and oil all details carefully** before assembling. Check that the O-ring in the cover is intact and in correct position.

2 **Before re-installing the gear wheel,** all contact surfaces should be cleaned and oiled.

3 **Pull the gear wheel (2) on to the shaft,** by using the tool 837012, including the washer (3).

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 friction ring elements** (20).

5 **Reinstall the washer (3)**

6 **Tighten the screws (4) a little** and check that the gear wheel is in the right position.

7 **Tighten the screws to torque** according to chapter [07].

8 **If the gear wheel (2) has been changed,** check the backlash after mounting the pump on the engine.

2. Gear wheel
3. Washer
4. Screw
20. Conical ring elements

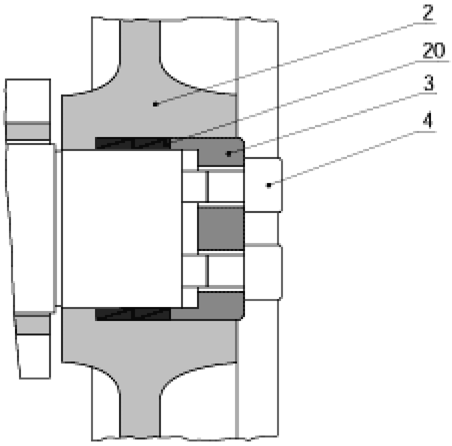

figure: 18-3 Mounting of gear wheel to oil pump

18.4 Lubricating oil pressure control valve and safety valve

18.4.1 Description

The pressure control valve is mounted on the lubricating oil pump and controls the oil pressure before the engine by conducting 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 oil distributing pipe, where the pressure is kept constant in engines running at a wide speed range. This pressure actuates the servo piston (9) and the force is transferred to the control 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 run at varying speeds the valve is arranged to give a constant pressure until the speed point where the overflow has creased. For lower speeds, the prelubricating pump is automatically started.

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 admit oil to pass to the servo piston (9) which will open the control 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, [Fig 18-2].

3 **Check that no details are jamming.**

Do not forget the copper sealing rings (8) and (11) when reassembling. 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 on the valve function.

4 **After reassembling, check** that the piston (14) closes (especially if some details have been replaced by new ones).

18.5 Tube cooler for lubricating oil

18.5.1 Description

A tube stack (2) is inserted in a jacket (3). The tube stack is locked at one end while the other one is movable in a longitudinal direction to allow expansion. Both ends are provided with two O-rings (5).

The oil flows outside the tubes, while the cooling water flows inside the tubes through the cooler.

The tube stack is made of copper nickel and the water boxes of cast iron,[Fig 18-4].

18.5.2 General maintenance

1 **Clean and test the cooler** by hydraulic pressure at intervals according to chapter [04] or if the lubricating oil temperature tends to rise abnormally.

2 **Water side can be cleaned** by removing the water boxes without removing the cooler from the engine. Remove the cooler to clean more carefully.

3 **Always when cleaning, check for corrosion** and test by hydraulic pressure.

It is preferable to change the tube stack too early, rather than too late. Water leakage to lubricating oil has serious consequences.

18.5.3 Disassembling and assembling of cooler

A) Disassembling

1 **Open the vent screw (4) and drain the tube side.**

2 **Remove the end covers (1)** and the fixation plates (12).

3 **Remove the free O-rings (5).**

4 **Mark the position of the tube stack** relative to the jacket.

5 **Move the tube stack to one side** until the second O-ring is accessible. Remove the O-ring.

6 **Draw the tube stack from the jacket** to the other side.

B) Assembling

1 **Check cleanliness and scratches** on all gasket surfaces. Recondition them and use new O-rings. Grease slightly with an appropriate O-ring lubricant.

2 **Move the tube stack into the jacket.** Check tube stack position using the marks mentioned above.

3 **Mount the O-rings** on the free tube sheet

4 **Move the tube stack as far as needed** to expose the O-ring grooves on the other side.

5 **Mount the other O-rings.**

6 **Move the tube stack** into its correct position.

7 **Mount the fixation plates (12).**

8 **Mount the end covers (1).**

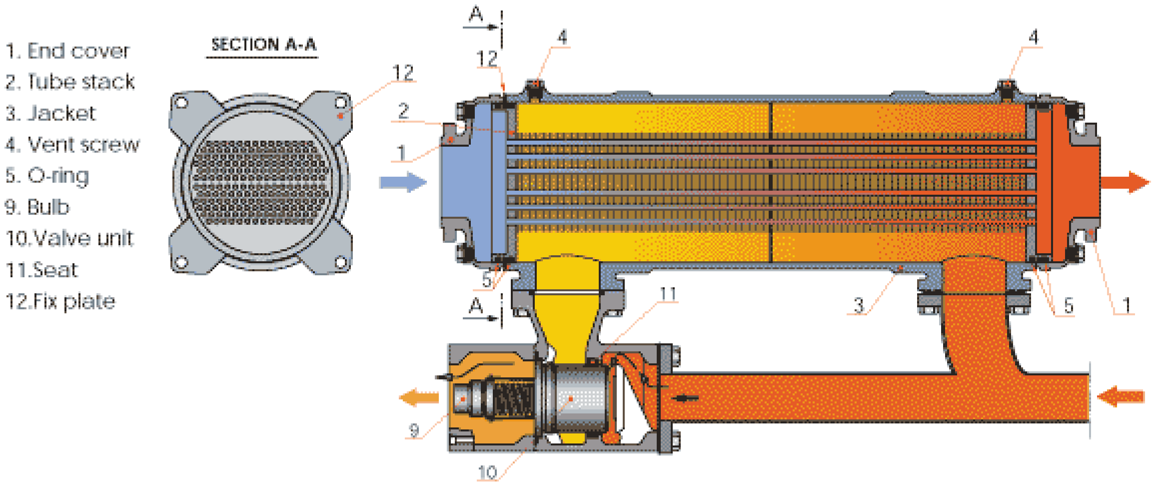

figure: 18-4 Lube oil cooler

18.5.4 Cleaning of oil side
Fouling of the oil side is normally insignificant. On the other hand, possible fouling will influence the cooler efficiency very strongly.
Due to the design, the tube stack cannot be cleaned mechanically on the outside. Slight fouling can be removed by blowingsteam through the tube stack.
If the amount of dirt is considerable, use chemical cleaning solutions available on the market:
Alkaline degreasing agents:
Suitable for normal degreasing, however, not effective for heavy greases, sludge and oil coke. Requires high temperature. Always pour degreasing agent slowly into hot water, never the contrary. Rinse carefully with water after treatment.
Hydrocarbon solvents:
Include the whole range from light petroleum solutions to chlorinated hydrocarbons, e.g. thrichlorethylene. These products should be handled with care as they are often extremely volatile, toxic and/or narcotic.
Solvent emulsions:
Heavy fouling, e.g. oil coke, can often be dissolved only by using these solutions. Several brands are available on the market.

Follow the manufacturer's instructions to achieve the best results.

18.5.5 Cleaning of water side
The cleaning should be carried out so that it does not damage the natural protective layer on the tubes. Use nylon brushes, metallic brushes can damage the natural protective layer.
Remove loose sludge and deposits with brush 4V84F06. Rinse with water.
If the deposit in the tubes is hard, e.g. calcium carbonate, it can be removed chemically by using commercial agents. After this treatment the tubes should be rinsed and, if necessary, treated with a solution neutralizing the residual washing agents. Otherwise, follow the manufacturer's instructions.
18.6 Plate cooler for lubricating oil
18.6.1 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 x 2.6 mm), [Fig 18-5].
18.6.2 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.

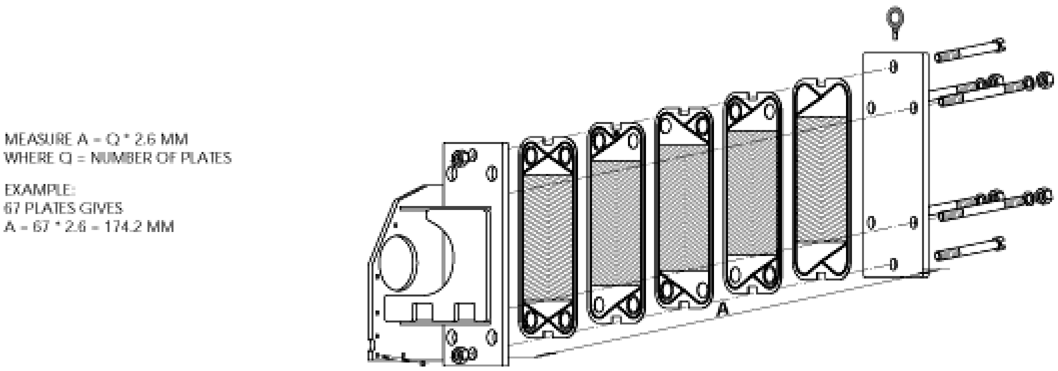

figure: 18-5 Plate oil cooler

18.6.3 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 **Slacken the nuts** in turn diagonally.

Note!

During opening, the slant of the pressure plate must not exceed 10 mm (2 turns/nut).

5 **Dismantle the plate pack.**

18.6.4 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. Maximum temperature 60°C.
Note!

Rinse well.

18.6.5 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 18-5].

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. Maximum deviation: 2 mm. (Maximum 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 maximum tightening torque:

9 **Check the number** of the plates and measure A

10 **Check that the nuts run easily.** If not, clean, lubricate or change them.

18.7 Thermostat valve

18.7.1 Description

The figure shows the valve in closed position the left. When the temperature exceeds the nominal value the contents of the bulb (9) expands and forces the valve unit (10) towards the seat (11) thus passing part of the oil through the cooler (figure on the right). This movement continues until the right temperature of the mixed oil is obtained. As the cooler becomes dirtier the temperature will rise some degrees, which is quite normal, because the valve needs a certain temperature raise for a certain opening to increase the oil flow through the cooler.
Depending on the number of cylinders, the engine can be equipped with a thermostatic valve, that contains one or two valve units (10), [Fig 18-6].

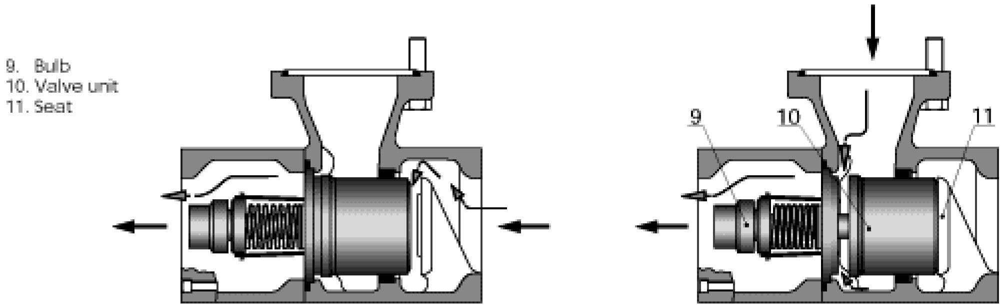

figure: 18-6 Thermostatic valve for oil system

18.7.2 Maintenance

Normally, no service is required. Too low an oil 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 cover** by unscrewing the pipe after the valve.

2 **Remove the thermostatic element** and withdraw the element.

3 **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 one is the fully open value.

4 **Change the defective element.** Check the O-rings and change, if necessary.

5 **Mount the thermostat housing** and the oil pipe. Check the O-rings.

18.8 Lubricating oil main filter

18.8.1 Description

This description applies to in-line engines. V-engines have two similar filters in parallel.
The filter is a full-flow duplex filter, i.e. the whole oil flow passes through the filter(s). The flow can be adjusted by the three-way valve (9) to pass over one side or the other, or over both sides in parallel.
The direction of the flow appears from the mark on the cock. Normally, both sides of the filter (for V-engines both sides of both filters) are used at the same time to provide maximum filtration. [Fig 18-7] C, shows the valve (9) in this position. When changing cartridges during operation one side can occasionally be closed, e.g. closing of the right side according to [Fig 18-7] D.

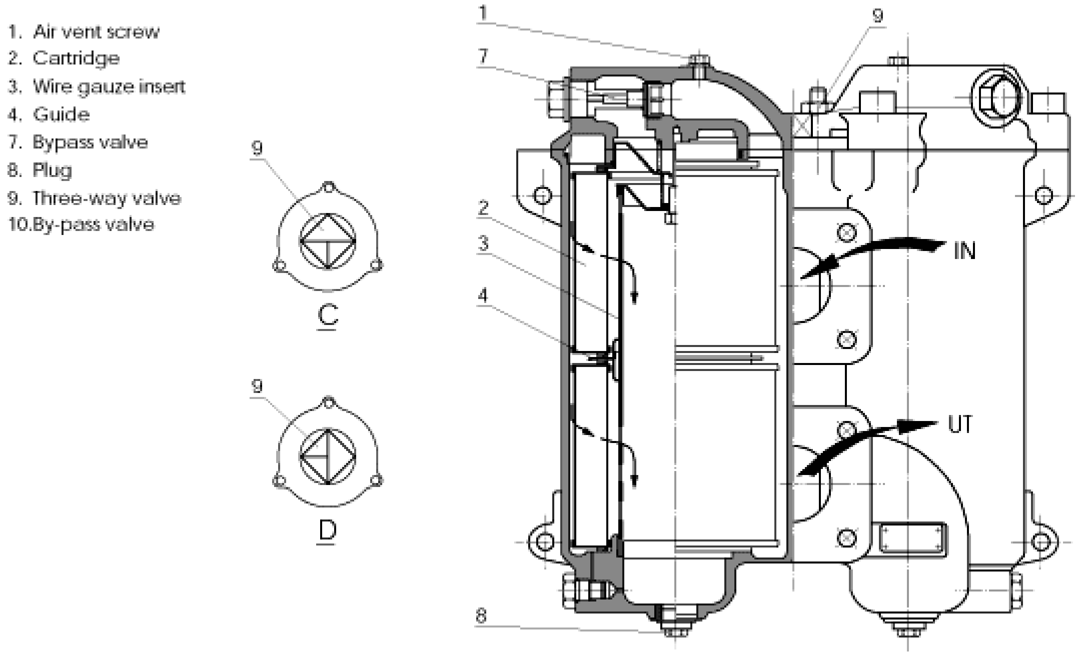

figure: 18-7 Lube oil filter for in-line engine

The arrows in the figure show the flow through the filters. At first, the oil flows through a cartridge (2), made of special paper, separating particles larger than 10 - 15 µm, then through an insert (3) consisting of a pleated wire gauze around a perforated case. The wire gauze insert, with a mesh size of 60 µm, serves as a safety filter in case of failure or by-passing of the paper cartridge.
The filters are provided with a bypass valve (7) over the paper cartridges which opens at a pressure drop of 2 - 3 bar (the pin comes out). The filter is provided with a combined visual indicator/ electrical switch connected to the alarm system, which indicates too high pressure drop over the filter which means that the paper cartridges should be changed as soon as possible.

18.8.2 Changing of filter cartridges

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, to a great extent, depends 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 the 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 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 **Shut off the filter side** to be served.

2 **Remove the protection cover** on V-engines.

3 **Open the air vent screw (1)** about two turns.

4 **Open the plug (8)** and drain the oil.

5 **Open the filter cover.**

6 **Remove the wire gauze insert.** Wash in gas oil. Check that it is intact.

7 **Remove the paper cartridges** and throw away.

Paper cartridges cannot be cleaned. Always keep a sufficient quantity of cartridges in stock.

8 **Clean and rinse the filter housing** carefully with gas oil.

9 **Fit new paper cartridges** and the cleaned wire gauze insert. Check that all seals are intact and in position.

10 **Check that the guide (4)** slides into position.

11 **Mount the plugs and the cover.** Tighten the vent screw.

12 **Move the three-way valve** over to working position ([Fig 18-7] C).

18.9 Centrifugal filter

18.9.1 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 (13) containing a hardened steel spindle (3) on which a dynamically balanced rotor unit (5) 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 (6) into the upper part of the rotor, where it is subject to a high centrifugal force, and the dirt is deposited on the walls of the rotor in the form of heavy sludge.
The oil then passes from the cleaning compartment through the separation cone (9) into the driving compartment which carries two driving nozzles (12). 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. The filter is provided with a cut-off valve (15) which opens at about 2.5 bar, [Fig 18-8].

18.9.2 Cleaning

It is very important to clean the filter regularly (chapter [04]) as it collects considerable quantities of dirt and thus unload the main filter giving longer lifetime for the paper cartridges. If it is found that the filter has collected the maximum quantity of dirt (about 12 mm, which corresponds about 3.7 kg) at the recommended cleaning intervals, it should be cleaned more frequently.
Clean the filter as follows, the engine being running, by closing the valve on the oil delivery pipe to the filter:

1 **Slacken off the filter cover clamp (11),** unscrew the cover nut (1) and lift off the filter body cover (4).

2 **Withdraw the rotor assembly** from the spindle (3) and drain oil from the nozzles before removing the rotor from the filter body (13). Hold the rotor body and unscrew the rotor cover nut (2), then separate the rotor cover (5) from the rotor body.

3 **Remove the upper circlip (8)** and the separation cone (9).

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, and wipe clean.

5 **Clean the separation cone.**

6 **Wash all details,** for example in gas oil.

1. Cover nut
2. Nut
3. Spindle
4. Body cover
5. Rotor unit
6. Central tube
7. O-ring
8. Circlip
9. Separation cone
10. O-ring
11. Cover clamp
12. Driving nozzle
13. Housing
14. Plug
15. Cut-off valve

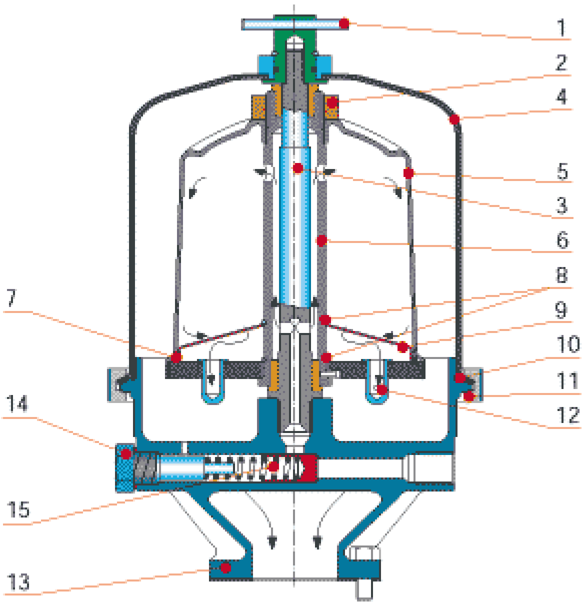

figure: 18-8 Centrifugal filter

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 or excessive wear. Examine the O-ring (7) for damage. Renew, if necessary.

8 **Reassemble the rotor complete,** align the location pins and tighten the nut (2). Do not forget the O-ring (7) as this will cause leakage of the rotor which, in turn, will cause unbalance and damage the filter.

9 **Examine the spindle journals** to ensure that they are free from damage or excessive wear. Examine the O-ring (10) for damage. Renew, if necessary.

10 **Remove the cut-off valve plug (14)** and cut-off valve assembly. Check that the spring and shuttle are undamaged and free to move. Change the plug seal, if necessary.

11 **Reassemble the filter,** checking that the rotor assembly is free to rotate, and then replace the filter body cover (4). Tighten the cover nut (1) and secure the filter cover clamp, [Fig 18-8].

18.10 Prelubricating pump

18.10.1 Description

The pump is of the screw type, driven by an electric motor.

The pump is provided with an adjustable pressure control valve (15). The pressure should be limited to the minimum 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.

As a shaft seal a mechanical seal is used consisting of two plane sealing surfaces facing each other - one of them (8) rotating with the shaft and the other one (6) being stationary, [Fig 18-9].

18.10.2 General maintenance

Lubricating interval, see chapter [04].

After 3 - 6 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 the sealing faces with your fingers, [Fig 18-9].

18.10.3 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)** together with the O-ring out of the front plate by using a chisel.

8 **To remove the ball bearing (4)** from the front plate, first remove the locking ring, [Fig 18-9].

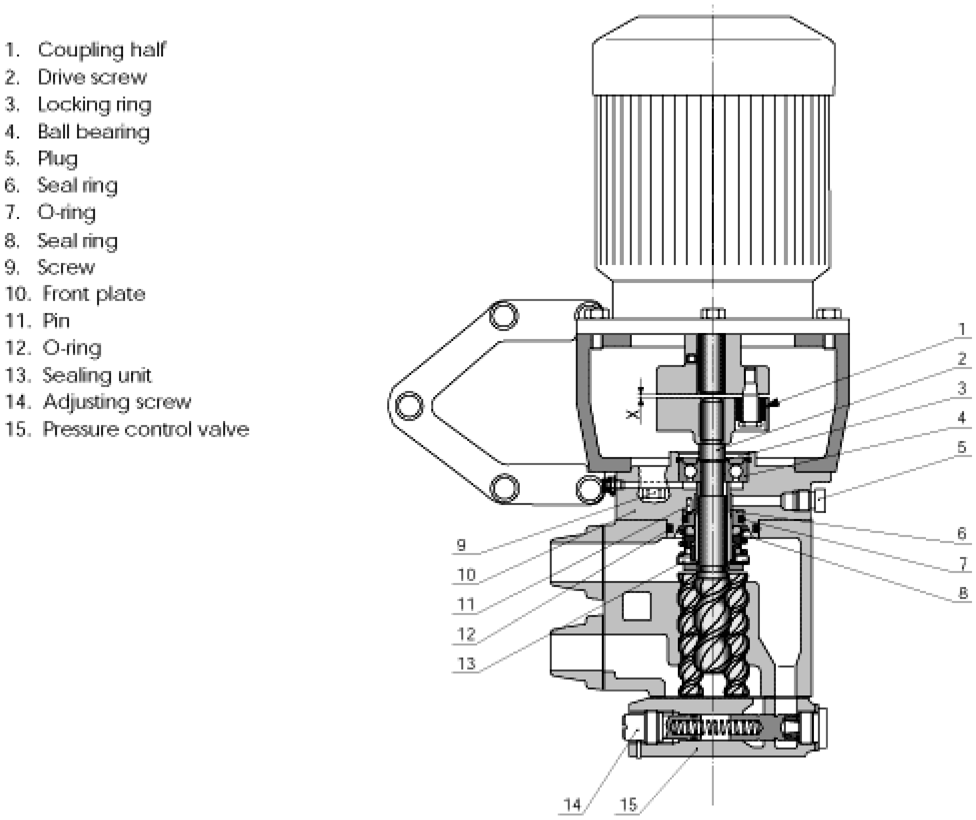

figure: 18-9 Prelubricating pump

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.

18.10.4 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) ,** [Fig 18-9]. Insert the stationary sealing ring (6) in the front plate. Take care not to damage the sealing faces and check 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 in 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. See chapter 02., section [02.2.7].

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 (X in [Fig 18-9]) is 2 mm.

10 **If the electric motor has been disconnected** or changed, check that it rotates in the right direction by switching it on a few times.

19 Cooling Water System

version : 19-9601-00

19.1 General description

19.1.1 General

The engine is cooled by a fresh water system, divided into a high temperature circuit (HT) and a low temperature circuit (LT). The fresh water is cooled in a separate central cooler.
The LT circuit is provided with a temperature control valve which keeps the temperature in the circuit at a load dependent level. Thus the temperature in the LT system rises at low load and the charge air is heated instead of cooled. The heat for this purpose is gained from the oil system via the oil cooler.
The system outside the engine can vary widely. [Fig 19-1] shows a system with separate coolers (14) and (16) for the LT and HT circuit. The system can also be built with a common cooler for the HT and LT circuit.

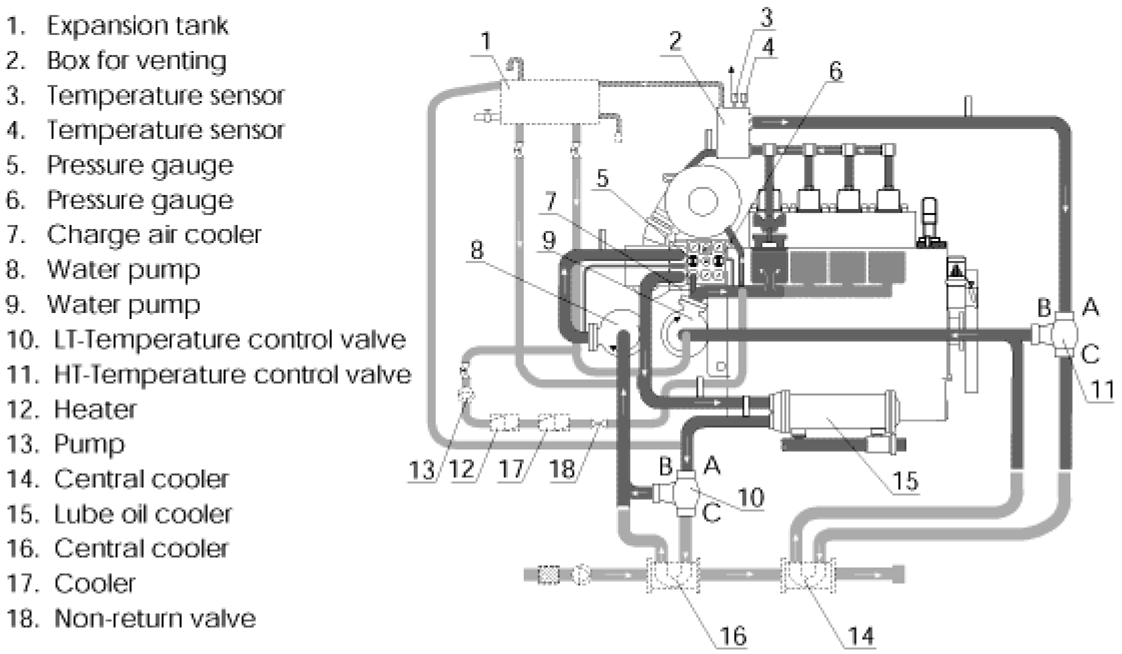

figure: 19-1 Cooling water system

19.1.2 HT circuit

The HT circuit cools the cylinders, cylinder heads and turbocharger(s).
A centrifugal pump (9), direct driven by the engine, 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.
Parallel to the flow to the cylinders, part of the water flows to the turbocharger(s). The necessary cooling is gained from the central cooler (14), [Fig 19-1].

19.1.3 LT circuit

The LT circuit consists of a charge air cooler (7) and a lube oil cooler (15) through which a pump (8), identical to the HT pump, pumps the water. The circuit temperature is controlled by a temperature control valve (10) maintaining the LT circuit temperature at a load dependent level. The necessary cooling is gained from the central cooler (16), [Fig 19-1].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 pipes of the pumps (8, 9). 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

Before start, the HT and LT circuits are heated up to about 70 - 80°C. This is of utmost importance when starting and idling on heavy fuel. As the lube oil is also heated (indirectly) by the LT water, all fluids are close to working temperatures when the engine is started. Thus the charge air is heated directly in the charge air cooler when starting.

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 be followed.
The 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 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 trouble free 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 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 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 by overhauling a cylinder liner and check 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 structure and consistence. 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 [18.5.4]).
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 the 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 acid resistant steel, the impeller (2) and the sealing ring (3) of bronze and the remaining details of cast iron.
The shaft is mounted in two ball bearings (11) and (12), which are lubricated by splash oil entering through the opening (20). The radial seal (13) prevents the oil from leaking out and, at the same time, dirt and leak water from entering. Also the axial seal (14), sealing against the outside of the seal (13), assists in this.
The gear wheel (24) is fastened to the shaft by conical ring elements (25). When the screws (21) 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 (6) rotates along with the shaft and is sealed against it with the O-ring (7). The spring (5) presses the rotating ring against a fixed ring (8) which is sealed against the housing with the O-ring (9). Possible leak-off water from the sealing can flow out through the opening (15), see [Fig 19-2].

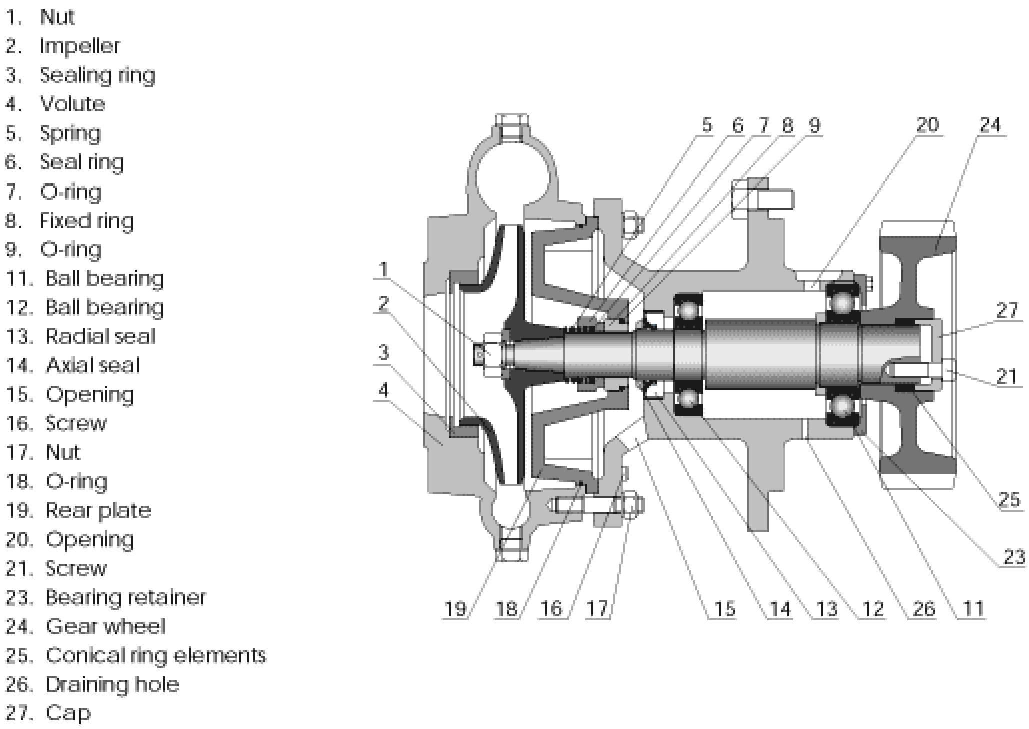

figure: 19-2 Cooling water pump

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 impeller

1 **Remove the volute casing** by loosening the nuts (17).

2 **Remove the cotter pin** and loosen the nut (1). Clockwise/counter-clockwise depending on the direction of rotation.

3 **Pull off the impeller** by using the tool 837012.

4 **When reassembling the impeller,** tighten the nut to torque, see chapter [07].

5 **Secure the nut** with a new stainless cotter pin.

6 **Check that the O-ring (18) is intact** and in position when reinstalling the volute casing. Check that the volute casing is in position. The opening (20) should be turned upwards when the pump is installed, [Fig 19-2].

If the bearing housing is turned wrongly, the bearings (11) and (12) will be left without lubrication. Before mounting the pump on the engine, fill up the bearing housing (20) with oil until oil flows out through the draining holes (26).

B) Disassembling and assembling mechanical shaft seal

7 **Remove the impeller** according to pos. a) above.

8 **Carefully dismantle all seal details.** The sealing rings are very fragile.

9 **Take particular care** not to damage the sealing surfaces as a slight scratch may disturb the sealing function.

10 **Replace the complete seal** if it is leaky, if the sealing faces are corroded, uneven or worn. Avoid touching the sealing faces with your fingers.

11 **Note that the seal is dependent** on the direction of rotation due to the self-locking effect of the spring on the shaft. In a clockwise rotating engine the spring should be left-wound (and contrarily right-wound in a counterclockwise rotating engine). Untensioned, the spring (5) may cause the ring (8) not to rotate properly with the shaft, whereby the O-ring gets worn thus causing leakage.

12 **Reassemble the details** in proper order and install the impeller according to pos. a) above. Do not forget the thin washer (6) between the spring (5) and the O-ring (7).

C) Replacing bearings

13 **Remove the pump from the engine.**

14 **Disassemble the impeller and mechanical seal** according to pos. a) and b) above.

15 **Remove the rear plate (19)** by undoing the screws (16).

16 **Loosen the screws (21)** and remove the cap (27).

17 **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).

18 **Loosen the bearing retainer** (23) and drive out the shaft and bearing. In doing this also the seal (14) will come loose.

19 **Check the seals** (13) and (14) and the bearings for wear and damage, see pos. d).

20 **Remove the bearings.**

21 **Before fitting the bearing,** oil the collar. See [Fig 19-3]A.

22 **Press the bearing** (12) by its inner ring with a suitable pipe.

23 **Turn the shaft** according to [Fig 19-3]B.

24 **Fit the distance ring** and oil the collar.

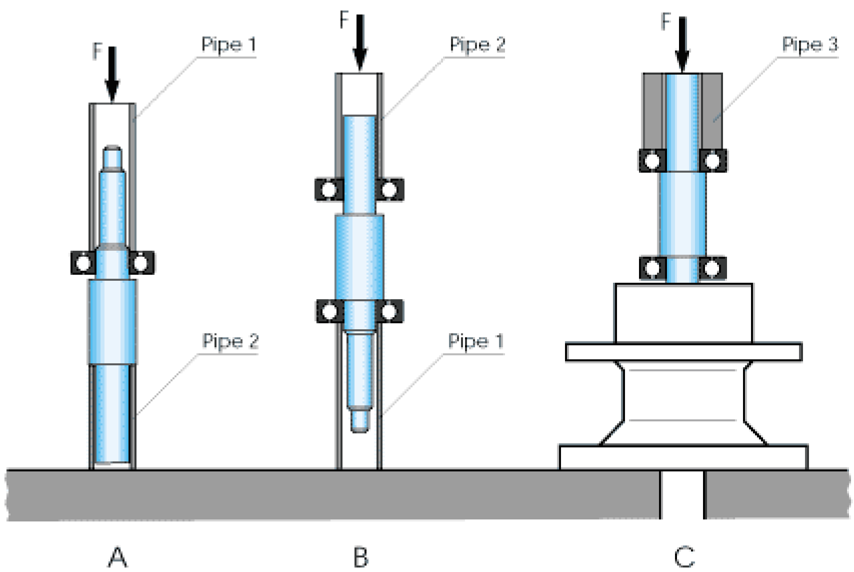

figure: 19-3 Mounting of bearings

25 **Press the bearing (11)** by its inner ring with a suitable pipe. See [Fig 19-3]B.

26 **Turn the bearing housing** according to [Fig 19-3]C and oil the outer surfaces of the bearings. Press the shaft into the housing by both the inner and outer ring of the bearing (11) with a suitable pipe.

27 **Fit the bearing retainer (23).**

28 **Before reinstalling the gear wheel,** all contact surfaces should be cleaned and oiled.

29 **Reinstall the gear wheel.**

30 **Reinstall the conical ring elements (25)**

Reinstall the ring elements exactly as situated in [Fig 19-4].

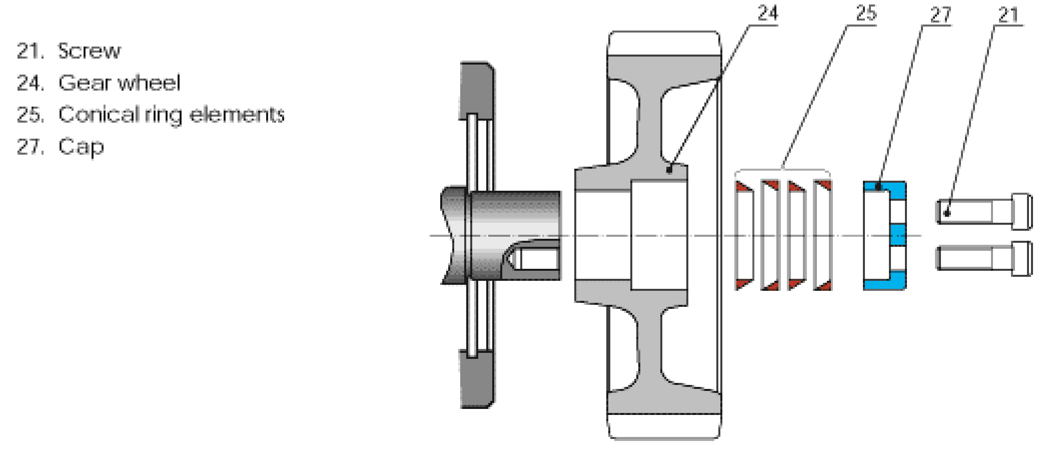

figure: 19-4 Mounting of gear wheel to water pump

The conical elements should fall easily in place and must not jam.

31 **Reinstall the cap** and the screws.

32 **Tighten the screws a little** and check that the gear wheel is in the right position.

33 **Tighten the screws to torque** according to chapter [07].

34 **Reinstall the seals (13) and (14),** see pos. d) below.

35 **Reinstall the rear plate (19)** as well as the mechanical seal, impeller and volute casing according to pos. a) and b) above.

D) Replacing 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 of changing the bearing, proceed as follows:

36 **Remove the volute casing** and mechanical seal according to pos. a) and b) above, as well as the rear plate (19).

37 **Remove the seals (14) and (13)** by prying (damaging) without scratching the shaft.

38 **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.

39 **Oil the new seal and fit it** by pressing against the shoulder.

40 **Grease the axial seal (14)** and install by using the tool 837018.

41 **Install the rear plate** as well as the mechanical seal and the volute casing according to pos. a) and b) above.

19.4 Temperature control system

19.4.1 General description

The HT-thermostatic valve is a conventional valve with one set point (In some special engines a load dependent system was also used on the HT-side. The valve was of the same as on the LT-side). The LT-valve has two set points.
At low load the LT-valve controls at high temperature, and at high load it controls at low temperature, by the thermostatic elements (6), [Fig 19-6]. Set points according to chapter 01., section [01.2].
The change-over between high and low temperature is pneumatically controlled.
The signal is taken from the charge air receiver by a pressure switch (4). [Fig 19-5]. The switch controls a three-way solenoid valve (3) providing air pressure to the pneumatic cylinder (1) on the temperature control valve at low load operation. Thus the valve will work as a constant low temperature valve without air pressure or without signal from the pressure switch. Engine specified for MDF have no signal for high temperature function. The air pressure is taken from the starting air pressure, maximum 30 bar. This pressure is reduced by the pressure reducing valve to a constant pressure of about 6 bar.
The complete system is mounted on the engine.
The switch (4) has a small hysteresis to make the system stable in the change-over area.

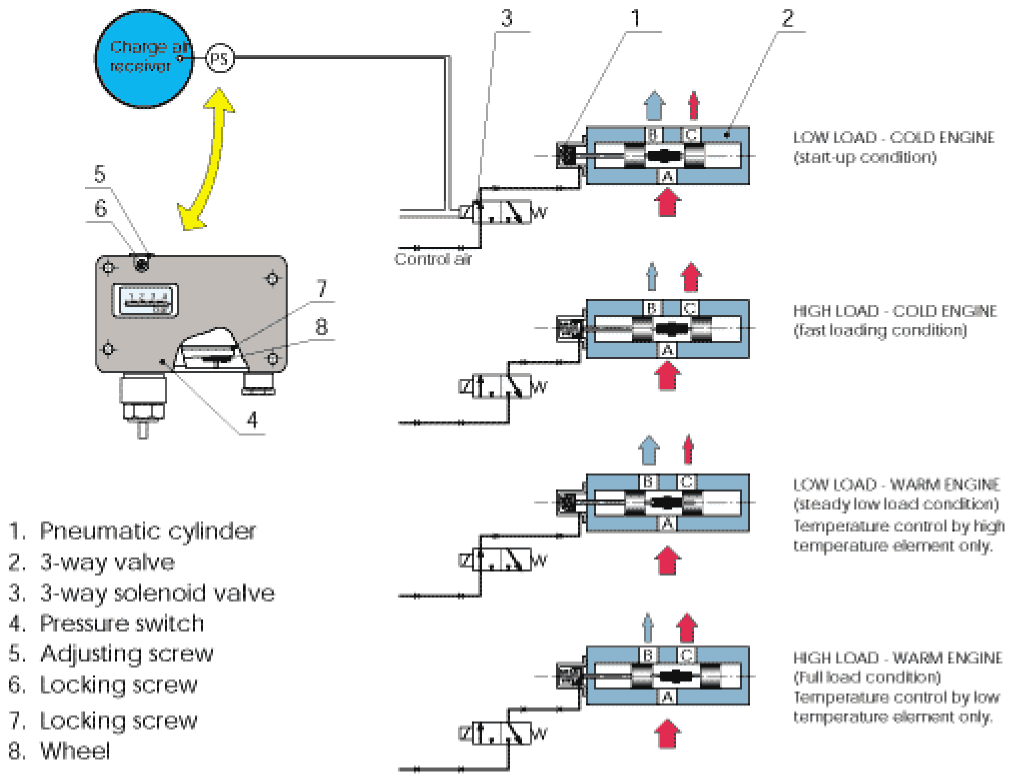

figure: 19-5 Temperature control system

19.4.2 Temperature control valve for LT circuit

19.4.2.1 Description

The valve is a two-step valve working with two fixed thermostatic elements (6) mounted in series inside the valve.
The water to be controlled, is the inlet to the charge air cooler, which is connected to port A, by-pass to B and cooling to C. The springs (10) force the valve (8) to the left (by-pass position).
At high load - low temperature operation there is no control air pressure (14) beneath the position control piston (3). Thus the spring (12) forces the piston (3) to the right (high load - low temperature position). In this situation the low temperature thermostatic element controls the valve while the high temperature thermostatic element is completely compressed. When the temperature rises the low temperature element expands and moves the valve against cooling position until steady state is reached.
At low load - high temperature operation the position control piston (3) moves to the left against the spring (12) to low load - high temperature position. The valve is then by-passing until the low temperature thermostatic element has expanded completely and the high temperature element starts expanding and takes over the control of the valve.
The pin (18) shows the position of the valve.
The drain bore (15) gives an indication of leakage of water (or air), [Fig 19-6].

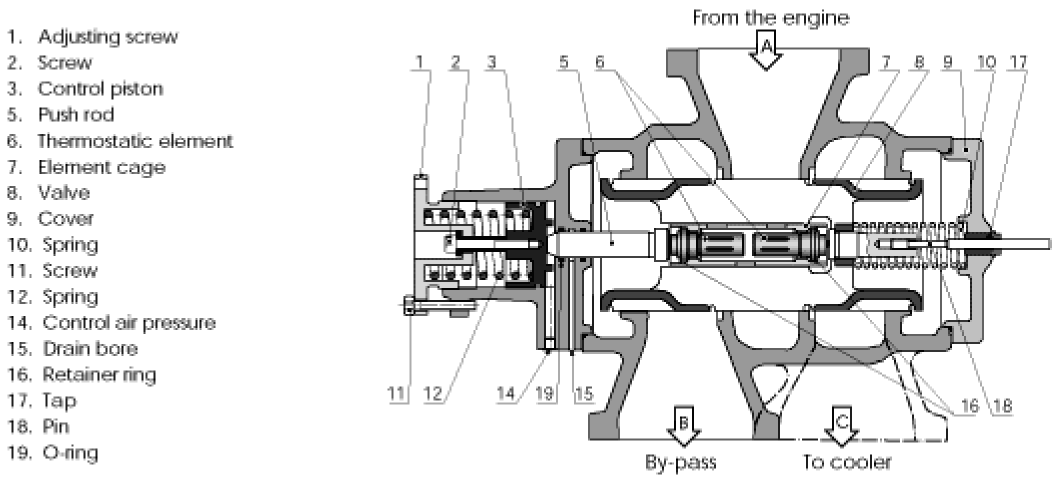

figure: 19-6 Thermostatic valve

19.4.2.2 Maintenance

Check the valve according to the recommendations in chapter [04] or if the temperatures are abnormal. Open and clean, change sealings, adjust according to section [19.4.2.2] c) and check temperatures at high and low load.
Wrong temperatures may be caused by damaged thermostatic elements, dirt or corrosion in the valve, fault in the position control system. Trouble-shooting can be carried out according to the steps below.
A mark (e.g. tape) on the indicator pin (18) for closed position of the valve (cooling cut off) will help in indicating the position of the valve. The movement of the valve is maximum 11 mm for normal control and maximum 30 mm when changing from low to high load.

A) Too low temperature at low load

When idling the temperatures can be somewhat lower than the guidance values.

1 **Check that the position piston** (3) is in high temperature position (moved to the left). This can be seen from the position of the screw (2).

1. Piston in correct position:

check the thermostatic elements

check that the valve (8), pin (5) and element cage (7) move freely

check the adjustment according to pos. c) below.

2. Piston in wrong position:

check if control air is fed to the piston

if there is pressure, the piston (3) jams, or the pressure is too low: Check pressure and clean the parts. Also check for air leakage in the opening (15). Leakage indicates that the O-ring (19) is damaged and has to be replaced by a new one for proper function of the thermostatic valve.

if there is no pressure: Check the signal from the switch (3) in [Fig 19-5].

if the signal is not correct: Change the switch

if the signal is correct: Check the pressure before the three-way valve.

2 **If the pressure is too low,** or if there is no pressure at all, check the pressure control valve (9), [Fig 21-2], and the primary pressure before the valve. If the pressure cannot be adjusted to correct value with correct primary pressure, clean the valve. If no improvement, change the valve.

3 **If pressure and control signal** to the three-way valve (2), [Fig 19-5], is satisfactory, check the valve itself.

4 **Check the coil.** Change if damaged.

clean the valve.

5 **Change the complete valve,** if damaged.

B) Too high temperature at low load

6 **Cooling is insufficient.** Check temperature after the central cooler. If the valve is fully open for cooling, the pin (18) is in outer position.

7 **Damaged thermostatic element(s).** (The low temperature element should also work correctly to give the correct high temperature

characteristic).

8 **The valve is jamming.** Clean the valve.

C) Too low temperature at high load

9 **Defective thermostatic element(s)** (the element(s) will not go back to cold position).

10 **Jamming valve.** Clean the valve.

11 **The valve is not closing correctly.** Check adjustment according to pos. d) below.

D) Too high temperature at high load

12 **Cooling is insufficient.** Check the temperature after the central cooler. Check that the valve is fully open. Utilize the indicator pin (18).

13 **Defective low temperature element.** Change the element.

14 **Check that the piston** (3) is in low temperature position, utilize the position of the screw (2).

15 **If the position piston** (3) is in wrong position, check pressure (14) before the cylinder.

16 **If there is no pressure,** the valve is jamming. Open and clean the valve.

17 **If there is pressure,** the position control system is faulty.

18 **If the pressure disappears** when opening the connection (14) the drain hole of the three-way valve (2), [Fig 19-5], can be clogged. Clean the drain opening.

19 **If the air flow does not stop,** check the switch (3), [Fig 19-5].

20 **If the switch is intact,** clean the three-way valve (2), [Fig 19-5], or change if damaged.

19.4.2.3 Adjustment of the valve

For correct closing position, adjust as follows:

1 **The air supply to the valve** should be shut off and drained before adjusting the valve.

2 **The temperatures of the valves** must not exceed 25°C when adjusting. This is to guarantee that the low temperature elements are completely compressed.

3 **Remove the screw (11).**

4 **Turn the adjusting nut (1) clockwise** until the indication pin (18) starts moving. Then turn the adjusting nut counter clockwise about one turn.

5 **Mount the screw (11)** in the nearest hole to lock the adjustment.

The temperatures can be altered only by changing the elements inside the valve.

19.4.2.4 Changing of thermostatic element

1 **Drain as much cooling water** as necessary to empty the valve.

2 **Shut off air supply.**

3 **Loosen the indicator pin (18)** but do not remove it from the tap (17).

4 **Remove the tap (17)** and the indicator pin.

5 **Carefully remove the cover (9).** Notice that the cover is spring loaded.

6 **Remove the complete valve assembly (8).**

7 **Remove the element cage (7).**

8 **Remove the retainer ring (16),** after which the thermostatic elements can be changed.

9 **Check the parts,** including the push rod (5), for wear and corrosion.

10 **Mount the elements** and the valve in reverse order.

19.4.2.5 Check of the thermostatic element

The elements can be checked by heating up slowly in water. Put a strong rubber ring longitudinally over the element and its push rod to keep the rod pressed into the element.

At the nominal opening temperature, stamped on the element (for example 4.051.35 means that the nominal opening temperature is 35°C); the push rod of the element should be flush with the end surface of the body. At a temperature 10°C higher, the movement of the push rod should be about 10 mm (i.e. stroke 10 mm from the stamped temperature).

Note!

There are two different elements in the valve according to below.

LT-circuit: one element 35°C and one element 65°C.

19.4.3 Check of change-over point

1 **Raise the load slowly over the change-over point,** normally at 35 % ± 2 % load (if no other value has been agreed with the manufacturer). Check the change-over from the movement of the screw (2), [Fig 19-6], or from the electrical side (no current at high load). Adjust the set value (5) of the pressure switch, if necessary. Open the locking screw (6) during adjustment, [Fig 19-5].

2 **Decrease the load slowly over the change-over point** which should be 2 - 3 % lower than the point of increased load. Adjust the hysteresis (Δp) of the switch (8), if necessary. Open the locking screw (7) during adjustment,[Fig 19-5].

19.4.4 HT-thermostatic valve

The HT-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 HT-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 HT-water outlet temperature. If ever required, the HT-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.

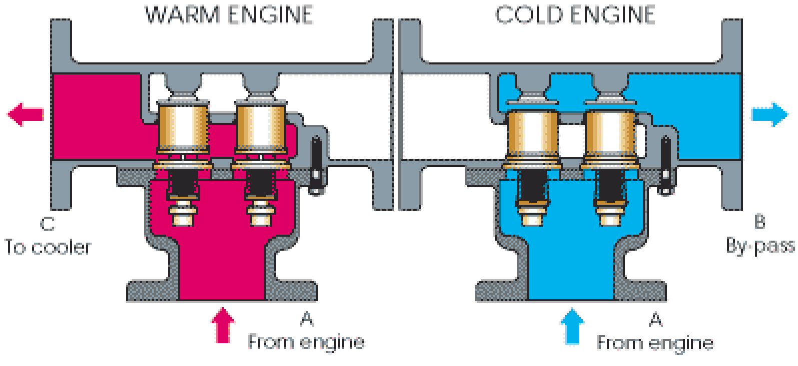

figure: 19-7 Water flow in thermostatic valve

No adjustments are ever required on the HT-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 HT-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.

Note!

This thermostatic valve is sometimes used as LT thermostatic valve.

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 HT-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.

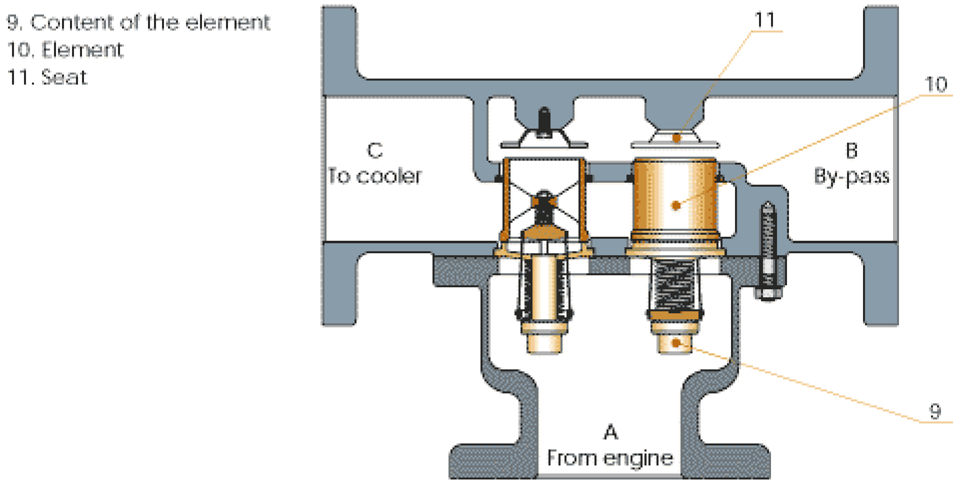

figure: 19-8 Cooling water thermostatic valve

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.

19.4.5 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.

4. **Install the elements**

20 Exhaust System

version : 20-9601-00

20.1 Description

The exhaust pipes are cast of special alloy nodular cast iron, with separate sections for each cylinder.
Metal bellows of the multiply type absorb heat expansion between the cylinder heads and the pipe system as well as between the turbocharger and the pipe system.
All connections between pipes, expansion bellows, cylinder heads and turbocharger are made with rigid flanges and gaskets.
The pipe system is supported and fixed by a bracket (5) but is free to move axially in the supporting bracket (3). The disc springs (2) maintain a positive force between the bracket and the pipe, [Fig 20-1].
The complete exhaust system is enclosed by an insulation box built up of insulated sandwich steel sheets, flexibly mounted on the engine structure. Mineral wool is used as insulating material.
The exhaust gas temperatures can be checked on local thermometers after each cylinder. Sensors for remote measuring of the temperature (or for the alarm system) can be mounted after each cylinder as well as before and after the turbocharger.

1. Flexible element
2. Disc spring
3. Supporting bracket
4. Cover
5. Bracket
6. Cover

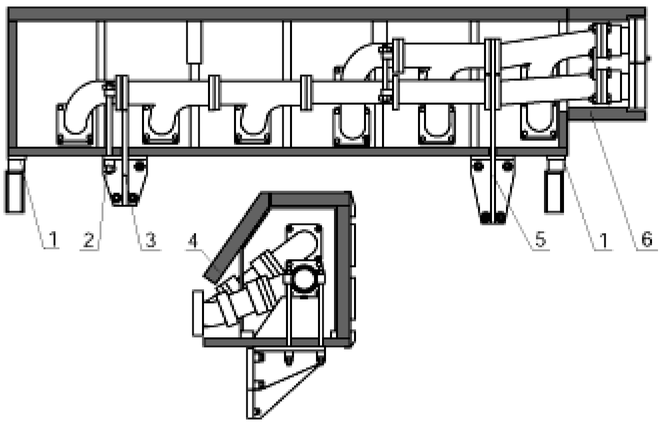

figure: 20-1 Exhaust system

20.2 Replacing expansion bellows

1 **Remove the cover (4)** of the insulation box to get access to the expansion bellows between the exhaust pipes and the cylinder head.

2 **Remove the covers (6)** to get access to the expansion bellows between the exhaust pipes and the turbocharger.

3 **Check that the flanges** between the turbocharger and the exhaust pipe are parallel and located on the same center line to avoid lateral forces on the bellows when mounting, [Fig 20-1].

Caution!

The surface of the insulation box is hot.

20.3 Suspension of the insulation box

The insulation box is mounted with flexible elements (1) to dampen vibrations thus protecting the insulation. Replace the elements by new ones, if necessary, [Fig 20-1].

20.4 8- and 16-cylinder engines

In 8- and 16-cylinder engines (VASA 8R22, 8R22/26 and 16V22) differencies in exhaust gas temperatures between the cylinders might occur. The exhaust manifold in these engines is a so-called pulse charging system with pulse converters, two for each turbocharger, which collect the exhaust gases to the turbochargers through two gas inlets. This charging system provides the best total engine efficiency.
The exhaust gas temperatures recorded in the two cylinders which are closest to the turbochargers are higher because of disturbing gas pulses which are conveyed to the same gas inlet from other cylinders. [Fig 20-2] shows typical exhaust gas temperature profiles for a 8R engine. The difference in temperatures between the cylinders depends on the engine speed and load.
On the basis of practical and theoretical studies made by Wärtsilä Diesel, it has been found that the thermal load on the exhaust valves is not larger on a cylinder where high temperatures are recorded.

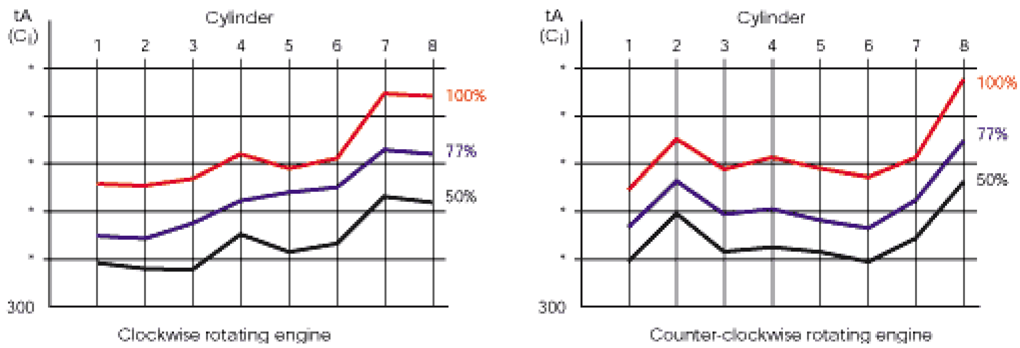

figure: 20-2 Exhaust gas profiles

When estimating the function of a cylinder on the basis of the exhaust gas temperatures under normal conditions, the values recorded in the acceptance test should be used as reference values. A deviation from them by 50°C is acceptable provided the ambient conditions and the fuel quality are equivalent to these in the acceptance test.

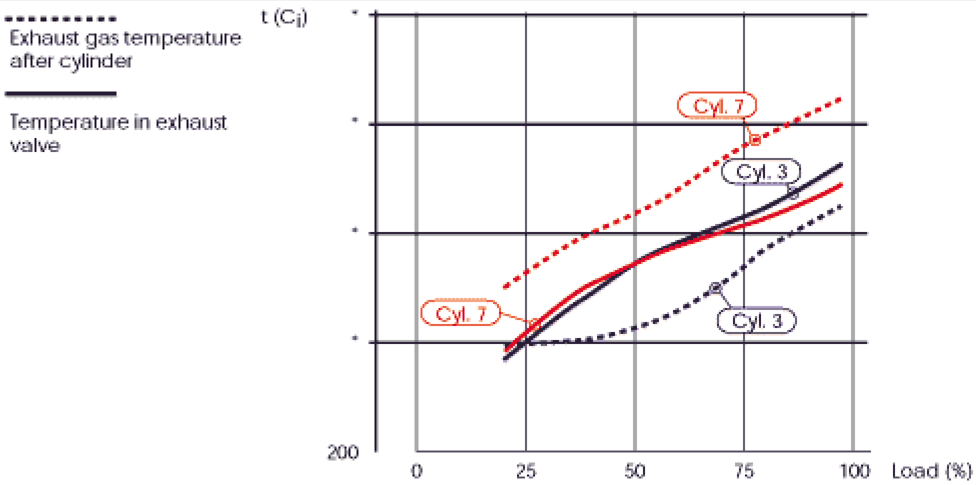

figure: 20-3 Exhaust gas and valve temperatures

The exhaust gas temperatures of cylinders 7 and 8 in a clockwise rotating engine and of cylinder 8 in a counter-clockwise rotating engine are usually 50-120°C higher than the mean temperature of the other cylinders.
The temperature difference between the cylinders should not be balanced by readjusting the fuel pump racks, which causes uneven loading of the cylinders. The deviation between the fuel rack positions of the cylinders in an engine must not exceed 1 mm.

21 Starting Air System

version : 21-9601-00

21.1 General description

The engine is started with compressed air of maximum 30 bar. The minimum pressure required is about 11 bar depending on the cylinder number and the installation. A pressure gauge (15) indicates the pressure before the main starting valve.
The inlet air pipe from the starting air receiver includes a non- return valve (21) and a filter (20). A blow-off valve (14) is located before the main starting valve. The main starting valve may be operated either with the lever (1) at manual starting or with a solenoid valve (8) at remote or automatic starting of the engine.

1. Lever
2. Lever
3. Pin
4. Spring
5. Air space
6. Servo piston
8. Solenoid valve
10. Plug
11. Sealing piston
12. Air space
14. Blow-off valve
15. Pressure gauge
16. Flame arrester
17. Guiding piston
18. Spring
19. Cam
20. Filter
21. Non-return valve
22. Control piston
23. Start blocking valve
24. Nut

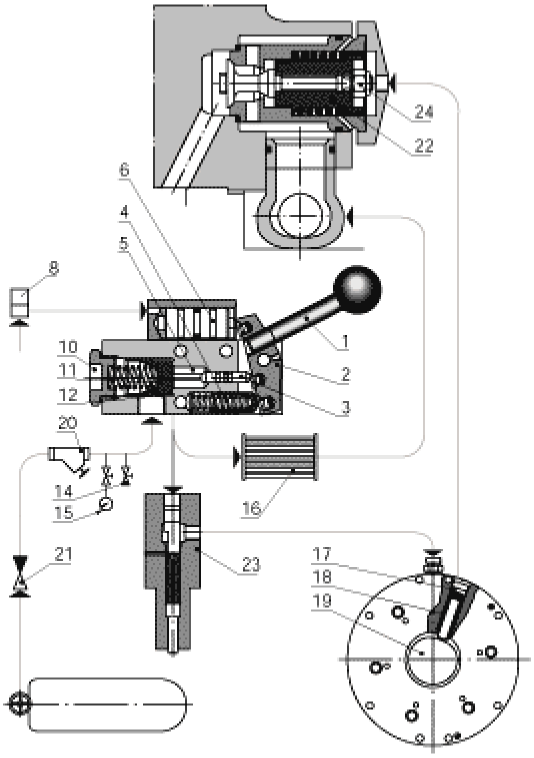

figure: 21-1 Starting air system

When the main starting valve opens, starting air passes partly through the flame arrester (16) and partly through the start blocking valve (23). The start blocking valve prevents the passage of control air if the cover to the turning opening at the flywheel is removed.
The starting air distributor guides the control air to the starting valves which open and admit starting air to flow to the various cylinders for suitable periods.
Four-cylinder engines are optionally equipped with a pneumatic starting motor which turns the crankshaft through a gear ring on the flywheel until the engine has reached a speed enabling start, see [21.7].
V-engines have starting valves on the A-bank, only. See [Fig 21-1].

21.2 Main starting valve

21.2.1 Description

The starting air for the engine is led to the space (12), and through holes in the sealing piston (11) also to the rear side of the piston which means that the piston normally is closed.
At manual start, open the valve by depressing the lever (1). The pin (3) will then move the piston (11) and starting air is admitted to the space (5), to which the distributing pipe and the starting air distributor inlet pipe are connected.
At remote or automatic start the solenoid valve opens and the servo piston (6) moves the sealing piston (11) upwards through the lever (2) and the pin (3). The solenoid valve opens when it is energized. When it closes, the space behind the servo piston (6) is vented and the main starting valve closes, [Fig 21-2].

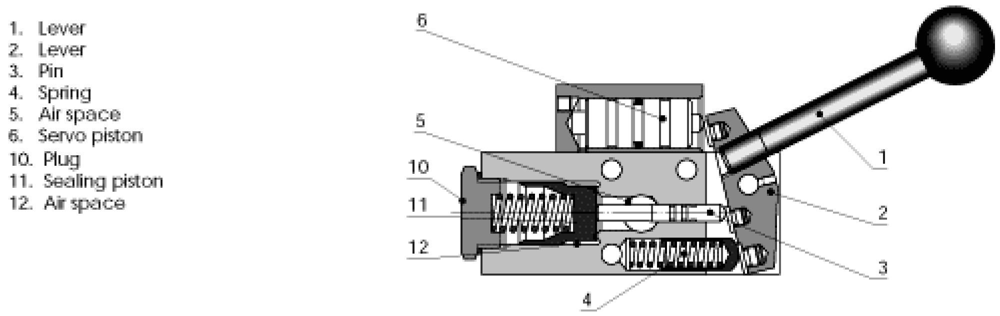

figure: 21-2 Main starting valve

21.2.2 Maintenance

Normally, the main starting valve requires little maintenance. In case it is to be opened for inspection:

1 **Remove the valve** from the engine by loosening the starting air pipe, the pipe from the valve to the start blocking valve and the bracket with the starting lever. On V-engines, also remove the pressure gauge pipes from the instrument panel and, as a unit, the instrument panel and the bracket with starting lever. The valve can now be removed from the end cover.

2 **Open the plug (10),** [Fig 21-2], for inspection. Clean the sealing piston (11) and the seat. Do not use hard tools.

3 **Check the pin (3)** and the servo piston (6) for free movement. The servo piston is removed by undoing the two hexagon socket head screws by which the cylinder is fixed. Replace the O-rings, if necessary.

4 **Lubricate the details** before reassembling. Fill the servo piston lubricating grooves with Molykote Paste G.

5 **When installing,** check that the O-rings are undamaged and in position.

Lubricate the contact faces of the lever arm with Molykote.

The solenoid valve (8), [Fig 21-1], requires, in principle, no maintenance. If the coil has broken, e.g. because of overvoltage, replace the coil by a new one. If the valve is probable to be clogged by dirt it can be dismantled for cleaning if caution is observed. Check that the sealing surfaces are not damaged. Reinstall all details in correct position and order. If further troubles, replace the valve by a new one.

21.3 Starting air distributor

21.3.1 Description

The starting air distributor is of the piston type. The distributor pistons are guided by a cam (19), [Fig 21-1], at the camshaft end. When the main starting valve opens, the guiding pistons (17) are pressed against the cam, whereby the guiding piston of the engine cylinder which is in starting position admits control air to the control piston (22) of the starting valve. The starting valve opens and allows pressure air to pass into the engine cylinder. The procedure will be repeated as long as the main starting valve is open or until the engine speed is so high that the engine fires.
After the main starting valve has closed, the pressure drops quickly and the springs (18) lift the pistons off the cam, which means that the pistons touch the cam only during the starting cycle. Thus wear is insignificant.

21.3.2 Maintenance

Normally, the starting air distributor is only slightly worn. If it has to be opened for inspection and cleaning:

1 **Take care** not to damage the sliding surfaces of the piston and the distributor housing bores.

2 **The pistons** are individually matched and are not interchangeable. Utilize the cylinder number stamped at every control air outlet.

3 **Apply Molykote Paste G** to the piston sliding surfaces and fill up the lubricating oil grooves before reassembly. Check that the pistons do not stick.

4 **After installing, check the distributor** but before connecting control air pipes, check that all pistons are working satisfactorily, e.g. by connecting compressed air to the distributor air inlet and turning the crankshaft; it is then possible to see whether the pistons follow the cam profile.

Caution!

If the control air pipes have been connected prior to checking the crankshaft will rotate.

21.4 Starting valve in the cylinder head

21.4.1 Description

The valve is an exchangeable unit consisting of a valve spindle with a spring-loaded control piston installed in a housing.

21.4.2 Maintenance

Check and, if necessary, clean the valve when overhauling the cylinder head.

1. **Remove the flange** and pull out the starting valve.
2. **Unscrew the self-locking nut (24),** [Fig 21-1], and remove the piston (22).
3. **Check the sealing faces** of the valve disc and valve seat.
4. **After reassembling the piston,** spindle and spring, check that the valve moves easily and closes completely.
5. **When installing the valve,** check that the sealing under the valve is in position and intact.
6. **Tighten the valve to torque** recommended in chapter [07].

21.5 Starting air vessel and piping

The starting air system should be designed so that explosion is prevented.
An oil and water separator should be included in the feed pipe between the compressor and the starting air vessel. At the bottom point 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 with intervals according to chapter [04]. 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 damage on the seats, which in turn causes leakage. Leaky and worn valves including safety valves should be reground. Pressure test the safety valves.
The filter (20), [Fig 21-1], on the engine should be inspected and cleaned with intervals according to chapter [04]. Drain the filter from condensate with the built-on drain valve.

21.6 Pneumatic system

21.6.1 General description

The engine is equipped with a pneumatic system for control of the following functions by means of identical solenoid valves:

- start of the engine
- stop of the engine
- starting fuel limitation
- change-over of the thermostat valve.

The system includes a filter (12), an vessel (6) and a non-return valve (11) to ensure the pressure in the system in case of lacking feed pressure.
The main starting valve (8), which is described in detail in section [22.2], is actuated by the solenoid valve (3) at remote start. [Fig 21-3] shows the solenoid valve. The valve is equipped with a push button and can be energized manually.
At the same time as the main starting valve is actuated, an impulse goes to the automatic water separator, which opens during the starting cycle to expel condensated water separated by the filter (12).
The starting fuel limiter (15) is described in detail in chapter 22., section [22.7]. During the starting cycle it is automatically actuated by the solenoid valve (2), which is energized from the speed monitoring system.
The pneumatic overspeed trip devices (13), described in detail in chapter 22., section [22.6], are controlled by the valve (14) which is actuated by the solenoid valve (4) on an electric signal from the speed monitoring system, whereby the engine stops.
The push button of the solenoid valve is able to function as a local stop.

1. Solenoid valve
2. Solenoid valve
3. Solenoid valve
4. Solenoid valve
5. Pressure control valve
6. Vessel
7. Draining valve
8. Main starting valve
9. Valve
10. Draining valve
11. Non-return valve
12. Filter
13. Pneumatic overspeed trip device
14. Valve
15. Starting fuel limiter
16. Thermostat valve
17. Valve
18. Valve

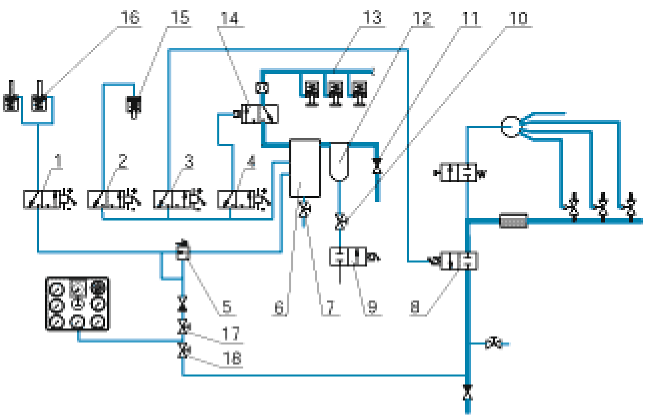

figure: 21-3 Pneumatic system

The thermostat valves (16), described in detail in chapter [19], are actuated by the solenoid valve when the engine runs idle or at partial load. The solenoid is controlled by a switch in the charge air circuit. Set point, see chapter [19]., Temperature control system.

21.6.2 Maintenance
The system is built up of high class components. Usually it requires no other maintenance than check of function, cleaning of the air filter (12) and draining of condensated water from the vessel (6) using the draining valve (7).
21.6.3 Check
When starting, check that the automatic water draining works by watching whether water-mixed air flows out from the valve (9).
Regularly check the pressure after the pressure control valve (5). Shut off valve (18), open valve (17) and read the pressure on the manometer panel (starting air manometer), [Fig 21-3]. Reset the valves in their original position after reading.
21.6.4 Maintenance of pneumatic components
Filter ([Fig 21-3]/12, [Fig 21-4]/A). The bottom part of the filter is attached to the top part with a thread. To open the filter, expel air and turn the bottom part.
Clean the insert (1) and inside of the filter after each 8000 h.
Solenoid valve ([Fig 21-3]/1 - 4, [Fig 21-4]/B). In case of disturbance in the electric function of the valve, test the valve by pushing the button (1). Should there be mechanical malfunction, open the valve using a special tool.
Check that the bores (2) and (3) in the seat are open and the gasket (4) is intact. Change the valve if it does not function after cleaning.
Water draining valve ([Fig 21-3]/9). Clean the valve if there is any disturbance. The valve can temporarily be disconnected by shutting the valve (10).
Pressure control valve ([Fig 21-3]/5, [Fig 21-4]/C). The pressure control valve requires no maintenance. Should there be malfunction, change it.

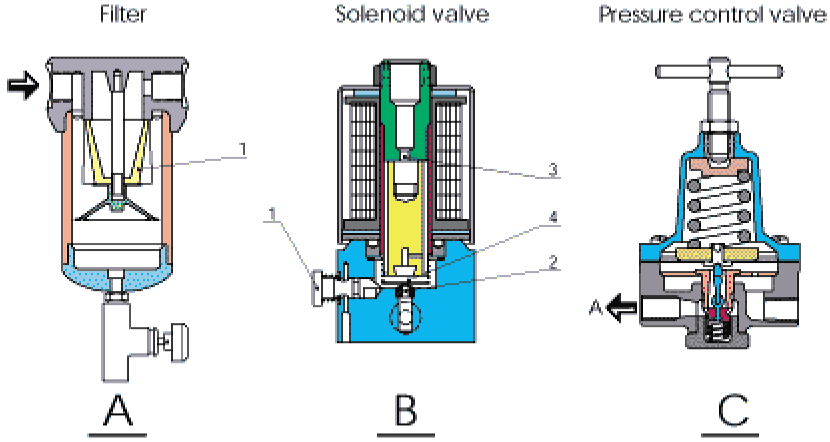

figure: 21-4 Pneumatic components

21.7 Starting air system equipped with pneumatic starting motor (4R22, 4R22/26)
21.7.1 Description
In order to ensure automatic start irrespective of the crankshaft position, the four-cylinder engines are optionally equipped with a pneumatic starting motor, which turns the crankshaft through a gear ring on the flywheel until the speed necessary for start is reached. The starting air pressure is maximum 30 bar. The minimum pressure for start is about 15 bar but it can vary from one installation to another.
As an extra safety measure there is a device on the engine that prevents undesirable starting during turning. Air is led through a start limiting valve (6), [Fig 21-5], that prevents the passage of control air if the cover to the turning opening at the flywheel is removed.
If the engine is started up manually, the push-button (7) should be released as soon as the engine starts, otherwise the starting motor is exposed to unnecessary wear.

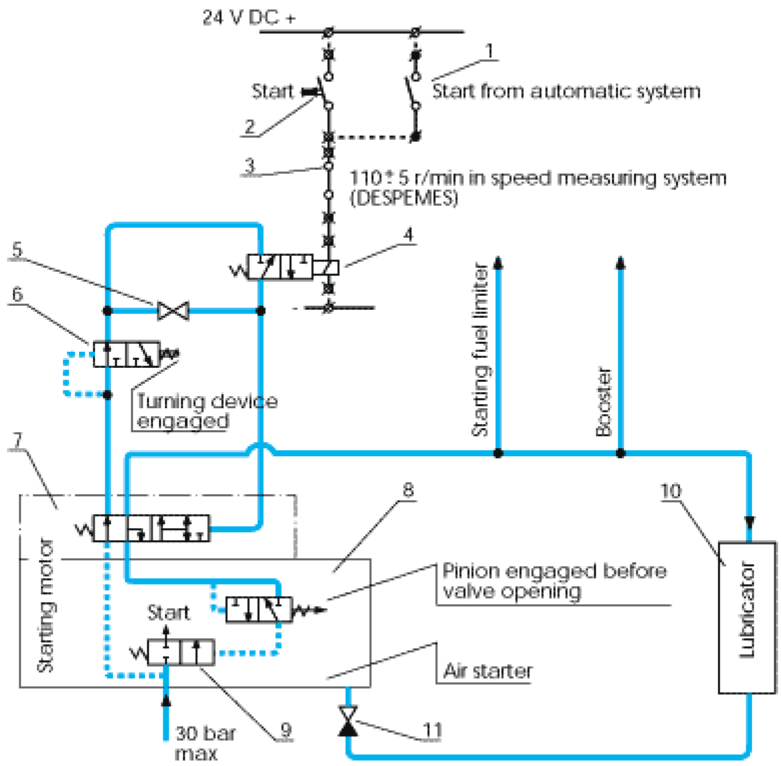

figure: 21-5 Starting air system with pneumatic motor

21.7.2 Maintenance

It is very important to keep the system free from dirt and condensate to achieve troublefree function. See section [21.5].
Vent the servo lubricator circuit when starting up a new motor or if, by mistake, the oil container went empty.

If the servo lubricator circuit is not thoroughly vented the starting motor will get no lubrication and may be damaged.

21.7.3 Venting

1 **Loosen the air connection** from the lubricator (10) and the oil connection from the non-return valve (11).

2 **Plug up the oil pipe opening** with a finger and, by means of an air nozzle, blow compressed air into the air connection several times until oil emerges from the oil pipe. If compressed air is not available, the connection "1" on the valve (7) can be opened and the valve can be connected to the servolubricator air connection. Then it is possible to use the normal start button of the engine for venting without starting the engine.

Warning!

When using the start button of the engine when venting as described above, connection on the valve (7) must absolutely be removed. Otherwise the engine will start when venting.

3 **Connect the pipe** to the non-return valve (11) and check that oil is supplied through the valve when blowing compressed air.

4 **Apply all pipes** to the initial connections.

5 **Check function** during a few starts. When pressing the start button, oil level in the glass tube should momentarily drop by 15 - 20 mm and then rise to a level corresponding the oil level in the container.

Regularly check that the oil level stays between the maximum and minimum marks. Use some of the following oils:

GALI HJ 33 EP

SHELL TURBO 27

CASTROL HYSPIN 80

BP ENERGOL HP 46

MOBIL DETERGENT LIGHT.

The oil brands are also engraved on the container.

In case of possible malfunction, see manufacturer's instructions attached, "POSSIBLE FAULTS AND THEIR SOLUTION"

22.1 Description

During normal operation the engine speed is controlled by a speed governor (22), [Fig 22-1], which regulates the injected fuel quantity to correspond to the load.
The regulating movement is transferred to the control shaft (10) through a spring-loaded rod (20) which enables stop or limit functions to be transferred to the control shaft irrespective of the governor position. The control shafts on the cylinder banks in a V-engine are connected with rods in such a way that the two control shafts work synchronously together.
The movement from the control shaft to the injection pump fuel racks (1) is transferred through the control lever (8) and the connection piece (4), in fuel-on direction through the follower (7) and the torsional spring (6), and in fuel-off direction through the torsional spring (9).
The torsional spring (9) allows the control shaft and consequently the other fuel racks to be moved to stop position even if one of the racks has jammed. In the same way the torsional spring (6) allows the control shaft to be moved towards fuel-on position even if an injection pump has jammed in no fuel position. This feature can be of importance in an emergency situation.
The indicator (17) indicates the fuel rack position.
The engine can be stopped by means of the stop lever (14). When the lever is moved to stop position, the lever (16) actuates the lever (15) forcing the control shaft to stop position.
The engine is provided with two independent overspeed trip devices, an electro-pneumatic device with tripping speed about 13-15 % above the nominal speed, and a mechanical device with tripping speed about 15-18 % above the nominal speed (see chapter 06, section [06.1]). The electro-pneumatic device moves every fuel rack to no-fuel position by means of a pneumatic cylinder on every injection pump. The mechanical device actuates the lever (13) moving the control shaft to stop position. Both the electro-pneumatic and the mechanical device can be tripped also manually, see section [22.5] and [22.6].
The speed governor is provided with a stop solenoid by which the engine can be stopped remotely. The solenoid is also connected to the electro-pneumatic overspeed protection system and to the automatic stop system which stops the engine at too low lube oil pressure, too high circulating water temperature, or at any other desired function.
When starting, a fuel limiter automatically limits the movement of the control shaft to a suitable value. A pressure air cylinder limits the position of the lever (11), see section [22.7].
Next to the governor there is a fixed mechanical limiter affecting the control shaft directly by means of the lever (18).

22.2 Maintenance

Special attention should be paid to the function of the system as a defect in the system may result in a disastrous overspeeding of the engine or in the engine not being able to take load.

A) The system should work with minimum friction. Clean and lubricate regularly the racks, connection piece, bearings (also the self-lubricating bearings (12)) and the ball joints with lubricating oil.

The maximum torque to which the control shaft can be moved at running temperatures (the speed governor disconnected) is 1 Nm/cylinder(= 8 Nm for a 8R22/26).
B) The system should be as free from clearances as possible. Check clearances of all connections. The total clearance may correspond to maximum 0.5 mm of the injection pump fuel rack positions.
C) Check regularly (see recommendations in chapter [04]) adjustment of the system; stop position, overspeed trip devices, starting fuel limiter, see section [22.3].
D) When reassembling the system, check that all details are placed in the right position, that all nuts are properly tightened and to torque, if so prescribed, that all locking elements like pins and self-locking nuts are in positions. Check according to pos. a - c above.

22.3 Check and adjustment

22.3.1 Stop lever stop position

A) Check:

set the terminal shaft lever (23) in maximum fuel position and the stop lever (14) in stop position,

check that the fuel rack position of all injection pumps is less than 5 mm.

B) Adjustment:

set the stop lever in the stop position and check that the lever (15) contacts the lever (16) properly. A small torque can be set from the governor, but not a too large one, because this will twist the shaft unnecessarily, although little,

adjust the fuel rack position to 4 mm by adjusting the screws (5).

1. Fuel rack
4. Connection piece
5. Screw
6. Torsional spring
7. Follower
8. Control lever
9. Torsional spring
10. Control shaft
11. Lever
12. Bearing
13. Lever
14. Stop lever
15. Lever
16. Lever
17. Indicator
18. Lever
19. Lever
20. Spring-loaded rod
21. Screw
22. Speed covernor
23. Lever

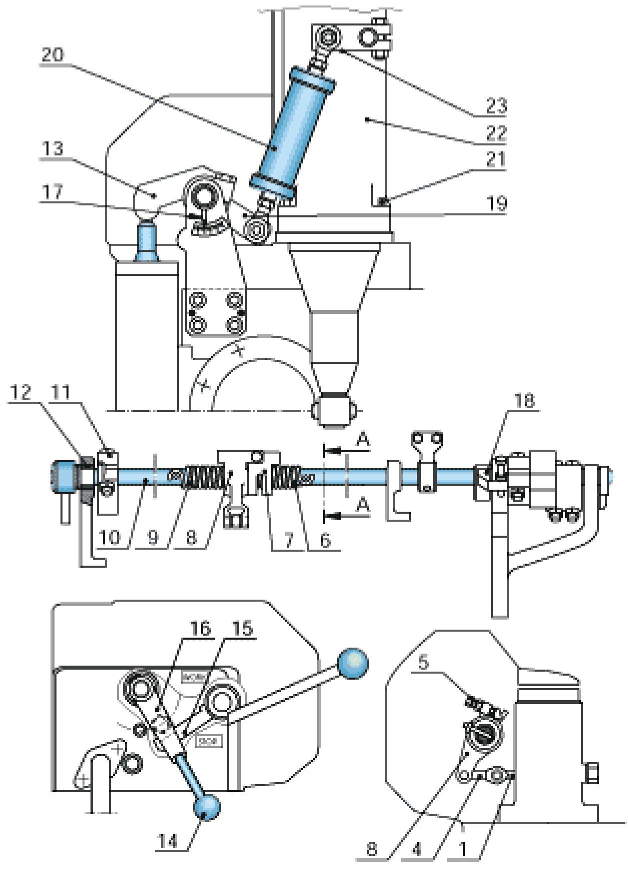

figure: 22-1 Control mechanism

22.3.2 Governor stop position

A) Check:

move the stop lever into work position,

set the governor terminal shaft lever in stop position,

check the fuel rack positions to be 4 mm.

B) Adjustment:

if the fuel rack positions are unequal, adjust first according to section [22.3.1] b),

adjust the spring-loaded rod so that the fuel rack position of 4 mm is obtained,

if changing the governor, see section [22.4].

22.3.3 Mechanical overspeed trip device

A) Check of stop position

set the stop lever in work position and the terminal shaft lever in maximum fuel position,

release the overspeed trip device manually,

check the fuel rack positions to be less than 5 mm.

B) Adjustment of stop position

the stop position is adjusted and locked by the engine manufacturer to provide a stop position equal to that of the stop lever. If deviations occur, check lever fixations and wear.

C) Check and adjustment of tripping speed

see section [22.5].

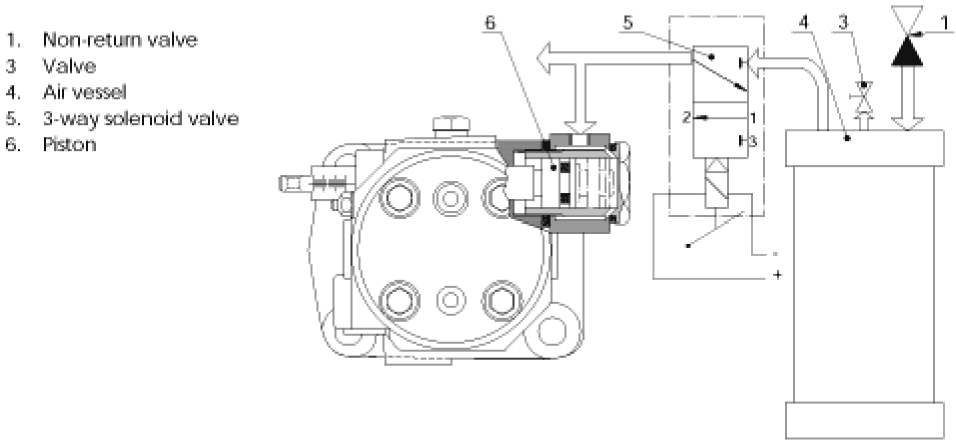

figure: 22-2 Electro-pneumatic overspeed trip device 22

22.3.4 Electro-pneumatic overspeed trip device

A) Check of stop position

set the stop lever in work position and the terminal shaft lever in maximum fuel position,

release the overspeed trip device manually,

check the fuel rack positions to be less than 5 mm.

B) Adjustment of stop position

the electro-pneumatic overspeed trip device requires no adjustment,

if a fuel rack position of less than 5 mm cannot be obtained, check for wear.

C) Check and adjustment of tripping speed

see section [22.6].

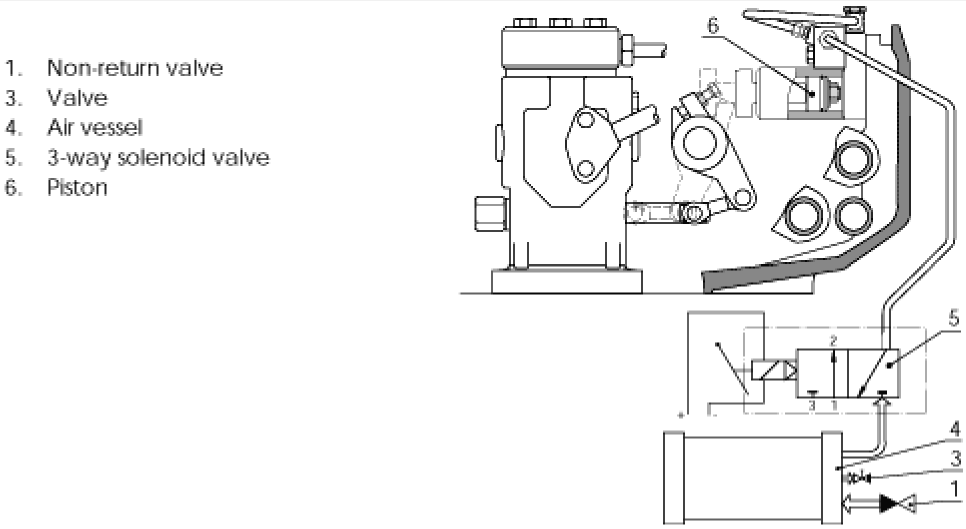

figure: 22-3 Electro-pneumatic overspeed trip device 22/26

22.3.5 Starting fuel limiter

A) Check of limit position

set the stop lever in work position and the terminal shaft lever in maximum fuel position,

connect pressure air to the nozzle (5), [Fig 22-4], at which the limiter piston (1) will turn the control shaft to the limit position,

check the fuel rack position. The suitable limitation depends on the installation, normally about 18 mm.

B) Adjustment of limit position

connect pressure air to the nozzle (5),

loosen the fastening screw (3) of the limitation lever,

turn the control shaft to the desired limitation of the fuel rack position,

move the limitation lever against the limitation piston (1). Tighten the fastening screw in this position,

check according to pos. a) above.

C) Check of function

see section [22.7].

22.3.6 Indicator of fuel rack position

Check that the indicator corresponds to the fuel rack positions. If not, loosen the grub screw and adjust the indicator to the correct value.

1. Piston
2. Cylinder
3. Screw
4. 3-way solenoid valve
5. Nozzle
6. Coil
7. Lever
8. Non-return valve

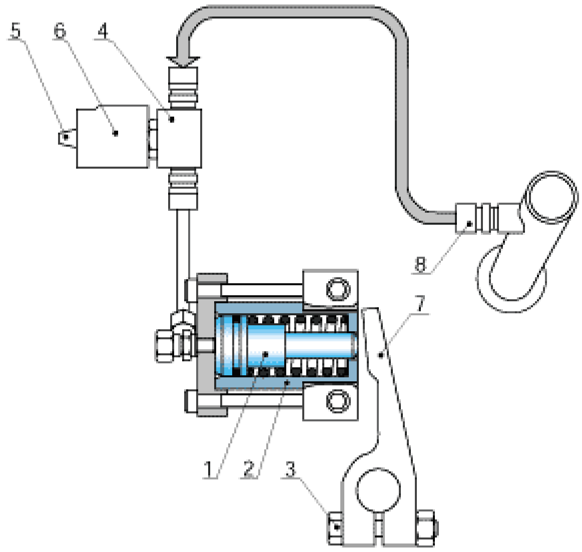

figure: 22-4 Starting fuel limiter

22.4 Speed governor

22.4.1 General

The engine can be equipped with various governor alternatives depending on the kind of application. Concerning the governor in itself, see the governor instruction book.

22.4.2 Hydraulic governor drive

The governor is driven by a separate drive unit which, in turn, is driven by the camshaft through helical gears. The governor is fastened to this drive unit and connected to the drive shaft through a serrated connection. The governor with drive can thus be removed and mounted as a unit or the governor can be changed without removing the drive unit.

Pressure oil is led through drillings in the bracket to the bearings and to a nozzle for lubricating the gears. The gear and the serrated coupling sleeve are mounted to the shaft with interference and secured with spring pins.

Check at recommended intervals:

the radial and axial clearances of the bearings,

the gear clearance,

the oil drillings and the nozzle to be open,

that the gears and serrated coupling sleeve are firmly fastened to the shaft.

Change worn parts.

22.4.3 Removal of governor

1 **Loosen the terminal shaft lever** (23), [Fig 22-1], and governor electrical connection.

2 **Open the screws** (21) and pull the governor vertically upwards. The governor must not fall or rest on its driving shaft.

22.4.4 Mounting of governor

When mounting the same governor, check that the mark on the lever (23), [Fig 22-1], corresponds to that of the shaft. Check the setting according to section [22.3].

When mounting a new governor, proceed as follows:

1 **Mount the governor** into position on the governor drive.

2 **Turn the governor terminal shaft** to stop position (in counterclockwise direction seen from the driving end).

3 **Mount the terminal shaft lever** (23) as follows, [Fig 22-1].

Woodward type	R22		R22/26		12V22		16V22	
	A	B	A	B	A	B	A	B

UG10	**20.1°**	**30°±5°**	35.3°	**20°±5°**				,	
PGA16	**50.3°**	80°±3.75°	47.0°	**80°±3.75°**	42.6°	**45°±3.75°**	65.8°	**45°±3.75°**
PGG16					**42.6°**	**45°±3.75°**	**65.8°**	**45°±3.75°**
EGB13	**45.4°**	**45°±3.75°**	60.1°	**30°±3.75°**			,	
EGB29					**42.6°**	**45°±3.75°**	**58.1°**	**45°±3.75°**
Regulator Europa	**30.3°**	**30°±5°**	45.4°	**20°±5°**	38.3°	**90°±5°**	28.6°	12° ±5°

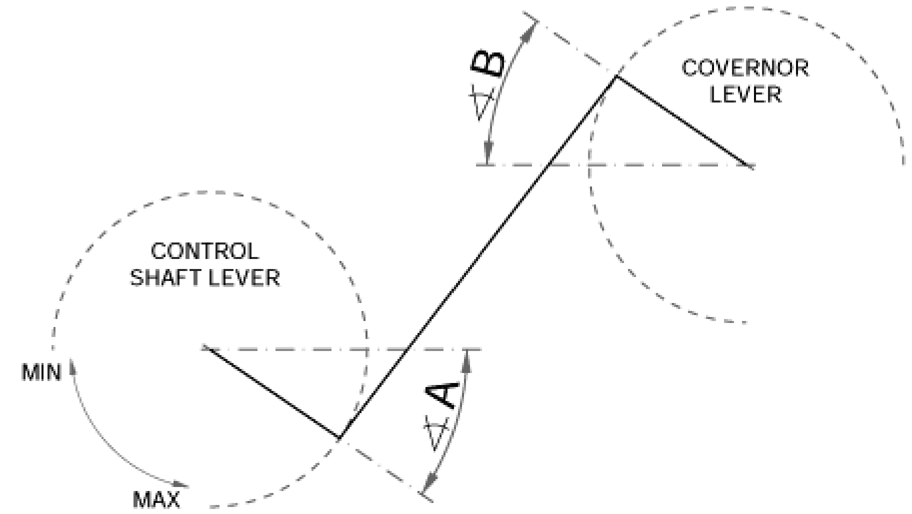

figure: 22-5 Linkage arrangement for covernor

4 **Lock the fastening screw** and mark the position of the terminal shaft lever with a mark on the shaft corresponding to that of the lever.

5 **Move the stop lever** into the stop position. (Fuel rack position 5 mm).

6 **Adjust the spring-loaded rod length** to fit between the levers (23) and (19). Do not forget to secure the nuts.

7 **Check according to section [22.3].**

22.5 Mechanical overspeed trip device

22.5.1 Description

The overspeed trip device is of the centrifugal type. It will trip when the engine speed exceeds the speed mentioned in chapter 06., section [06.1]. The tripping mechanism is fastened direct to the camshaft end. When the engine speed increases, the centrifugal force on the tripping mechanism increases and exceeds the force of the spring (1), [Fig 22-6], at the set tripping speed, whereby the weight (2) is thrown outwards forcing the latch (3) to turn, thus releasing the spindle (4), which is forced outwards by the working spring (5). The V-engine is provided with double working springs. The force is transferred to the control shaft by the lever (6) and a claw coupling on the control shaft, and the control shaft is turned to stop position.
The overspeed trip device may be tripped manually by the lever (7).
The engine cannot be restarted before the lever (6) has manually been depressed so far that the latch (3) engages the piston of the spindle (4).
A switch (8), indicating released overspeed trip device, may be provided.

22.5.2 Check of tripping speed

Check the tripping speed at idle by increasing the engine speed above the nominal speed by quickly turning the speed control knob of the governor. Turn the knob back approximately to the initial position and retension the working spring of the overspeed trip device manually by

means of the lever (6), [Fig 22-6]. Use a steel bar or pipe with the outside diameter of maximum 22 mm, e.g. the steel bar 844001. Do not increase the engine speed by more than 40 RPM above the tripping speed.
The tripping speed should be according to the values mentioned in section [06.1]. When checking the tripping speed, the electro-pneumatic overspeed trip device must be disconnected on the electrical side as it has a lower tripping speed. Do not forget to reconnect it.

22.5.3 Adjustment of tripping speed

1 **Remove the plug (9), [Fig 22-6].**

2 **Turn the crankshaft** until the locking screw (nut) (14) is in front of the opening.

3 **If a higher tripping speed is desired,** tension the spring by screwing the spring cap in. If a lower tripping speed is desired, screw the spring cap outwards.

1. Spring
2. Weight
3. Latch
4. Spindle
5. Spring
6. Lever
7. Lever
8. Switch
9. Plug
10. Control shaft
11. Screw
12. Hole
13. Screw
14. Adjusting nut
16. Screw
17. Spring
18. Cover
19. Housing
20. Spring cap

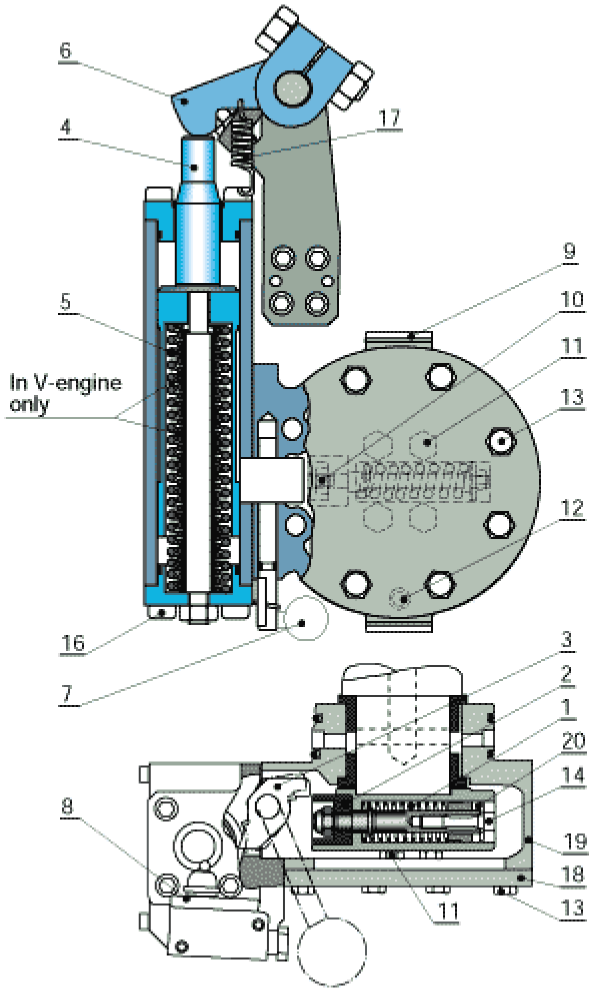

figure: 22-6 Mechanical overspeed trip device

4 **Lock the spring cap** with the locking screw(nut).

5 **Mount the plug** (9) and check the tripping speed according to section [22.5.2].

6 **The spring can be replaced** through the opening of the plug.

22.5.4 Maintenance

remove the tripping mechanism by removing the screws (13) and (11), [Fig 22-6],

remove the spindle (4) with piston and spring (5).

Be very careful when removing the spring (5). Use the tool 837015.

1 **Check all moving parts** for wear and replace by new ones, if necessary.

2 **Check the drain hole** (12) to be open.

3 **Tighten the screws (11) to torque** according to chapter [07]. when assembling and lock with steel wire.

4 **Tighten the screws (13) to torque** according to chapter [07].

5 **Use tool 837015 when mounting the spring.**

6 **Check the tripping speed** according to section [22.5.2].

22.6 Electro-pneumatic overspeed trip device

22.6.1 Description

The overspeed trip device is electronically controlled. Starting air of maximum 30 bar is used as operating medium. The tripping speed is according to chapter 06., section [06.1].

There are two separate air inlets, one for starting air and one for the electro-pneumatic overspeed trip device. The line for the electro-pneumatic overspeed trip device is provided with a non-return valve (1), [Fig 22-2], and an air vessel (4) large enough to make it possible to stop the engine even if the air pressure before the non-return valve disappears.

The three-way solenoid valve (5) gets the stop signal for overspeed from the electronic speed measuring system. Besides, the solenoid is also connected to the stop system.

When the solenoid valve opens, air is fed to the pneumatic cylinders, one for each injection pump. The piston (6) of the air cylinder actuates the fuel rack, moving it to stop position.

The stop signal is normally energized long enough to stop the engine completely. When de-energized, the air is evacuated through the three-way valve and the piston is forced back to the end position by the fuel rack.

In some installations (mostly main engines) the stop circuit is energized only during the time when the overspeed contact is closed (i.e. the slow down system). A parallel contact to the alarm system is used as an overspeed indicator. The solenoid valve can also be operated manually.

22.6.2 Check and adjustment of stop position

See section [22.3.4], a) and b).

22.6.3 Check of tripping speed

Check the tripping speed at idle by increasing the engine speed above the nominal speed by turning the speed control knob of the governor. Turn the knob back approximately to the initial position before restarting. Do not increase the engine speed by more than 60 RPM above the tripping speed.

The tripping speed should be 13-15 % above the nominal speed, see chapter 06., section [06.1].

22.6.4 Adjustment of tripping speed

Adjustments will be made in the box of the electronic speed measuring system, see the instructions for speed measuring system, chapter [23].

22.6.5 Maintenance

A) General

regularly remove condensate through the drain valve (3), [Fig 22-2],

check tightness of the non-return valve (1). If not tight, dismantle the valve and check the sealing surface of the rubber O-ring,

check that the valve element moves freely.

B) Three-way solenoid valve

if the solenoid is out of order, replace it by a new one,

if the valve does not move, clean all channels. Check the valve piston,

if air is leaking to the cylinders, change the sealings.

C) Air cylinder

check for wear,

check tightness of the piston. Replace the sealings by new ones, if necessary. Take care not to deform the teflon ring outside the O-ring more than necessary,

lubricate the sealings and the piston with lubricating oil,

check that the piston does not stick.

22.7 Starting fuel limiter

22.7.1 General

Always when starting either automatically, remotely or manually, a limiter automatically limits the injected fuel quantity.

Always when the engine is not operating, the three-way solenoid valve (4), [Fig 22-4], is energized connected to the air distributing pipe with the limiting cylinder. As the main starting valve is opened when starting the engine, starting air is admitted to pass from the distributing pipe through a non-return valve (8) to the limiting cylinder, whereby the piston (1) is forced out, thus limiting the fuel injection by a lever (7) which is fastened to the control shaft. As the engine reaches a speed of 100 RPM below the nominal speed, a relay in the speed measuring system de-energizes the solenoid valve (4). The de-energizing is delayed for two seconds so that the engine reaches the nominal speed before the limitation is cut off.

The pressure is relieved through the nozzle (5). On main engines started up to a lower speed, a lower de-energizing speed may also be used.

22.7.2 Check and adjustment of limitation

A) Check of limit position

set the stop lever in work position and the terminal shaft lever in maximum fuel position, connect pressure air to the nozzle (5), [Fig 22-4], at which the limiter piston (1) will turn the control shaft to the limit position,

check the fuel rack position. The suitable limitation depends on the installation, normally about 18 mm.

B) Adjustment of limit position

connect pressure air to the nozzle (5),

loosen the fastening screw (3) of the limitation lever,

turn the control shaft to the desired limitation of the fuel rack position,

move the limitation lever against the limitation piston (1). Tighten the fastening screw in this position,

check according to pos. a) above.

C) Check of function

See section [22.7.3].

22.7.3 Check of function

1 **Check that limitation is achieved** as soon as the main starting valve opens.

2 **Check that correct limitation is achieved** during the acceleration period.

3 **The limitation is cut off** when 100 RPM below the nominal speed delayed with two seconds. This can be checked by increasing the speed very slowly above the cutoff speed by turning slowly the speed control knob of the governor. On main engines a cutoff speed lower than the minimum running speed is applied.

22.7.4 Maintenance

1 **If limitation gradually retires** before the three-way solenoid valve (4), [Fig 22-4], releases the pressure through the nozzle (5), it can depend on:

leaky piston (1). Replace the sealing by a new one. Take care not to deform the teflon ring outside the O-ring more than necessary. Apply a few drops of lubricating oil on piston before assembly,

the non-return valve (8) does not close. Dismantle the valve and clean. If the valve does not, however, keep tight, replace it by a new one,

leaky three-way valve.

2 **If the valve does not receive voltage** or receives voltage during wrong periods, check the control relays. See wiring diagram and manufacturers instruction, chapter [23].

3 **If the limiter does not work,** check the coil (6). If the coil (6) is undamaged, check that the cylinder (2), three-way valve (4) or the non-return valve (8) does not stick.

4 **The three-way valve** requires normally no maintenance. If the coil has broken, e.g. due to overvoltage, replace the coil by a new one. If the valve is probable to be blocked by dirt, it can be dismantled for cleaning provided that special care is taken. Do not damage the sealing faces. Check that all parts are mounted correctly. If further troubles, replace the valve by a new one.

5 **Check according to section [22.7.2] and [22.7.3].**

23.1 Monitoring equipment mounted on the engine

23.1.1 Instrument panel

The instrument panel is flexibly suspended on three rubber elements at the free end of the engine. The following instruments are included:

Manometer for:	Sensor code
▪ starting air before engine	**P302**
▪ fuel oil before engine	**P106**
▪ lube oil before engine	**P209**
▪ high temperature (HT) water before engine	**P407**
▪ low temperature (LT) water before engine	**P408**
▪ charge air	**P601**
Instrument for engine speed	**S707**
Running hour counter	**K701**

The connection pipes to the manometers are provided with valves which make it possible to change the manometers during operation.
The instruments require no service. Erroneous or damaged instruments should be repaired or changed at the first opportunity.
The rubber elements for suspension of the instrument panel are to be checked after longer operating periods and to be replaced by new ones, if necessary.

23.1.2 Thermometers

exhaust gas thermometer for each cylinder (18), [Fig 23-1],

for lube oil before (20) and after (22) the lube oil cooler,

for HT-water before (2) and after (24) the engine,

for HT-water after the turbocharger (25),

for charge air in the air receiver (17),

for LT-water before the charge air cooler (11), after the charge air cooler (same as before lube oil cooler) (29) and after the lube oil cooler (30),

for fuel before the engine (28).

Erroneous and damaged thermometers are to be replaced by new ones at the first opportunity.

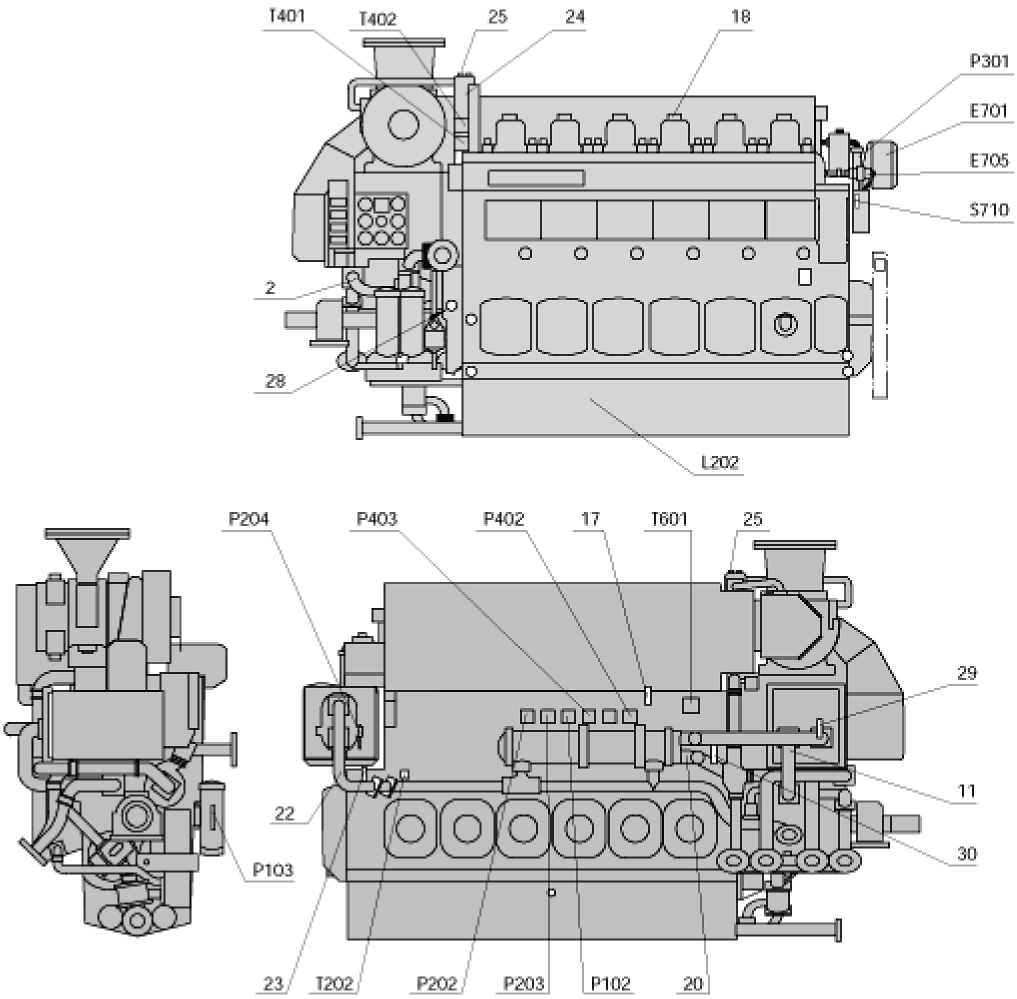

figure: 23-1 Monitoring equipment, Vasa 22

23.1.3 Combined visual pressure drop indicators and alarm switches

for too high pressure drop across the lube oil filter (P204). The indicator/switch is mounted on each lube oil filter,

for too high pressure drop over the fuel filter when mounted on the engine (P103).

23.1.4 On/off switches

A) Alarm switches

The following switches for automatic alarm may be mounted on the engine as standard:

too high charge air temperature after the charge air cooler (T601),

low lubricating oil pressure before the engine (P202),

low lubricating oil pressure of prelubrication (P203),

low fuel oil pressure (P102),

low HT-water pressure, before engine (main engines, only), (P402),

low LT-water pressure (main engines, only), (P403),

too low lubricating oil level (L202),

too high lubricating oil temperature, before engine (T202),

too high HT-water temperature after the engine (T402),

B) Stop switches

The following switches for automatic stop are mounted on the engine as standard:

for too low lube oil pressure (P201),

for too high cooling water temperature after the engine (T401).

C) Indicating switches

The following switches for indication are mounted on the engine as standard:

for tripped mechanical overspeed trip (S710),

As extra equipment the following switches may be supplied:

- for load indication; one or two switches (E705).

The switches may differ from the above mentioned.

D) Other switches

Pressure switch is connected to the air receiver for control of the load dependent cooling system (this applies to 22HF).

23.1.4.1 Check of switches:

All switches are preadjusted at the factory.

Check the function of all switches at intervals recommended in chapter [04]. If any switch is supposed to be wrongly set or broken, it should immediately be checked and, if necessary, adjusted or replaced by a new one. Pressure and temperature switches can be checked during operation.

A) Temperature switches: The switches are fitted into special pockets and can thus be lifted off for checking also during operation. The check should be carried out so that the sensor part of the switch is immersed in liquid, e.g. oil, which is slowly heated. Watch at which temperature the microswitch opens. Note that there are two switching points to be checked in the double switches. The correct temperature is stated in chapter [01] and is normally stamped on the switch as long as the switch has not been adjusted to another temperature. Connect the switch correctly when mounting. Also the pockets are to be removed and cleaned when the systems are emptied for other reasons.

B) Pressure switches: The manometer of the instrument panel may be utilized for checking during operation as follows:

- shut the ball cock on the common pipe to the manometer and the switch,
- open carefully the pipe union nut on the pressure switch so that the pressure switch gives signal.

The alarm switch for too low prelube oil pressure is set for rising pressure and, thus, this method does not give the correct value. A rough check can however be made when taking into consideration that the switch will display a value about 0.2 bar lower at falling pressure.

All pressure switches can also be connected to a separate test unit.

C) Pressure drop indicator: Remove the lube oil switch from the filter and the fuel switch from the pipes.

Connect a hydraulic pressure test device (pump + manometer) to the switch connection which is connected to the filter inlet (the higher pressure).

Raise the pressure to the switching point which should be 1.5 ± 0.3 bar. At this point a red indicator ring at the end of the switch should be visible.

D) Indicator switches: These switches can easily be checked when the engine is standing, for instance:

- the mechanical overspeed trip device is tripped manually and should give indication,
- the control shaft is turned until the load indicating switch operates. Check which load this corresponds to.

Note!

Never set any of the alarm or stop switches out of function.

If any of the switches gives a false alarm the reason should be found out and the problem must be remedied immediately.

23.1.5 Transducers for remote measuring

The engine is as standard supplied ready for connection of the following transducers:

A) Temperatures: The connection points are located next to the respective local thermometers unless otherwise stated.

- charge air in the air receiver,
- lubricating oil before and after the oil cooler,
- HT-water before and after the engine,
- inlet LT-water,
- exhaust gas temperatures for the individual cylinders,
- exhaust gas temperatures before and after the turbocharger.

B) Pressures: The connection points are located on the pipes of the respective manometers in the instrument panel.

- charge air pressure,
- lubricating oil pressure before the engine,
- inlet LT-water,
- fuel oil after the filter,
- starting air.

C) Miscellaneous:

- transducers for turbocharger speed,
- detector for crankcase smoke (one per cylinder),
- load indicator

The instrument specification supplied with the engine documentation specifies which transducers should be installed, as to type as well as to manufacturing.

23.2 Despemes Speed Measuring System for Diesel Engine

23.2.1 Introduction

DESPEMES - Diesel Engine Speed Measuring System - is an electronic speed measuring system especially designed for diesel engines in marine and stationary installations.

The following functions are included in the equipment:

- measuring of engine speed,

4 speed-controlled relay functions,

measuring of one or two turbocharger speeds,

3 additional relay functions as option.

23.2.2 Theory of operation

23.2.2.1 Diesel engine speed

The engine speed is sensed by means of a touchfree, inductive proximity switch mounted to count the cogs passing its sensing head when the engine is running.

The frequency output from the sensor, proportional to the engine speed, is converted to a DC-voltage of 0 - 10 V. This voltage is buffered and fed out to be measured by the remote voltage-measuring, panel mounted, speed indicators.

23.2.2.2 Relay functions

The speed signal is transferred to the relay driver circuit, controlling the relay functions. There are 4 separate relays, which can individually be adjusted to switch at any speed of the engine speed range, additionally with an individually adjustable delay.

The relays have two change-over contacts with a breaking capacity of 110 V DC/0.3 A or 24 V DC/1 A.

23.2.2.3 Turbocharger speed

A magnetic sensor is attached against the end of the turbocharger shaft, sensing its speed. The sinusoidal voltage from the sensor is amplified and converted to a square wave signal before being converted into a speed proportional DC-voltage.

23.2.2.4 Digital output

The speeds can be measured as a frequency with a frequency counter.

Note!

The frequency is not equal to the numerical value of the speed. The actual conversion factors are written on the printed circuit cards.

23.2.2.5 Additional relay functions

Additional triple-relay card with voltage-controlled relays can be supplied as option.

The relays can be controlled by engine speed or by an external DC-voltage or with a potentiometer.

23.2.3 Functional circuit cards

The DESPEMES speed measuring system includes the following printed circuit boards:

1 **Power supply**

```
DC/DC ............................................................................24 V DC
alt. 48...110 V DC.................................................................C1
```

2 **nDEP255 measuring converter with relay function**

```
for engine speed...................................................................C2
```

3 **Relay I**

```
3 speed-controlled relay functions with optional delay.................................C3
```

4 **nTCP255 measuring converter**

```
for one or two turbochargers...........................................................C4
```

5 **Relay II**

```
3 voltage-controlled relay functions with optional delay...............................C5
```

23.2.3.1 C1, Power supply DC/DC

```
Supply voltage:.....................................................18...40 V DC smoothed
.......................................................................alt. 40...160 V DC
Output voltage:.............................................................±12 V ±0.5 V
Output current:.................................................................±500 mA
Output ripple:...............................................................max±100 mV
Ambient temperature:......................................................- 25 ... + 71°C
Short-circuit-proof:.................................................by current limitation
Isolation voltage:.....................................................2 kV, 50 Hz, 1 min
..........................................................................5 kV, 1.2/50 µs
Fuse:...................................................................1.6 A, 5 x 20 mm
```

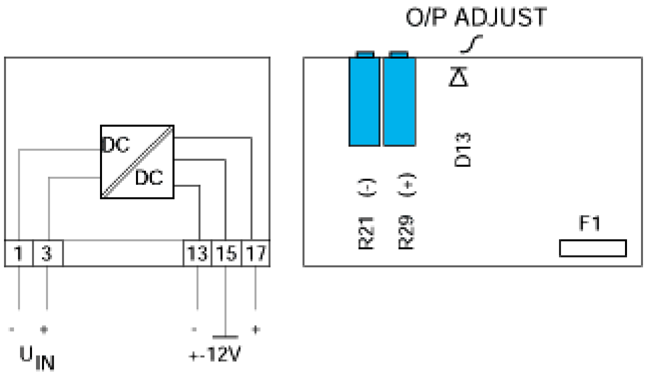

figure: 23-2 Power supply C1

23.2.3.2 C2, nDEP255 measuring converter with relay function for the engine speed

A) Theory of operation: The speed sensor is touchfree proximity switch attached against a cogwheel to count the cogs passing. The output from the sensor is a square-wave frequency proportional to the engine speed.

The frequency is converted to a DC-voltage proportional to the input frequency. This voltage flows through a buffer which provides the measuring voltage for the remote speed indicators. The same buffered voltage operates the relay.

The switchpoint can be adjusted over the whole speed range with an adjustable delay.

Frequency output can be used for measuring the speed digitally.

There is an on-card precalibrated test function which simulates a certain engine speed and can be used for checking the system.

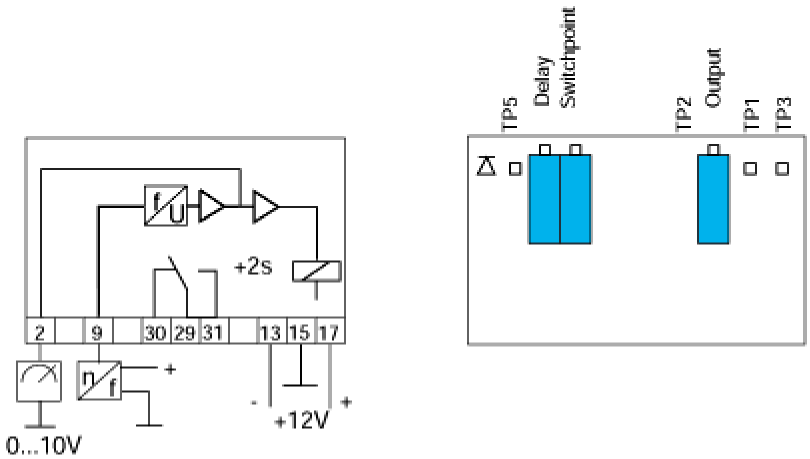

figure: 23-3 nDE measuring converter C2

B) Adjustment procedures:

the analog speed measuring signal 0 - 10 V DC

The card is accurately precalibrated at the factory. Nevertheless, if a recalibration is required, there is a potentiometer, P501, at the outmost left hand side of the card. When turning clockwise, the output will increase and vice versa,

the relay switchpoint and delay.

The switchpoint is preadjusted at the factory. However, if an adjustment is required, the procedure is as follows:
P502: switchpoint: the middle potentiometer
P503: delay: at the right hand side of the card

1 **Determine the nDE-card amplification:**

$$n_{max} \text{ (rpm)} = U_{max} \text{ [V DC]}$$

2 **Calculate corresponding output voltage at specified relay switching speed:**

$$U_x \text{ [V DC]} = n_x \text{ (rpm) x } U_{max} \text{ (V DC) / } n_{max} \text{ (rpm)}$$

3 **Adjust P502 to the calculated TP4 voltage:**

Ex: VASA 22: Specified switching speed: 900 rpm

1500 rpm =^ 10 V DC

$$U_{900} = 900 \text{ rpm x } 10 \text{ V DC / } 1500 \text{ rpm} = 6.0 \text{ V}$$

Adjust the TP4 voltage to 6.0 V
The delay can be determined by bridging TP3 and counting the delay time until the relay turns on and the LED lights up.
Test points
TP1: The pulse train from the speed sensor or the calibrating frequency when TP3 is bridged.
TP2: The unbuffered output from the frequency/voltage converter: 0 - 10 V DC, depending on the engine speed.
TP3: Bridging the points, using eg. a small screwdriver, the test oscillator will start. (The sensor cable must be disconnected.)
TP4: The P502 adjusted voltage corresponding to the relay switchpoint wanted.
TP5: The P503 adjusted voltage corresponding to the specified delay.
C) Thecnical specification
Inputs:

Frequency:..0...8000 Hz
....12 V pk square wave
Supply voltage:...+12 V, -12 V, 0 V
Current consumption:..Max. 40 mA

Outputs:
Frequency:..12 V pk, square wave
....short-circuit-proof
Voltage:...0...10 V DC
....15 mA, short-circuit-proof
Unlinearity:...±0.1 %
Temperature coefficient:...0.03 %/K

Relay function
Switchpoint:...0...100 % of measuring range
Delay:...0...10 sec
Contacts:...2 change-over contacts
Breaking capacity:..110 V DC/0.3 A
....24 V DC/1.0 A

Test
Test point:...Approx. 80 % of full scale
Ambient temperature:...- 25...+71°C

23.2.3.3 C3, Relay Card

A) Theory of operation: The card includes three relays each relay having two change-over contacts. The output voltage from the nDE-card: C2 is supplied to three comparators where the relay switchpoints can be individually adjusted for each relay optionally with adjustable delay.
The relays operate either according to the closed circuit principle or to the open circuit principle.
The relays can be programmed for either delay on operate or release or without delay.
The third relay channel can be programmed with self-holding, demanding external reset. One change-over contact of the relay is, however, needed for this operation. A green or red light emitting diode indicates that the relay is switched on.

B) Adjustment procedures: The switchpoint of the relays are adjustable with trimpotentiometers. The testpoints indicate the adjustment.
P601, TP1...relay nDE1
P602, TP2...relay nDE2
P603, TP3...relay nDE3

1 **Determine the amplification of the nDE-card:**

$$n_{max} \text{ (rpm)} = U_{max} \text{ [V DC]}$$

(nmax is normally 1500 rpm and Umax 10VDC on VASA 22)

6 **Calculate the voltage corresponding** to the rotation speed at which the relay switches on.

$$U_x \text{ [V DC]} = n_x \text{ (rpm)} \times U_{max} \text{ (V DC)} / n_{max} \text{ (rpm)}$$

7 **Adjust the channel potentiometer** to the calculated value of the TP voltage.

By short-circuiting TP3 on the nDE-card (C2) the possible delay of the relays can de determined. Respective trimpotentiometers are P604, P605, P606.

Note!

During the test the adjusted switchpoint of the relay can be adjusted to a value below the test voltage, if this is higher than the voltage generated by the test oscillator (TP3 at card C2).

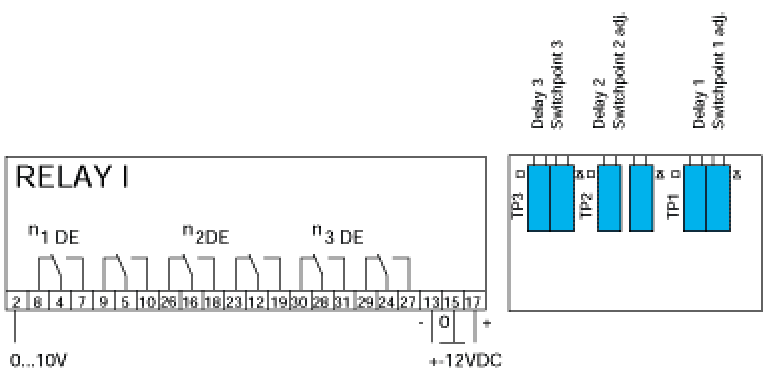

figure: 23-4 Relay card C3

A) Technical specification

Inputs:
Supply voltage:...+12 V, 0, -12 V
Current consumption:..max 60 mA
Control voltage:...0...10 V DC

Outputs:
Switchpoint:.......................................0...100 % of the measuring range
Delay:...0...30 sec.
Breaking capacity:..110 V DC/0.3 A
....24 V DC/1.0 A
Ambient temperature:..-25...+71°

23.2.3.4 C4, TC-card: Measuring converter for one or two turbochargers

A) Theory of operation: The sine wave signal of the turbocharger speed sensor is amplified and transmitted to a squarewave signal. This can be measured by frequency counter.

The square wave frequency signal is converted to a speed-proportional voltage 0 - 10 V. This voltage is buffered and forms the measuring voltage for the remote speed indicators.

The card may consist of two channels.

B) Adjustment procedures: The analog output re-adjustment can be done by means of the potentiometers P701 and P711.
When turning the potentiometer clockwise, the output will increase and vice versa.

C) Technical specification:

Inputs:

```
Frequency:..........................................................0...8000 Hz
....................................................................> 100 mVpp sine
Supply voltage:.....................................................+12 V, 0, -12 V
Current consumption:................................................max 35 mA
```

Outputs:

```
Frequency:..........................................................12 Vpp
.......................................................10 mA, short-circuit-proof
Voltage:..........................................0...10 V, 15 mA, short-circuit-proof
Unlinearity:........................................................± 0.1 %
Temperature dependence:.............................................< 0.03 %/K
```

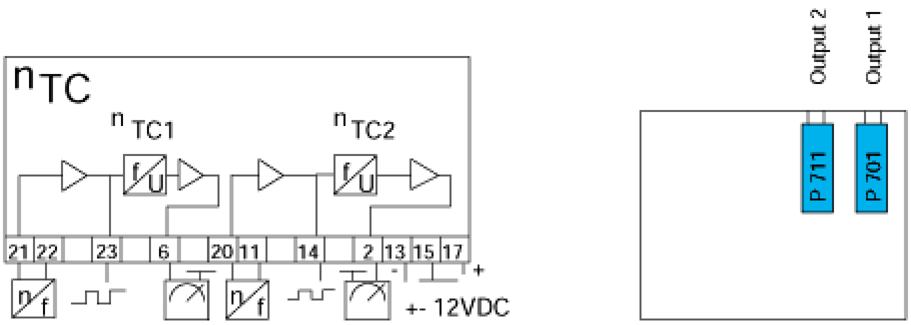

figure: 23-5 TC-card C4

23.2.3.5 C5 Relay II

A) Theory of operation: The card consists of 3 voltage-controlled relays, each having one change-over contact.

Any internal or external voltage between 0 and 10 V DC can be used as control. The switchpoints and delays are adjustable. LED indicates an activated relay.

B) Adjustment procedures: See adjustment instruction for C3 relay card.

C) Tehcnical specification:

Inputs:

```
Control in:.........................................................0...10 V DC
Supply voltage:.....................................................+12 V, 0, -12 V
Current consumption:................................................60 mA
```

Outputs:

3 relay functions, each having one change-over contact.

```
Switchpoint:.......................................0...100 % of measuring range
Delay:..............................................................0...30 sec
Breaking capacity:..................................................110 V DC/0.3 A
....................................................................24 V DC/1.0 A
Ambient temperature:................................................-25...+71°C
```

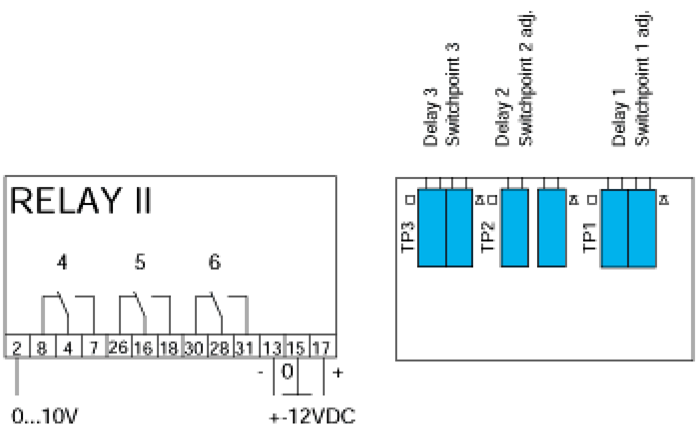

figure: 23-6 Relay II C5

23.2.4 Engine Speed Sensor

A) Theory of operation: The sensor is an inductive, touchfree poximity switch supplied with +12 V and 0 V DC. The third pin is a speed-proportional pulse train.

The electronics of the sensor is resin-moulded into a tubular housing of nickel plated brass with external thread of 18x1.5 mm. The three-wire cable is connected by means of a four-pole connector (Euchner BS4).

B) Mounting the sensor: Turn the engine until the top of a cog is visual in the sensor mounting hole. Screw the sensor completely in. Unscrew the sensor 2,5 mm and tighten it well to the shown sensing displacement (see [Fig 23 - 7])

The output signal (terminal 55 in the electronic box or TP1 on the nDE-card) should now be appr. 12 V DC. If the sensor is between two cogs, the output will show appr. 0 V.

Note!

The engine must not run while the sensor is mounted.

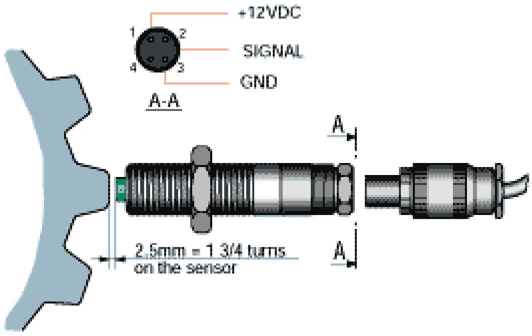

figure: 23-7 Engine speed sensor

23.2.5 Turbocharger Speed Sensor

A) Theory of operation: This sensor is magnetic, therefore it does not require any voltage supply.

The sensor head is splitted by a yoke causing a sinusoidal output voltage when a magnetic material passes its sensing head. The metal housing is threaded to 12 x 1.25 mm.

On the BBC type VTR, the turbocharger housing and a disc with six holes in the end of the turbocharger shaft is prepared for this type of sensors. When the turbocharger rotates and the above mentioned holes pass the sensor head, a sinusoidal voltage is generated. The cable is connected by means of a four-pole connector (Euchner BS4).

B) Mounting the sensor: Screw the sensor completely in and then unscrew it for a sensing gap about two turns.

Note!

The engine must not run while the sensor is mounted.

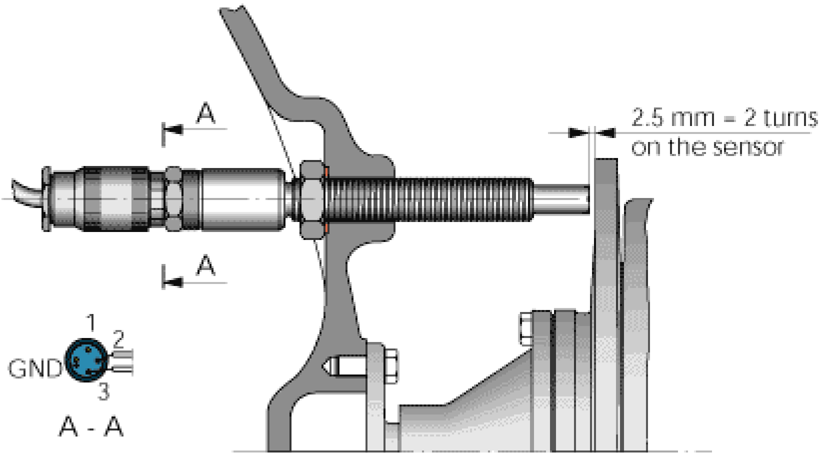

figure: 23-8 Turbocharger speed sensor

23.2.6 Adjustments of the Despemes cards

Adjustments of the Despemes cards					
Card	**Function**	**Adj.**	**Measured at**	**Ind.**	**Remarks and**

			V	Hz		normal set point
C1 DC/DC	Power supply	R21/R29			LED	Adjustment normally not needed.
C2	Rot. speed of engine	P501	TP2	TP1	Tach.	1500 RPM=950 Hz=10 VDC
nDE	Fuel lim. control	P502	TP4		LED	Diagram A. Set point: 100 RPM below nominal or idling speed
	2 s. delay	P503	TP5	TP1	LED	Diagram B Set point: 2 seconds on-delay
	Simulation of running engine		TP2	TP1	Tach.	Make shortcirc. at TP3 and disconnect engine pickup
C3	Relay 1: Engine running (300 rpm)	P601	TP1		LED 1	Hour count., prelub. control blocking signals, diagram A
Relay card	Delay	P604	P604 mid		LED 1	0...30 s, diagram C. Set point: No delay
	Relay 2: Optional or 115 RPM	P602	TP2		LED 2	Diagram A Set point: 115 RPM on 4-cyl. engines with start motor.
	Delay	P605	P605 mid		LED 2	0...30 s, diagram C. Set point: 20 s. offdelay on 4-cyl. engines with start motor.
	Relay 3: Overspeed protection	P603	TP3		LED 3	Diagram A. Set point: 15 % over nominal speed
	Delay	P606	P606 mid		LED 3	0...30 s, diagram C. Set point: No delay.
C4	Rot. speed of turbocharger	P701	TP2	TP1	Tach.	50.000 RPM=5.000 Hz=10 VDC (Setting valid for ABB, VTR-type turbochargers).
nTC	Rot. speed of turbocharger	P711	TP4	TP3	Tach.	For V-engines only, setting as above.
C5 Relay card	Varies					Optional card. Adj. method as C3.

See [Fig 23-9] for diagrams and testpoints.

Note!

All measurements to be performed between testpoints (TP) and internal system gnd. A gnd point can be found above terminal 11 on the motherboard, or e.g. at terminals 26 or 28.

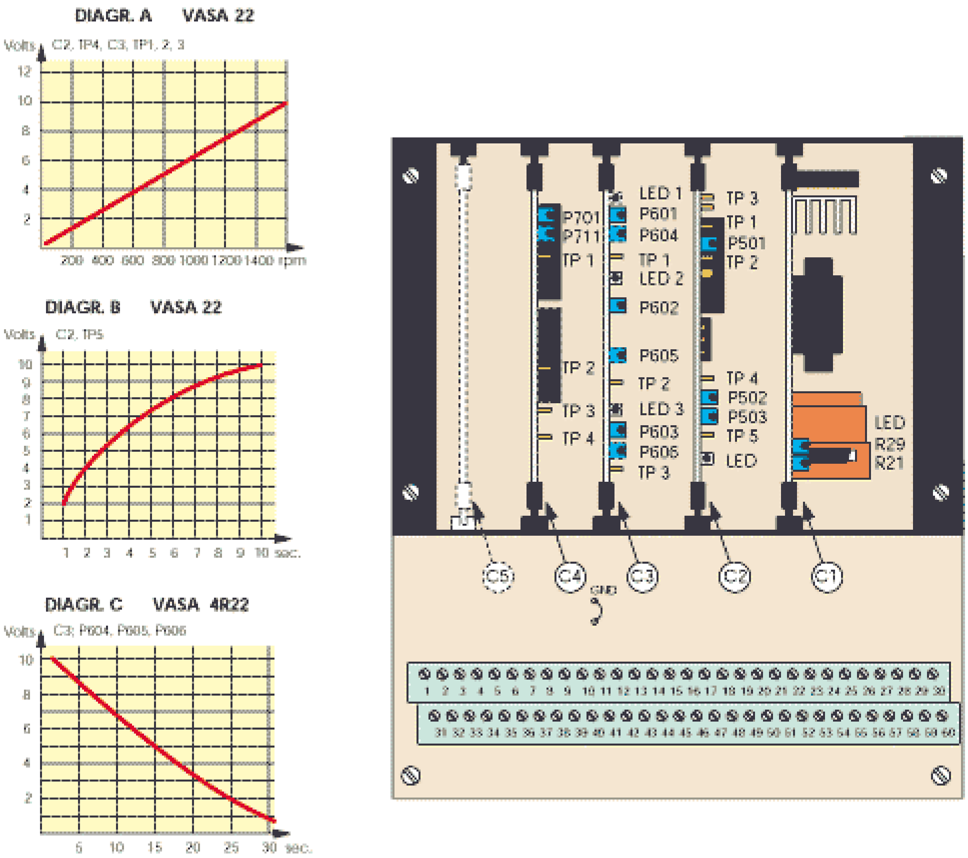

figure: 23-9 Despemes box

23.2.7 Trouble shooting procedures

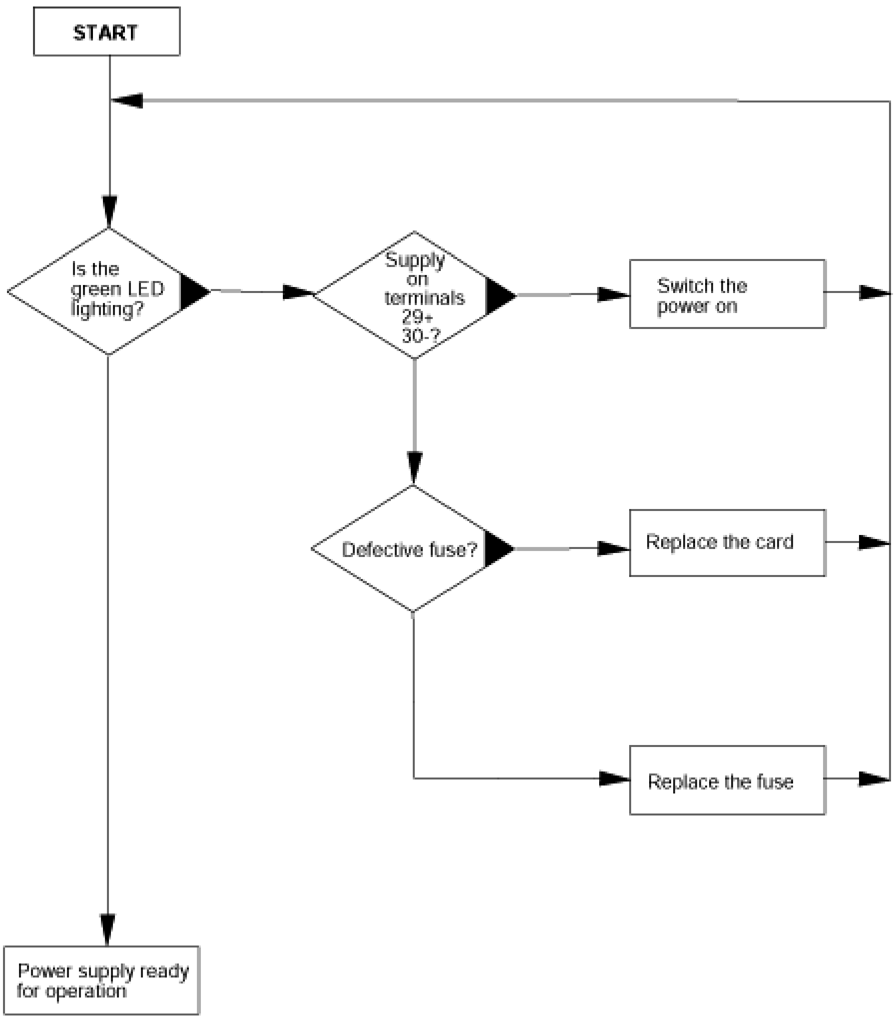

figure: 23-10 1. Power supply DC/DC

Power supply			
	Polarity	**Terminal**	**Card connector**
Operating voltage	++	29	3
	-	30	1
Output	+12 V	24	17
COM		26	15
	-12 V		13

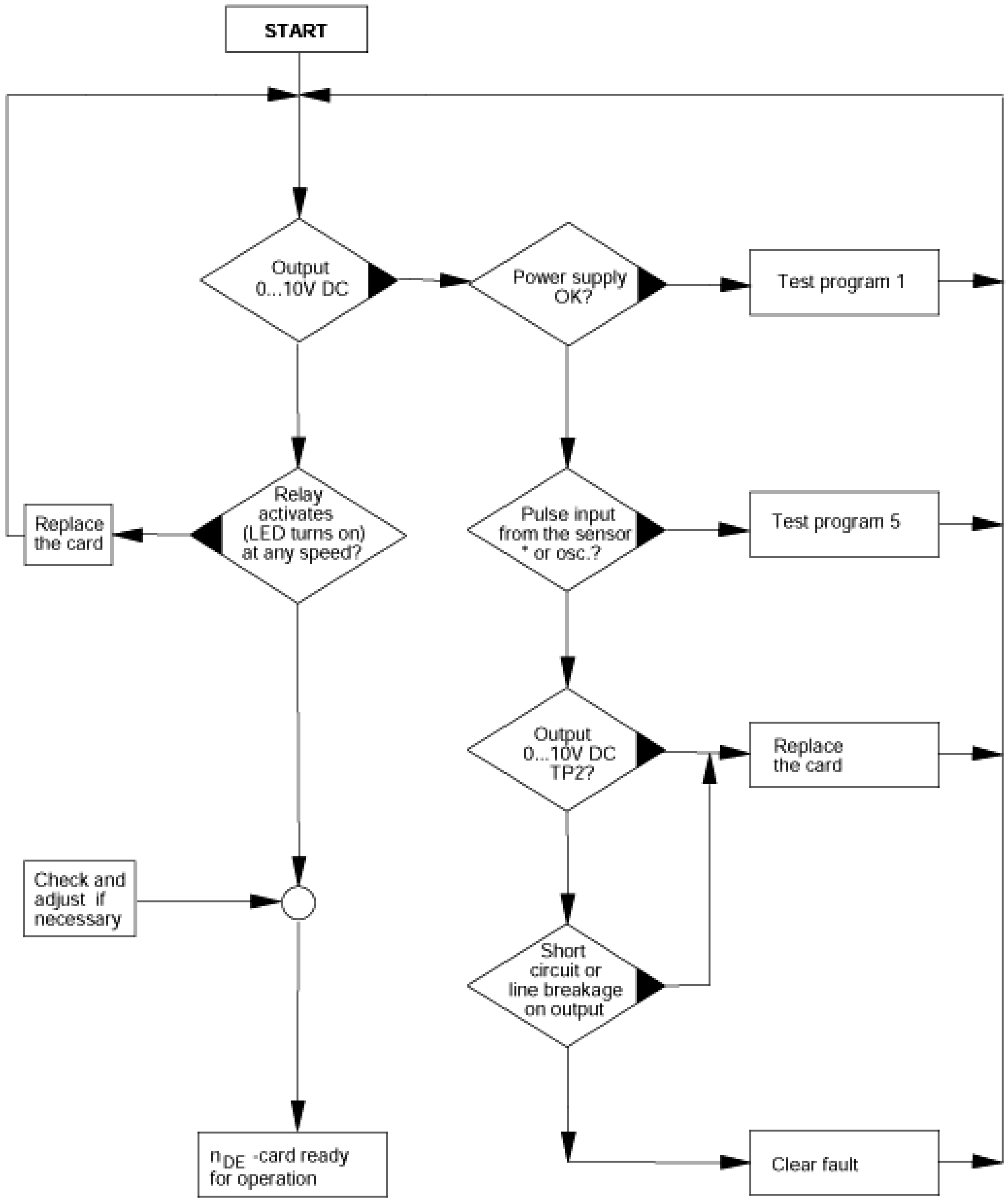

figure: 23-11 2. nDE-measuring converter with relay function

nDE-measuring converter		
	Terminal	**Card connector**
Frequency in	55(+)	19
	57(-)	15
Measuring voltage	25(+)	2
	26(-)	15

Pulse output	58(+)	
	59(-)	

*) V-meter reading: Sensor output 5.8 V DC. Osc. about 4.2 V DC.

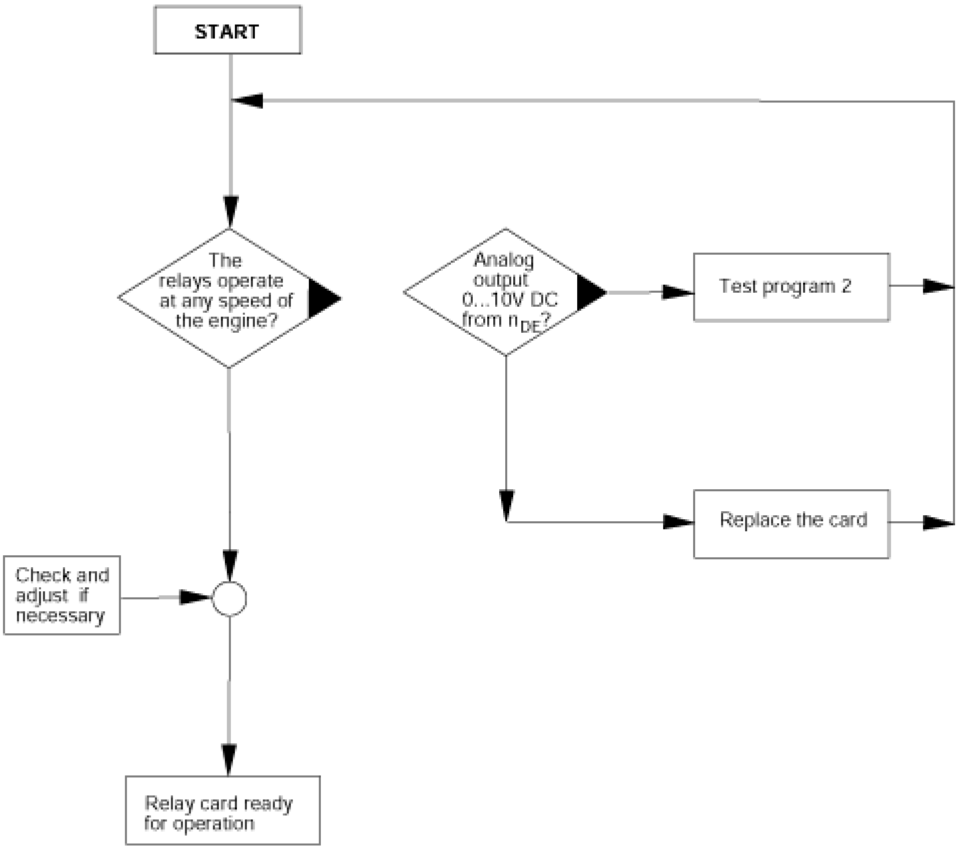

figure: 23-12 3. Relay card

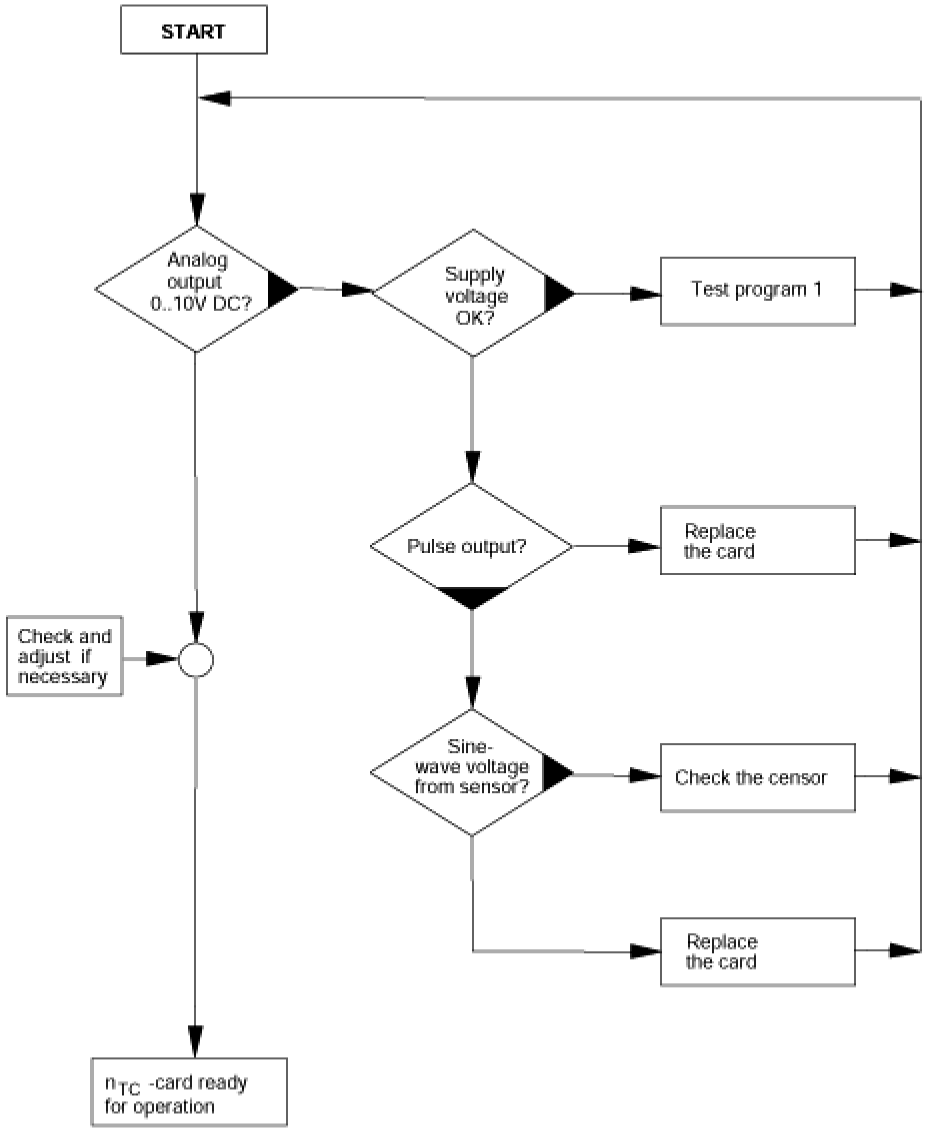

figure: 23-13 4. nTC-measuring converter with 2 channels

nTC-measuring converter			
		Channel 1	**Channel 2**
Pulse input	Terminal	10(+), 11(-)	39(+), 40(-)
	Card connector	21(+), 22(-)	20(+), 11(-)
Pulse output	Terminal	12(+), 13(-)	41(+), 42(-)
	Card connector	23	14
Voltage output	Terminal	8(+), 9(-)	37(+), 38(-)

	Card connector	8	2

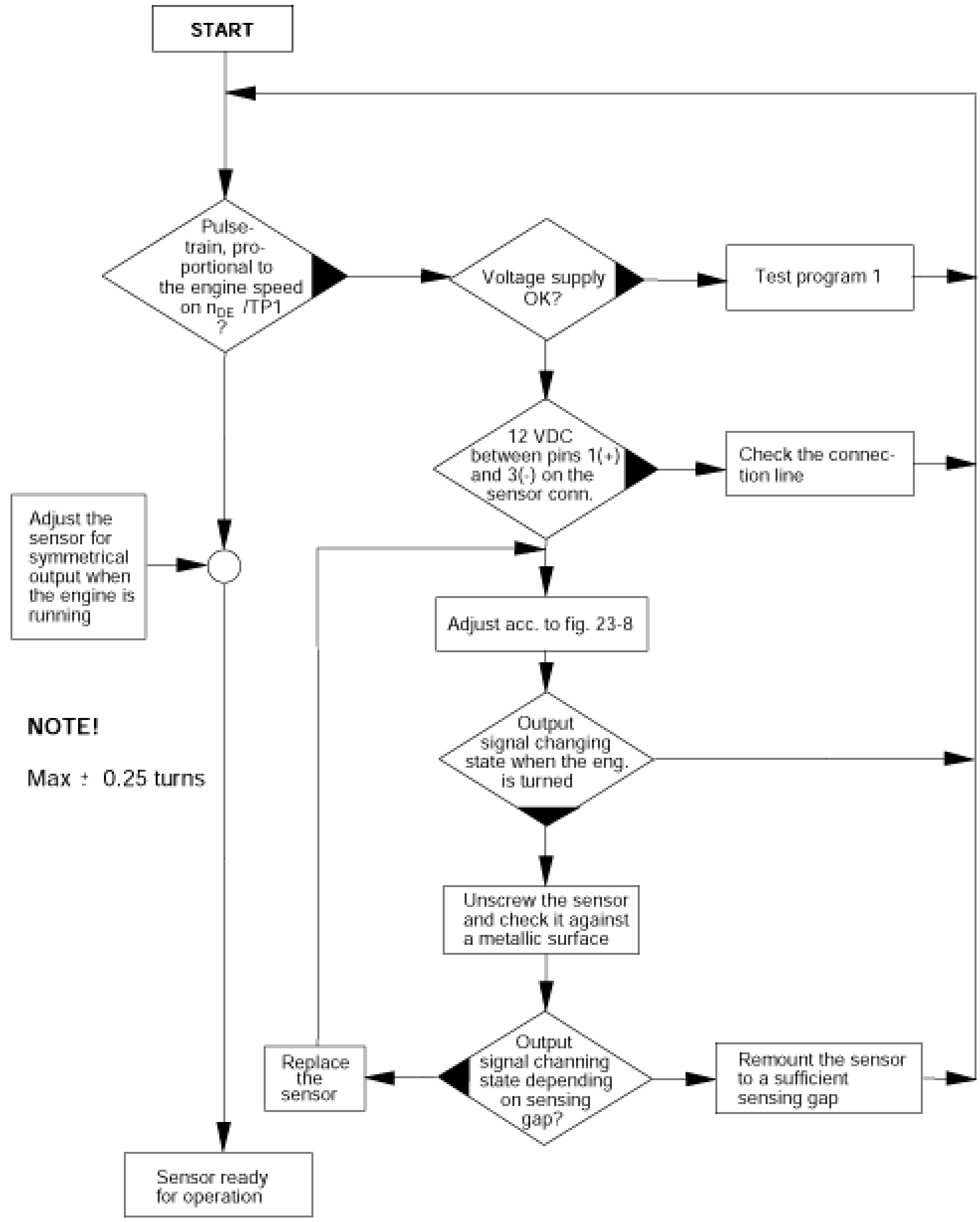

figure: 23-14 5. Engine speed sensor