INSTRUCTION MANUAL

Number	00000
Installation	Repsol
Engine type	18V32LN D
Engine number	PAAE150772
Specification	

This manual is intended for the personal use of engine operators and should always be at their disposal. The content of this manual shall neither be copied nor communicated to a third person.

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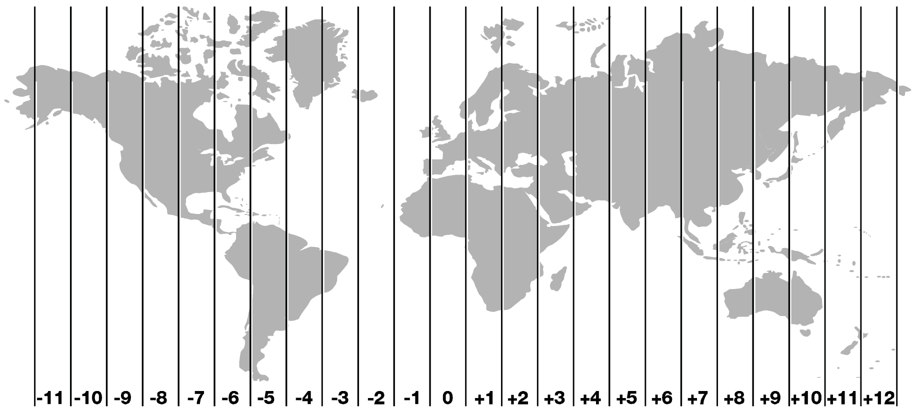


Table of Contents

00. Contents, Instructions, Terminology

V6

This Manual contains maintenance data, and instructions for correct and economical operation of the engine. It also contains instruction about personal protection, first aid and handling of fuel, lubricating oils, cooling water additives during normal operation and maintenance work.

Basic general knowledge about engine operation and maintenance has not been entered. Consequently, it is assumed that the staff is well informed of the care of diesel or gas engines.

Wärtsilä reserves for itself the right to minor alterations and improvements owing to engine development without being obliged to enter the corresponding changes in this Manual.

The diesel or gas engines are equipped as agreed upon in the sales documents. No claim can be made on the basis of this Manual as here are described also components not included in every delivery.

The system diagram plans (fuel, oil, cooling, etc.) are just indicative and thus do not cover all installations. See installation specific system drawings for more details.

Exact engine build-up in all details is defined by the engine number which is located on the engine name plate.

Note!
In all correspondence or when ordering spare parts, be careful to state engine type and engine number.

This Manual is supplemented by the Spare Parts Catalogue including sectional drawings or exterior views of all components (partial assemblies).

00.1. Operating and maintaining the engine

V1

1. **It is essential that this Manual is read carefully** before beginning operation or maintenance.
2. **Keep an engine log book for every engine.**
3. **Observe 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 similar.

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 **In marine engines,** all parameter changes, including components and engine settings, which may influence NOx emission of the engine, must be recorded in the "Record Book of Engine Parameters" according to "Annex VI to MARPOL 73/78".

7 **After reassembling,** check that all screws and nuts are tightened and locked according to stated instructions in this manual.

8 **Check that all shields and covers** are fully functional and in place and closed.

Note!
Predictive maintenance is important when it comes to fire protection. Regular inspection of fuel oil lines, lubricating oil lines and connections must be done.

00.1.1. Explanation of terminology

V11

The most important terms used in this manual are defined as follows, see Figure: Terminology.

Operating side and rear side: Details located at the operating side may be marked with "M" (operating side) and correspondingly "B" for the back of the engine (B-bank on a V-engine).

Operating side: The longitudinal side of the engine where the instrument panel (Local Display Unit) or operating devices (start and stop, local panel, speed governor) are located .

Rear side: The longitudinal side of the engine opposite the manoeuvering 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 Figure: Terminology.

Terminology

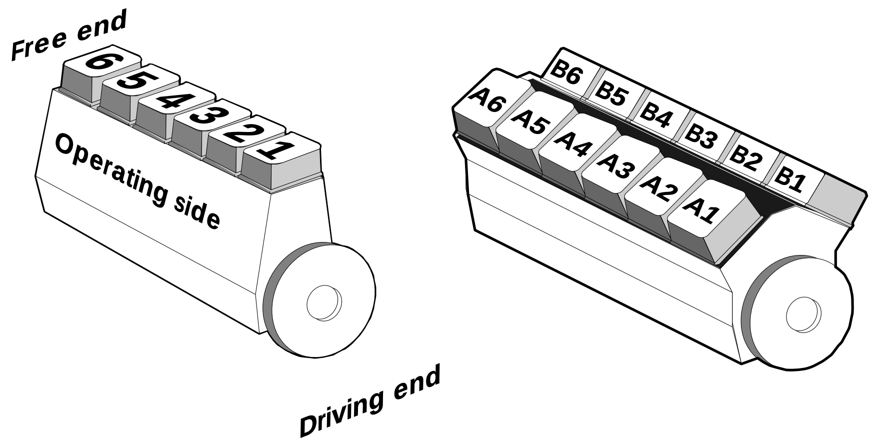


Fig 00-1 V1

Designation of bearings:

- **Main bearings:** The shield bearing (nearest the flywheel) is No. 0, the first standard main bearing is No. 1, the second No. 2 etc., see Figure: Designation of bearings.
- **Thrust bearing:** The thrust bearing rails are located at the shield bearing. The outer rails close to the flywheel are marked with 00 and the inner rails with 0.
- **Camshaft bearings:** The camshaft bearings are designated as the main bearings, the thrust bearing bushes being designated 00 (outer) and 0.
- **Camshaft gear bearings:** The bearing bushes are designated 00 (outer) and 0.
- **Upper and lower bearings shells:** In bearings where both the shells are identical, the upper one is marked with "UP".

Designation of bearings

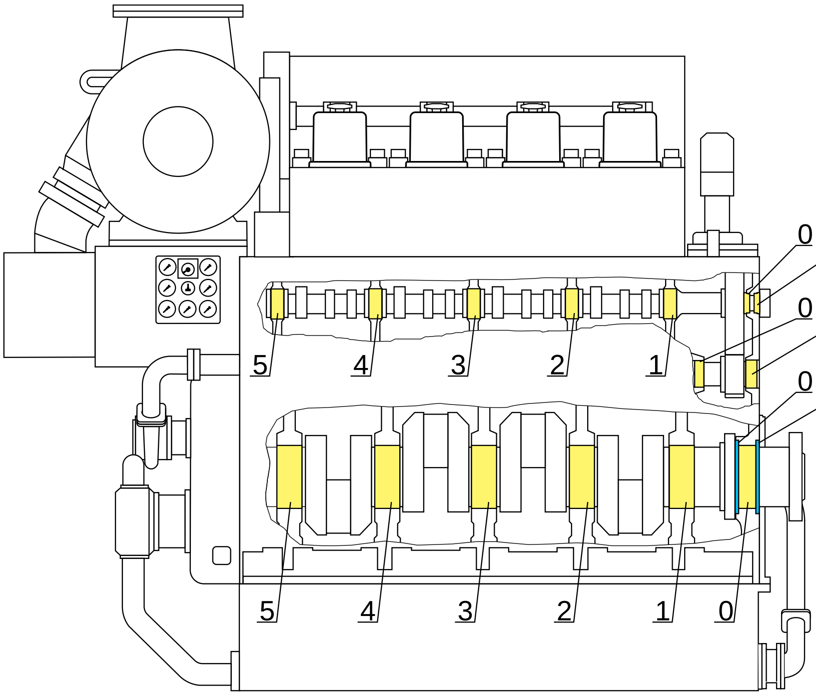


Fig 00-2 V1

Clockwise rotating engine: When looking at the engine from the driving end, the crankshaft rotates clockwise.

Counter-clockwise rotating engine: When looking at the engine from the driving end, the crankshaft rotates counter-clockwise.

Bottom dead centre: Abbreviated **BDC**, is the bottom turning point of the piston in the cylinder.

Top dead centre: Abbreviated **TDC**, is the top turning point of the piston in the cylinder. TDC for every cylinder is marked on the graduation of the flywheel. During a complete working cycle, comprising in a four-stroke engine two crankshaft rotations, the piston reaches TDC twice:

a) For the first time when the exhaust stroke of the previous working cycle ends and the suction stroke of the following one begins. Exhaust valves as well as inlet valves are slightly open and scavenging takes place. If the crankshaft is turned to and fro near this TDC, both exhaust and inlet valves 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.** At this point 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.

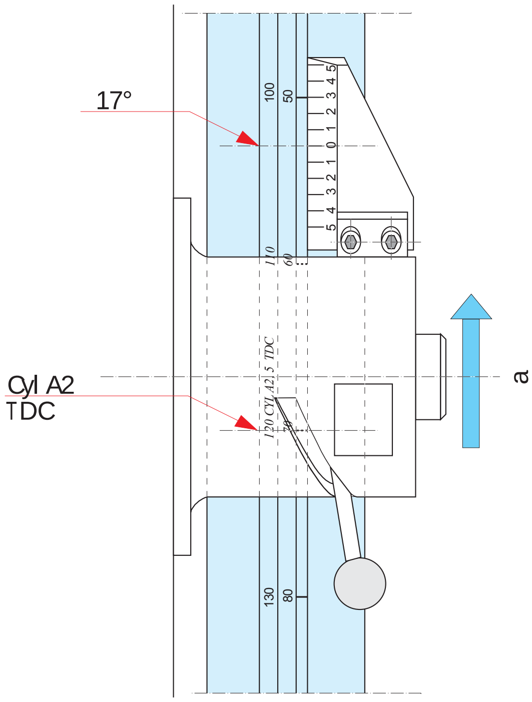
00.1.1.1. Markings on the flywheel V11

The flywheel is provided with a 360° scale, starting from **TDC at firing** for cylinder 1. TDC at firing for every cylinder is marked on the flywheel. There is a common marking for the cylinders in engines with even cylinder numbers, one cylinder is at TDC at firing and the other is at TDC at scavenging. See also firing order in chapter 01.

Firing intervals of an in-line engine (in degrees of crank angle) can be determined by dividing 720° with the number of cylinders.

There are separate scales for A- and B-bank in a V-engine. In V-engines the scale starts from **TDC at firing** for cylinder A1. TDC at firing for cylinder B1 is consequently at 45°. Firing intervals in a bank of a V-engine can be determined by dividing 720 ° with the number of cylinders of the bank.

Markings on the flywheel



a. Clockwise rotating engine.

Fig 00-3 V2

Example: *In this example of a clockwise rotating V engine, the fuel timing is read to 17° for cylinder A2 when the flywheel is in position shown in the figure above.*

00A. Risk Reduction

V5

Read the engine manual 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, For example gloves, hard hat, safety glasses and ear protection must be used in all circumstances. Missing, unsuitable or defective safety equipment might cause serious personal injury or loss of life.

The table below lists 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 and operated unintentionally[1)]	x	x		x	x	x	x	x		x							
Crankcase safety explosion 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								

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
Ejection of fuel injector if not fastened and crankshaft is turned		x				x				x							
Engine rotating due to engaged gear box or closed generator breaker during overhaul	x	x		x	x	x	x	x		x							
Fire or explosion due to leakage in 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			
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
High pressure hoses, risk of oil spray	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) Requires proper ventilation of engine room/plant.

4) Requires proper ventilation and/or gas detector in the engine room/plant.

00A.1. General identified hazards, hazardous situations or events

00A.1.1. Hazards that may be due to moving parts V3

- 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 their hand into the compressor housing when the silencer is removed and engine running.
- Unexpected movement of valve or fuel rack(s) due to a broken wire or a software/hardware failure in the control system.
- Unexpected movement of components.
- Turning device engaged during maintenance work.
- Turning device not engaged, e.g. If a turning device is removed for overhaul, this could cause the crankshaft to rotate during maintenance work.
- Mechanical breakage (e.g. of speed sensor) due to incorrect assembly of the actuator to the engine or faulty electrical connections.

00A.1.2. Hazards that may be due to incorrect operating conditions

V7

- 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.1.3. Hazards due to leakage, breakdown or improper component assembly

V4

- A fuel or gas pipe bursting and spraying fuel or gas
- A control oil pipe bursting and spraying oil (Common Rail)
- VIC housing bursting and spraying oil (If variable inlet close valve used)
- Leakage of:
  - fuel in joints on the low and/or high pressure side and components
  - 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 from a fuel line
- Fire due to oil or fuel/gas leakage
- Explosion or fire if flammable gas/vapour (crude oil) 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
  - leaks during maintenance work
- Oil spray if running without covers
- Ejection of fuel injector if not fastened and:
  - turning device engaged and turned
  - engine turning due to closed generator breaker/coupling.

00A.1.4. Hazards that may be due to electricity or incorrect electrical connections

V3

- Fire or sparks due to damage or a 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 shocks if electrical cables or connectors are damaged or if electrical equipment is dismantled with the power connected.
- Overheating of a control system component due to incorrect 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 due to a 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 an incorrect electrical connector or leakage in pipe connection.

00A.1.5. Other hazards

V7

Injury may be caused by:

- Slipping, tripping or falling
- Water additives and treatment products
- 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

- Burns if not correct protecting outfits are used in contact with hot parts
- Contact with fuel, lubrication oil or oily parts during maintenance work
- Exposure to high noise levels
- Touching or removing turbocharger insulation
- Preloaded fixation springs during check/replacement of sensor.

00B. Welding Precautions

00B.1. Welding safety

V3

Before starting welding, it is important that the welder has read the welding safety instructions and has been instructed in the safe use of the equipment by a qualified teacher or welder.

00B.1.1. Hazards and precautions

V4

Electrical shock can kill

- Wear dry, hole-free gloves. (Change as necessary to keep dry.)
- Do not touch electrically “hot” parts or electrode with bare skin or wet clothing.
- Insulate the welder from the workpiece and ground using dry insulation, e.g. rubber mat or dry wood.
- If wet area and welder cannot be insulated from workpiece with dry insulation, use a semi-automatic, constant-voltage welder or stick welder with a voltage reducing device.
- Keep electrode holder and cable insulation in good condition. Do not use if insulation is damaged or missing.

Fumes and gases can be dangerous

- Use ventilation or exhaust to keep air breathing zone clear and comfortable.
- Wear a helmet and position the head so as to minimize the amount of fumes in the breathing zone.
- Read warnings on electrode container and material safety data sheet (MSDS) for the electrode.
- Provide additional ventilation/exhaust where special ventilation is required.
- Use special care when welding in a confined area.
- Do not weld with inadequate ventilation.

Welding sparks can cause fire or explosion

- Do not weld on containers which have held combustible materials. Check before welding.
- Remove flammable materials from welding area or shield them from sparks and heat.
- Keep a fire watch in area during and after welding.
- Keep a fire extinguisher in the welding area.
- Wear fire retardant clothing and hat. Use earplugs when welding overhead.

Arc rays can burn eyes and skin

- Select a filter lens which is comfortable for you while welding.
- Always use helmet when welding.
- Provide non-flammable shielding to protect others.
- Wear clothing which protects skin while welding.

Confined space

- Carefully evaluate adequacy of ventilation, especially where electrode requires special ventilation or where gas may displace oxygen.
- If the welder cannot be insulated from the work and the electrode, use semi-automatic, constant/voltage equipment with a cold electrode or stick welder with voltage reducing device.
- Provide the welder with a helper and plan a method for retrieving the welder from the enclosure.

General work area hazards

- Keep cables, materials and tools neatly organised.
- Connect work cable as close as possible to area where welding is being performed. Do not allow parallel circuits through scaffold cables, hoist chains, or ground leads.
- Use only double insulated or properly grounded equipment.
- Always disconnect power from equipment before servicing.

Gas cylinders

- Never touch cylinder with the electrode.
- Keep cylinder upright and chained to support.

00B.2. Main principles V3

- Prevent uncontrolled current loops.
- Prevent radiation.
- Prevent the spread of welding splatter.
- Where possible, switch off or disconnect all nearby electrical equipment.

00B.2.1. Prevention of uncontrolled current loops V3

Welding current path must always be checked; there should be a direct route from the welding point back to the return connection of the welding apparatus.

The main current always flow along the path of least resistance; in certain cases the return current can therefore go via grounding wires and electronics in the control system.

To avoid this, the distance between the welding point and the return connection clamp of the welding apparatus should always be the shortest possible and should not include electronic components.

Attention must be paid to the connectivity of the return connection clamp; a bad contact might also cause spark and radiation.

00B.2.2. Prevention of radiation V3

The welding current and the arc is emitting a wide spectrum of electromagnetic radiation. This might damage sensitive electronic equipment.

To avoid such damages all cabinets and terminal boxes must be kept closed during welding. Sensitive equipment can also be protected by means of shielding with a grounded (earthed) conductive plate.

Also, avoid having the cables of the welding apparatus running in parallel with wires and cables in the control system. The high welding current can easily induce secondary currents in other conductive materials.

00B.2.3. Prevention of damage due to welding splatter V4

Welding splatter is commonly flying from the welding arc. Few materials withstand the heat from this splatter. Therefore all cabinets and terminal boxes should be kept closed during the welding. Sensors, actuators, cables and other equipment on the engine must be properly protected.

Welding splatter can also be a problem after it has cooled down; e.g. short-circuits, leaks.

00B.3. Precaution checklists

00B.3.1. Basic ECU (Despemes/Spemos) checklist V3

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

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

00B.3.2. WECS 2000 checklist V2

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

- Open all terminal fuses (F1- FX) in the cabinet.
- Close the covers of the cabinet and all the distributed units.
- Deactivate the system by disconnecting all external connectors (X1...X6).
- If convenient, protect cables, sensors and other equipment from spark with a proper metal sheet.

00B.3.3. WECS 3000 checklist

V2

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

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

00B.3.4. WECS 7000/8000 checklist

V3

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

- Deactivate the system by disconnecting all external connectors (X1...X6).
- If the welding point is close to (approximately within a radius of 2 m) an electronic module, disconnect all connectors to the module.
- If an electronic module is connected through a CIB (Connection Interface Box) then open the CIB cover, disconnect all connectors to the module and close cover again.
- Close the covers of the cabinet
- If engine is equipped with harness: disconnect the harnesses and the cabinet.
- If convenient, protect harnesses, cables, sensors and other equipment from welding splatter with a proper metal sheet.

00B.3.5. UNIC precautions checklist

V3

Pay attention to the following precautions before welding in the vicinity of a UNIC control system:

- Deactivate the system by disconnecting all external connectors from the PDM-10 or PDM-20 (X11, X12) and from the external interface connectors (XM#).
- If the welding point is close to (approximately within a radius of 2 m) an electronic module (IOM-10, MCM-10, CCM-20 etc.) disconnect all connectors to the module.
- Close the covers of the cabinet and all the distributed units.
- Where possible, protect cables, sensors and other equipment from welding splatter with a suitable metal sheet.

01. Main Data, Operating Data and General Design

01.1. Main data for Vasa 32

V1

Cylinder bore .... 320 mm

Stroke .... 350 mm

Piston displacement per cylinder .... 28.15 l

Firing order		
Engine type	Clockwise rotation	Counter-clockwise rotation
4R32	1-3-4-2	1-2-4-3
6R32	1-5-3-6-2-4	1-4-2-6-3-5
8R32	1-3-7-4-8-6-2-5	1-5-2-6-8-4-7-3
9R32	1-7-4-2-8-6-3-9-5	1-5-9-3-6-8-2-4-7
12V32	A1-B1-A5-B5-A3-B3-A6-B6-A2-B2-A4-B4	A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5-B1
16V32	A1-B1-A3-B3-A7-B7-A4-B4-A8-B8-A6-B6-A2-B2-A5-B5	A1-B5-A5-B2-A2-B6-A6-B8-A8-B4-A4-B7-A7-B3-A3-B1
18V32	A1-B1-A7-B7-A4-B4-A2-B2-A8-B8-A6-B6-A3-B3-A9-B9-A5-B5	A1-B5-A5-B9-A9-B3-A3-B6-A6-B8-A8-B2-A2-B4-A4-B7-A7-B1

Normally the engine rotates clockwise.

Lubricating oil volume in the engine							
Engine type	4R32	6R32	8R32	9R32	12V32	16V32	18V32
Approx. oil volume in litres							
Normal sump	670	1295	1655	1835	1875	2405	2670
Deep sump	1110	1910	2435	2700	2825	3620	4020
Oil volume between max. and min. marks approx. litres/mm	2.2	3.1	4.2	4.4	4.6	6.1	6.9

Note!

In certain off-shore installations, oil volumes according to "normal sump" in the table above is to be used although the engine is equipped with a "deep sump".

This to prevent the crankshaft from touching the oil surface in situations of large engine inclinations.

Lubricating oil volume in the turning device in litres	
LKV132	8.5 - 9.5

Lubricating oil volume in the speed governor in litres	
	1.8 - 2.2

Approx. cooling water volume in the engine in litres							
Engine type	4R32	6R32	8R32	9R32	12V32	16V32	18V32
Engine only	305	410	510	560	740	950	1060
Engine and inverse cooling system	470	600	750	750	950	1220	1360

01.2. Recommended operating data

V1

Apply to normal operation at nominal speed.

	Normal values (xxx)		Alarm (stop) limits (xxx)	
Load	100 %	30 %	30 - 100 %	30 %
Temperatures, (°C)				
Lube oil before engine	62 - 70	73 - 80	80	90
Lube oil after engine	10 - 13 higher	5 - 8 higher		
HT water after engine	91 - 100		100 (105)	
HT water before engine	5 - 8 lower			
HT water rise over turbocharger	8 - 12 (15)	6 - 10		
LT water before engine	30 - 38	65 - 70		
Charge air in air receiver	50 - 60	60 - 70	70 (80)(xxxx)	
Exhaust gas after cylinder	See test records		60 higher	
Preheating of HT water	50 (MDO) 70 (HFO)			
Gauge pressures (bar)				
Lube oil before engine at a speed of 600 RPM (10.0 r/s)	3.5	3 - 3.5	3.5 (2.5)	
720 RPM (12.0 r/s) - 750 (12.5 r/s)	4.5 - 5.5		3.5 (2.5)	

HT/LT water before HT/LT pump (=static)	0.7 - 1.5			
HT water before engine	2.2 - 4.8 (x)		(xx)	
LT water before charge air cooler	2.2 - 4.4 (x)		(xx)	
Fuel before engine	6 - 8		4 (HFO) 2 (MDO)	
Starting air	max. 30			
Charge air	See test records			
	Normal values (xxx)		Alarm (stop) limits (xxx)	
Load	100 %	30 %	30 - 100 %	30 %
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			

(x) Depending on speed and installation.

(xx)Alarm limit for main engine = idling pressure - 0.3 bar.

(xxx) For engines without load dependent cooling water system the values for 0 - 30% load are not applicable. Under 30% load the lubricating oil and water temperatures fall a little.

(xxxx) Stop or load reduction.

01.3. Reference conditions

V1

Reference conditions according to ISO 3046-1 (2002):

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:

$$\text{Reduction factor} = (a + b + c)\ \%$$

a = 0.5 % for every °C the ambient temperature exceeds the stated value in the sales documents.

b = 1 % for every 100 m level difference above stated value in the sales documents.

c = 0.4 % for every °C the cooling water of the charge air cooler exceeds the stated value in the sales documents.

01.4. General engine design

V1

The engine is a turbocharged intercooled 4-stroke diesel engine with direct fuel injection.

The engine block is cast in one piece. The crankshaft is mounted in the engine block in an underslung way. The main bearing cap is supported by two hydraulically tensioned main bearing screws and two horizontal side screws.

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

The lubricating oil sump is welded.

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

The liner is provided with an anti-polishing ring in the upper part of the bore to eliminate the risk of bore polishing.

The main bearings are fully interchangeable trimetal or bimetal bearings which can be removed by lowering the main bearing cap. A hydraulic jack is provided for every main bearing to lower and lift the main bearing cap.

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

The connecting rods in the Wärtsilä Vasa 32 Low NOX engines are of forged alloy steel and machined with round sections. All connecting rod studs are hydraulically tightened. The gudgeon pin bearing is of tri-metal type.

In older engines the connecting rods are drop forged. The big end is split 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 piston ring set in the Wärtsilä Vasa 32 Low NOX engines consist of two chromium-plated compression rings and one spring loaded oil scraper ring with chromium-plated edges.

In the older engines the piston ring set consists of three chrome-plated compression rings and one chrome-plated, spring-loaded oil scraper rings.

The pistons are fitted with a Wärtsilä patented skirt lubricating system. The top ring grooves are hardened. Cooling oil enters the cooling space through the connecting rod. The cooling spaces are designed to give an optimal shaker effect.

The cylinder head, made of special cast iron, is fixed by four hydraulically tensioned screws. The head is of the double deck design and cooling water is forced from the periphery towards the centre giving efficient cooling in important areas.

The inlet valves are stellited and the stems are chromium-plated. The valve seat rings are made of a special cast iron alloy and are changeable.

The exhaust valves, also with stellited seats and chromium-plated stems, seal against the directly cooled valve seat rings. For some applications Nimonic valves are used.

The seat rings, made of a corrosion and pitting resistant material, are changeable.

The camshafts are made up from one-cylinder pieces with integrated cams. The bearing journals are separate pieces and thus it is possible to remove a camshaft piece sideways.

The injection pumps have integrated roller followers and can normally be changed without any adjustment. The pumps and piping are located in a closed space which is heat insulated for heavy fuel running.

The turbochargers are normally located at the free end of the engine but, at request, can also be located at the driving end.

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

The charge air coolers are made as removable inserts, on the V-engines two identical ones.

The lubricating oil system includes a gear pump, oil filter, cooler with thermostat valve (not in V-engine), centrifugal bypass filter and an electrically driven prelubricating pump. The oil sump is dimensioned for the entire oil volume needed, and all cylinder numbers can be run in wet sump configuration. Dry sump running is also possible.

The starting system. The air supply into the cylinders is controlled by the starting air distributor run by the camshaft. The four-cylinder engine can alt. be provided with an air driven starting motor.

Cross-section of Wärtsilä VASA 32, in-line engine

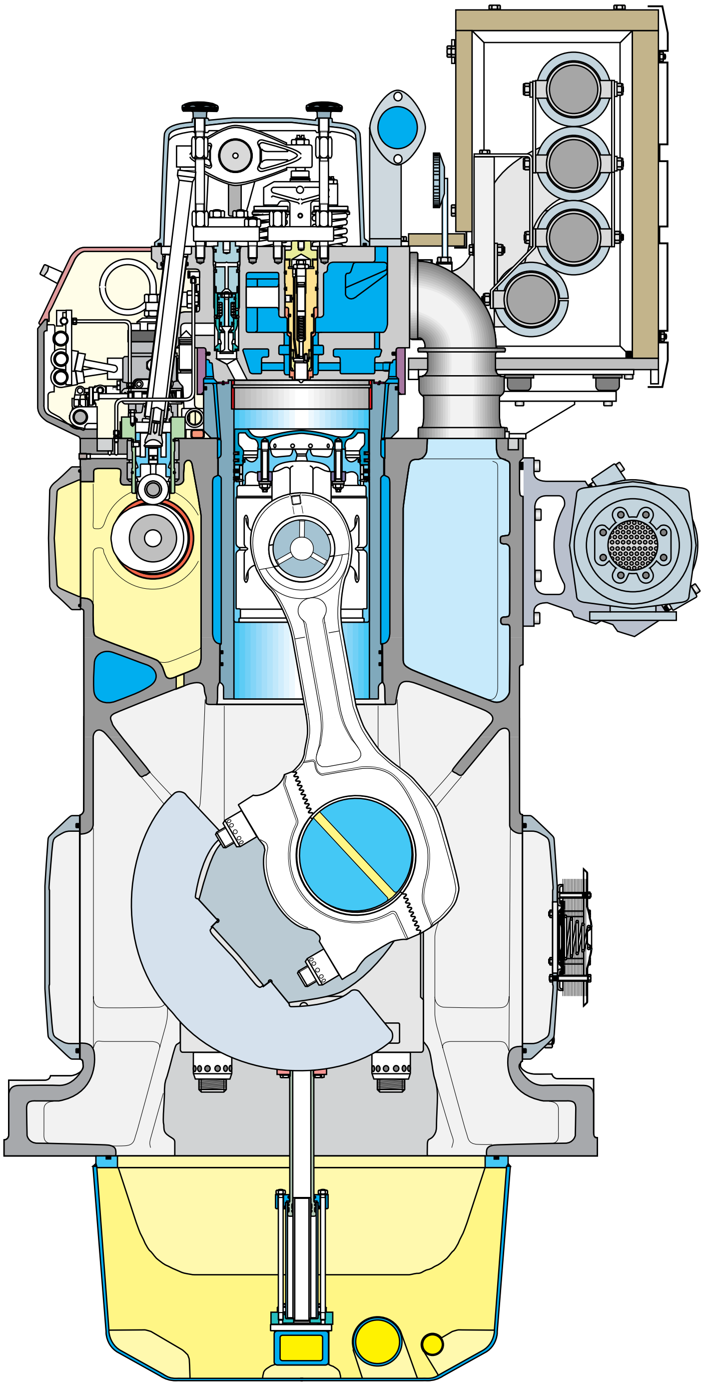


Fig 01-1

V1

Cross-section of Wärtsilä VASA 32, V-engine

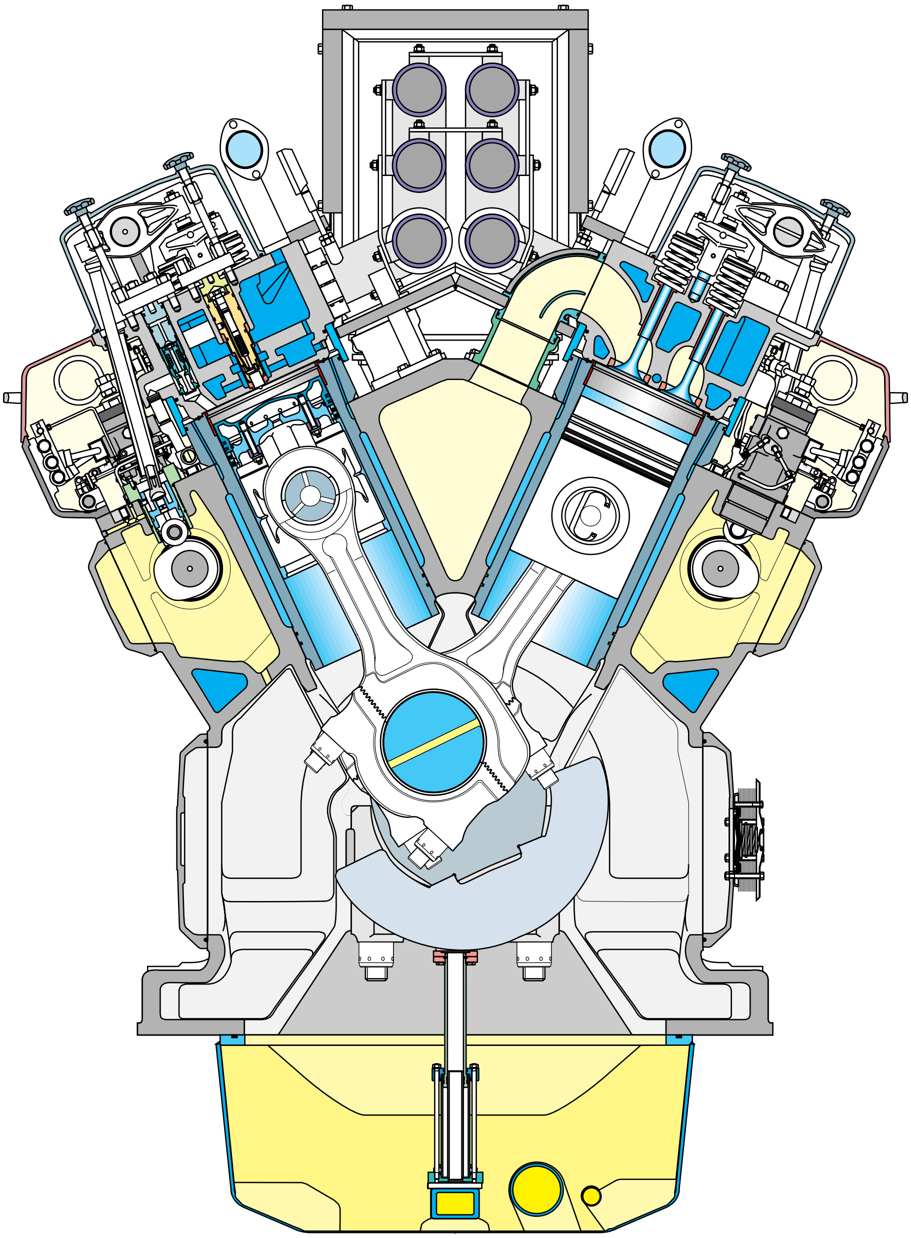


Fig 01-2

V1

02. Fuel, Lubricating Oil, Cooling Water

V2

Note!
For preventing and minimising the handling risks, read carefully chapter 02A., Environmental Hazards.

02.1. Fuel

V7

The Wärtsilä® medium-speed diesel engines are designed to operate on heavy fuel (residual fuel) with a maximum viscosity of 700 cSt at 50 °C (approx. 55 cSt at 100 °C, approx. 7200 Redwood No.1 seconds at 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/higher viscosity than values found in the table below, as such fuels may cause fuel injection pump plunger or fuel nozzle needle seizure.

Fuel viscosity limits at engine inlet in running conditions (cSt)		
Engine Type	Fuel	
	LFO, min	HFO
Vasa 32 & 32LN Wärtsilä 32	2,0	16 - 24

The maximum limits of fuel characteristics for a certain engine are stated in the documentation delivered with the engine.

Blended fuels (residuals and distillate) with a viscosity between approx. 4 and 7 cSt at 100 °C (12 and 30 cSt at 50 °C, 75 and 200 Redwood No.1 seconds at 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 a consequence.

When difficulties with filter clogging are experienced, fuel incompatibility can be tested by the ASTM D4740-00 or ISO 10307-1/93 (LFO) or ISO 10307-2/A/93 (HFO) test methods.

02.1.1. Fuel treatment

02.1.1.1. Fuel separation

V1

Most fuels, except good quality distillate fuels (ISO-F-DMX, DMA and DMB) must to be separated by a centrifugal separator before entering the engine. However, also separation of distillate fuels shall be considered, since fuels can e.g. be contaminated in storage tanks. The separator removes solid particles down to 5 microns and additionally free water from the fuel very efficiently. Even smaller particles are separated, but with reduced efficiency. There are several things to be taken into consideration, when designing the separation system. The following fuel parameters are the most important:

Viscosity

The viscosity is very critical when dimensioning the separator. Higher fuel viscosity means lower separation capacity for a certain separator model and will require a bigger separator size (or more separators) for the same amount of fuel/hour to be separated. The separator manufactures have tables with flow capacities for standard fuel viscosities. Standard separators can handle fuels up to 700 cSt at 50 °C. The viscosity is lowered as much as possible by heating the fuel to maximum temperature, which in standard HFO separators is 98 °C. For liquid biofuels the separation temperature is typically 50-55 °C. Also higher separation temperatures than 98 °C are possible to utilize, but then the question is not about standard separators and those need to be designed case by case. Higher separation temperatures are used with extremely high viscosity fuels. Separation temperature for distillate fuel is typically 40 °C.

Density

The separation of water from fuel is based on the difference in density between those two fluids. The water should always be heavier than the fuel to make the separation process possible. This limits the maximum density of the fuel to 1010 kg/m³ at 15 °C for standard separators and the separation capacity is de-rated when the fuel densities are between 990 and 1010 kg/m³ at 15 °C. It is also possible to separate fuels with higher density than 1010 kg/m³ at 15 °C, but this requires a special separator including a separate water treatment system to increase the density of the operating water. In that case it’s not possible to separate water from fuel, only solid particles.

Flash point

Flash point of heavy fuels varies a lot and some heavy fuel qualities are at a temperature above their flash point and some respectively below their flash point when separated. Distillate fuels are normally separated at a temperature being below their flash point. For special fuels, like many crude oils, having low flash point and containing light, easily evaporating fractions special explosion proof separators along with explosion proof electrical motors and other electrical components are needed. With these fuels also a system avoiding explosion inside the separator bowl by adding an inert gas is required. These systems are expensive and are used only in special cases.

Water content

If the water content is > 0.3% and the fuel density is > 990 kg/m³ at 15 °C the separator is de-rated (see diagram below).

Dimensioning of the separator

Requirement for the fuel separator unit flow is calculated according to the following formula:

$$\dot{V}_{HFOS} = n_{ENG} \times \frac{b_E}{\rho_{FUEL}} \times \left(1 + \frac{c_S}{100}\right) \times f$$

V_{HFOS} = Required separator capacity [m^3/h]
n_{ENG} = Amount of engines [pcs]
ρ_{FUEL} = Density at actual temperature [kg/m^3]
b_E = Fuel consumption / Engine [kg/h]
c_S = Separator safety factor [min. 15% is Alfa Laval's recommendation]
f = Derating factor, depending on the fuel density and water content

De-rating factor depending on the fuel density and water content

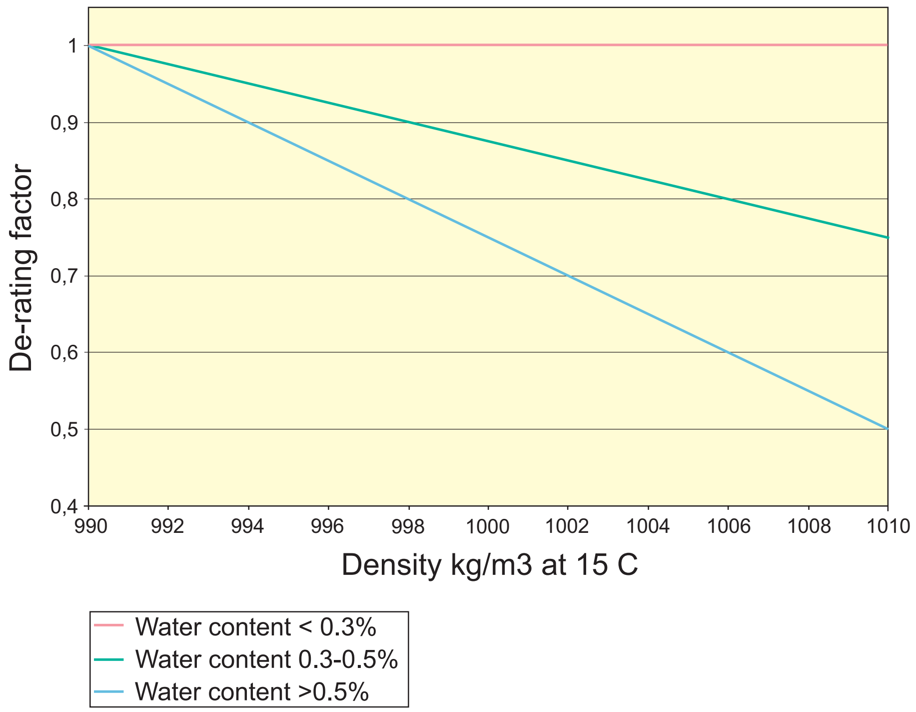


Fig 02-1 V1

Separator modules

The suppliers are making complete modules today including heaters and feeder pumps, which means that the equipment are automatically calculated and ready for the customer demand. The modules include a number of separators needed to meet the capacity of the installation along with an extra stand-by separator. This is made to ensure fuel supply also during the service of one separator.

02.1.1.2. Heating

V1

See diagram, Fig 02-2. Keep the fuel temperature about 10 °C above the minimum storage temperature indicated in the diagram in order to minimize the risk of wax formation, and the temperature after the final heater 5 - 10 °C above the recommended temperature before injection pumps to compensate for heat losses between heater and engine.

Fuel oil viscosity-temperature diagram

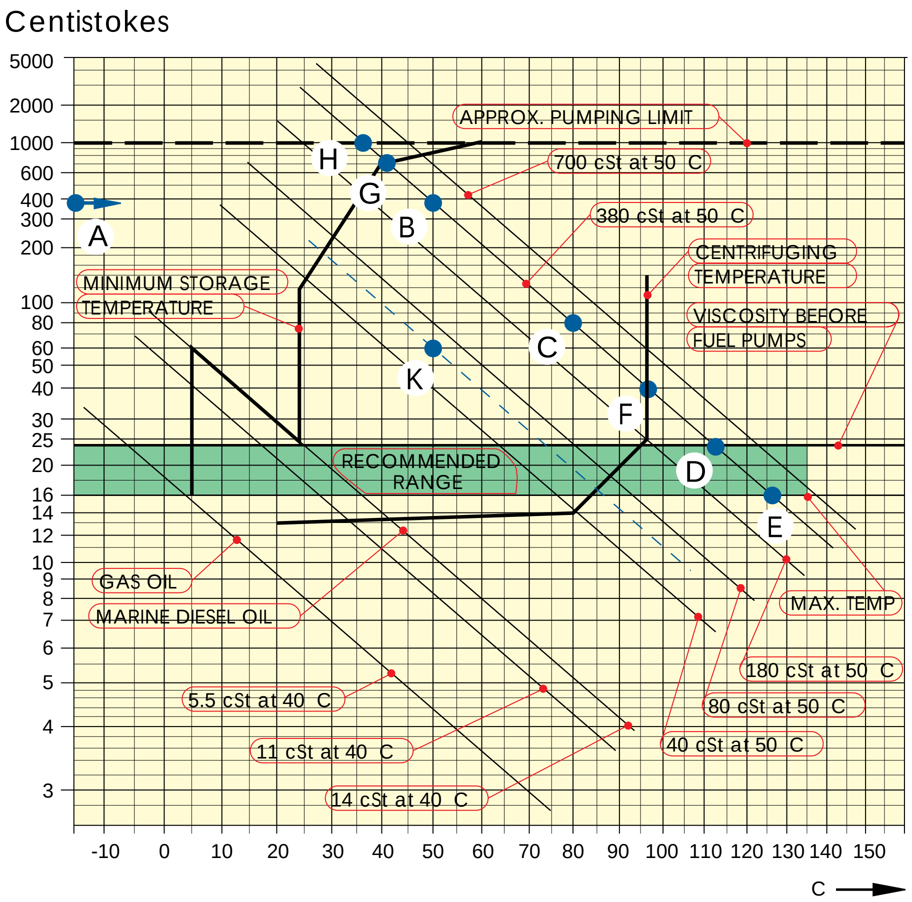


Fig 02-2 320261 V1

Example: *A fuel oil with a viscosity of 380 cSt (A) at 50 °C (B) or 80 cSt at 80 °C (C) must be preheated to 112 - 126 °C (D-E) before the fuel injection pumps, to 97 °C (F) at the centrifuge and to minimum 40 °C (G) in storage tanks. The fuel oil may not be pumpable 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.

Example: *Known viscosity 60 cSt at 50 °C (K). The following can be read along the dotted line: Viscosity at 80 °C = 20 cSt, temperature at fuel injection pumps 74 - 86°C, centrifuging temperature 86 °C, minimum storage tank temperature 28 °C.*

Conversion from various current and obsolete viscosity units to centistokes can be made in the diagram, Fig 02-3. The diagram should be used only for conversion of viscosities at the same temperature. The same temperatures should then be used when entering the viscosity/temperature point into the diagram, Fig 02-2.

Viscosity conversion diagram

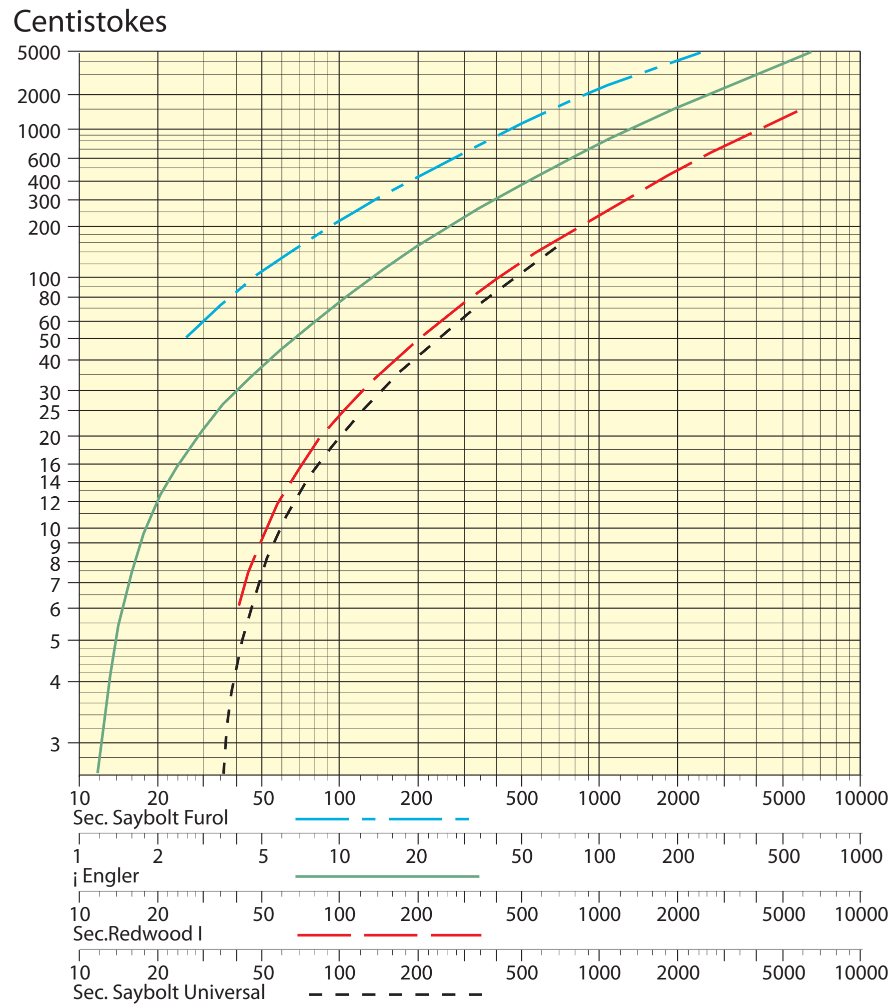


Fig 02-3 320253 V1

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.

02.1.1.3. Viscosity control V1

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.

02.1.2. Maximum limits for fossil fuel characteristics V7

The following types of fossil fuels are defined for the Wärtsilä Vasa 32 & 32LN:

- HFO 1 & 2, ISO 8217:2005(E), ISO-F-RMH 700 and RMK 700
- DO, diesel oil or LFO, light fuel oil
- CRO, Crude oil.

The diesel engine Wärtsilä Vasa 32 & 32LN, are designed and developed for continuous operation, without reduction of the rated output, on fossil fuels with the following properties:

Heavy fuel oil:

Fuel characteristics, maximum limits			
			Test method reference
Kinematic viscosity	cSt at 100°C cSt at 50°C Redwood No.1 sec.at 100°F	55 700 7200	ISO 3104
Kinematic viscosity	cSt at engine inlet	see 02.1	
Density	kg/m^3 at 15°C	991	ISO 3675 or 12185
Density [1]	kg/m^3 at 15°C	1010[1]	ISO 3675 or 12185
Water	vol-%	0.5	ISO 3733
Water, max. before engine	vol-%	0.3	ISO 3733
Flash point, min. (PMCC)	°C	60	ISO 2719
Pour point	°C	30	ISO 3016
Total sediment potential	mass-%	0.1	ISO 10307-2
Sodium	mg/kg	50	ISO 10478
Sodium, bef. engine	mg/kg	30	ISO 10478
Al + Si bef. engine	mg/kg	15	ISO 10478 or IP 501 or 470

The limits above also correspond to the demands:

- ISO 8217:2005(E), ISO-F-RMH 700 and RMK 700[1]
- BS MA 100:1996, RMH 55 and RMK 55[1]
- CIMAC 2003, class H 55 and K 55[1].

[1] Provided the fuel treatment system can remove water and solids.

The maintenance intervals are decided by the characteristics of the used fuel, see Chapter 04, Maintenance Schedule.

The differences between HFO 1 and HFO 2 are seen below:

Fuel characteristics, maximum limits				
		HFO 1	HFO 2	Test method reference
Sulphur	mass-%	1.50	1.51 - 4.50	ISO 8754 or 14596
Ash	mass-%	0.05	0.06 - 0.15	ISO 6245
Vanadium	mg/kg	100	101 - 600	ISO 14597 or IP 501 or 470
Al + Si	mg/kg	30	31 - 80	ISO 10478 or IP 501 or 470
Conradson Carb. Residue	mass-%	15.0	15.1 - 22.0	ISO 10370
Asphaltens	mass-%	8.0	8.1 - 14.0	ASTM D 3279
CCAI		850	851 - 870	ISO 8217, Annex B

Foreign substances or chemical waste, hazardous to the safety of the installation or detrimental to the performance of engines, should not be contained in the fuel.

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

02.1.3. Comments on fuel characteristics

V7

a) **The viscosity** is not a measure of the fuel quality, but determines the complexibility of the fuel heating and handling system, as the HFO has to be heated to reach a viscosity of 16 - 24 cSt at the point of injection. At low viscosities, the flow past the plunger in the injection pump increases. This leads to a decrease in the amount of injected fuel, which in bad cases might make it impossible to reach full engine output. The standard engine fuel system is laid out for max. 700 cSt at 50 °C fuel (approx. 55 cSt at 100°C, approx. 7200 Redwood No. 1 seconds at 100°F).

b) **The density** influences mainly on the fuel separation. Separators can remove water and to some extent solid particles from fuels having densities of up to 991 kg/m $_3$ at 15°C. There are also separators on the market that can clean fuel with densities of up to 1010 kg/m$_3$ at 15°C. The separator capability must be checked before purchasing a fuel with a very high density, as a bad separation will lead to abnormal wear due to unremoved particles and water. The separator disc must be chosen according to the fuel density.

Caution!
Fuels having a low viscosity in combination with a high density usually have bad ignition properties!

c) **Ignition quality.** Heavy fuels may have very low ignition quality. 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 a long ignition delay and can cause a fast pressure rise and very high maximum pressures. This increases the mechanical load and can even damage engine components such as e.g. piston rings and bearings severely. Deposits on the piston top, on the exhaust valves, in the exhaust system, and on the turbine nozzle ring and turbine blades can also be expected. The turbocharger fouling will lead to decreased turbocharger efficiency, and increased thermal load.

A symptom of low ignition quality is diesel knock, i.e. hard, high pitched combustion noise. The effects of diesel knocking are increased mechanical load on components surrounding the combustion space, increased thermal load, as well as increased lubricating oil consumption and contamination.

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

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 a distillate fuel can be determined according to several methods, i.e. Diesel Index, Cetane Index, and Cetane Number. The ignition quality of a heavy fuel oil can be roughly determined by calculating the CCAI (= Calculated Carbon Aromaticity Index) from the viscosity and density of a fuel.

Determining of CCAI:

$$CCAI = \rho - 81 - 141 \log_{10}\log_{10}(v_k + 0.85)$$

Where:

ρ = density (kg/m^3 at 15°C)
v_k = kinematic viscosity (cSt at 50 °C)

Note!
An increased CCAI value indicates decreased ignition quality!

CCAI can also be determined (but with limited accuracy) by the nomogram, see Fig 02-4.

Straight run fuels show CCAI values in the 770 - 840 range, and are very good igniters. Cracked residues may run from 840 to over 900, while most bunkers remain in the 840 to 870 range at present.

The CCAI is not an exact tool for judging fuel ignition. Following rough guidelines can however be given:

- Engines running at constant speed and load over 50 % can without difficulty use fuels with CCAI-values of up to 870.
- Engines running at variable speed and load can without difficulty run on fuels with CCAI-values up to 860.

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

- Sufficient preheating of the engine before start.
- Proper function of the inverse cooling system.
- Proper function of the injection system, especially the injection nozzle condition must be good.

Nomogram

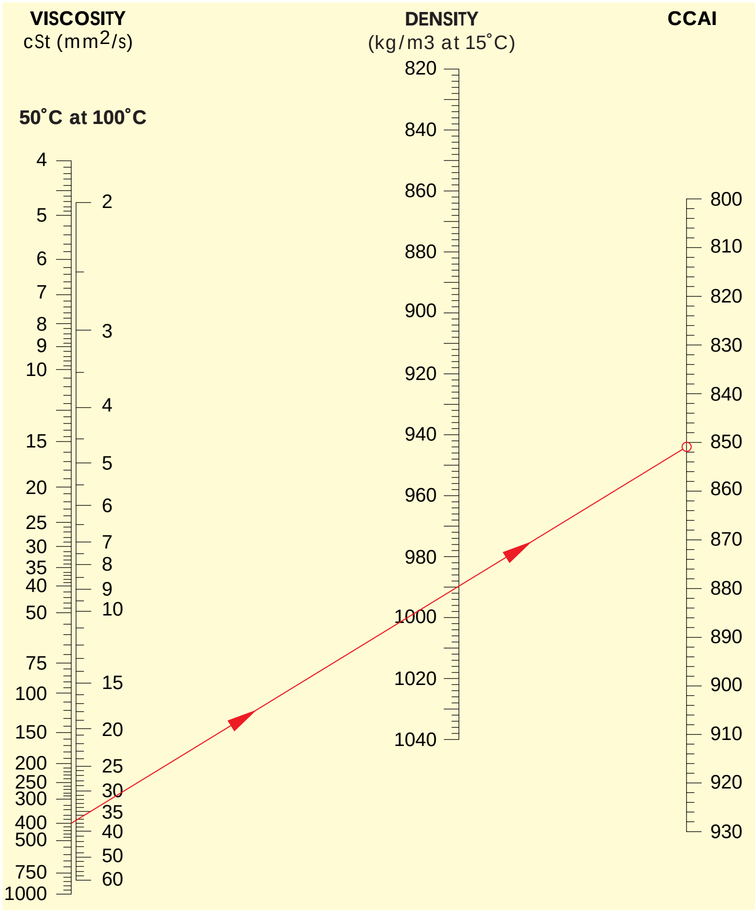


Fig 02-4

320259 V1

d) **The water content** of heavy fuel oils varies widely. Water may come from several different sources, it can either be fresh or salt. It can also originate from e.g. condensation in the installation's bunker tanks.

- If the water is sweet and very well emulgated in the fuel, the effective energy content of the fuel decreases with increasing water content, leading to an increase in fuel consumption.
- If the fuel is contaminated with sea water, the chlorine in the salt will cause corrosion of the fuel handling system, including the injection equipment. The effects of sodium, that also originates from salt, are described more in detail below.

To avoid difficulties in the engine fuel injection system the water content must be reduced to a max. of 0.3 % prior to the engine.

e) **The sulphur** in the fuel may cause cold corrosion and corrosive wear, especially at low loads. Sulphur also contributes to deposit formation in the exhaust system, normally together with vanadium and/or sodium in the form of sulphates. The deposits can also cause high temperature corrosion, as described below.

f) **A high ash content** may be detrimental in several ways. Different ash components can cause different problems:

- **Aluminium and silicon** oxides originate from the refining process, and can cause severe abrasive wear mainly of the injection pumps and nozzles, but also of cylinder liners and piston rings. An efficient fuel separation is a must for minimising wear.
- Oxides of **vanadium and sodium** , mainly sodium vanadyl vanadates, are formed during the combustion, and mix or react with oxides and vanadates of other ash components, e.g. nickel, calcium, silicon and sulphur. The melting temperature of the compound may be such, that ash particles stick to surfaces and deposits are formed on a valve, in the exhaust gas system or in the turbo-charger. This deposit is highly corrosive in the molten state, destroying the protective oxide layer on e.g. an exhaust valve and leads to hot corrosion and a burned valve. Deposits and hot corrosion in the turbocharger, especially on the nozzle ring and turbine blades will cause a decreased turbocharger efficiency. The gas exchange will be disturbed, less air flows through the engine and thus the thermal load on the engine increases. The deposit formation increases at increased temperatures and engine outputs.

To avoid the above mentioned problems when running on high ash fuels, it is important to:

- Have an efficient fuel separation.
- Clean the turbocharger regularly with water, see section 15.2.4.
- Have a strict quality control of the bunkered fuel, i.e. to see that the amounts of ash and dangerous ash constituents stay low.
- Maintain clean air filters and charge air coolers by regular cleaning based on pressure drop monitoring.

g) **High carbon residue content** may lead to deposit formation in the combustion chamber and in the exhaust system, especially at low loads.

- Deposit formation on injection nozzle tips will disturb the fuel atomisation and deform the fuel sprays, decreasing the combustion process efficiency, and even leading to locally increased thermal loads.
- Deposits in the piston ring grooves and on the rings will hinder the movement of the rings, causing, among other things, increased blow-by of combustion gases down to the crank case, which in turn increases the fouling of the lubricating oil.
- Deposits in the exhaust gas system and in the turbocharger will disturb the gas exchange and increase the thermal load.

h) **High asphaltene content** may contribute to deposit formation in the combustion chamber and in the exhaust system, especially at low loads. Asphaltenes are complex, highly aromatic compounds with a high molecular weight, that usually contain sulphur, nitrogen and oxygen, as well as metals like vanadium, nickel and iron (see "Ash" above). A high asphaltene content indicates that a fuel may be difficult to ignite and that it burns slowly. If the fuel is unstable, asphaltenes may precipitate from the fuel and block filters and/or cause deposits in the fuel system, as well as excessive centrifuge sludge.

i) **A low flash point** (high vapour pressure) is often seen especially for crude oils.The low flash point will not influence the combustion, but the fuel can be dangerous to handle and store. This is especially the case if the pour point is high, and the fuel has to be heated due to this. Special explosion proof equipment and separators can be used in extreme cases. A high vapour pressure (low flash point) can also cause cavitation and gas pockets in the fuel pipes. These can be avoided by using an elevated pressure in the fuel handling system. It is to be noted that some insurance companies demand the use of fuels having a flash point higher than 60°C.

j) **The pour point** tells below which temperature the fuel does not flow, and determines how easy it will be to handle the fuel. The whole fuel handling system, including tanks and pipes, must be heated to a temperature at least 10 - 15°C above the pour point.

k) **Total sediment potential** tells something about the fuels stability. If the TSP is high, the danger of sediment and sludge formation in tanks and fuel handling systems increase, as well as the probability for filter clogging.TSP can also be used as a check for the compatibility of two different fuels: The two fuels are mixed, and if the TSP for the mix remains low, the fuels are compatible.

02.1.4. Measures to avoid difficulties when running on heavy fuel

V4

Poor fuel quality will influence on wear, engine part lifetime 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 sodium 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 % m/m), carbon content (Conradson carbon above 12 % m/m) and/or asphaltene content (above 8 % m/m). Idling should be avoided as far as possible. For more information on low load operation and idling, see Operation at low load and idling on page 03-6.

02.1.5. Low sulphur & low viscosity distillate fuel (LFO) operation

V4

Low fuel viscosity is generally speaking not a severe problem for 4-stroke engines, but can in severe cases damage the fuel injection equipment and affect on the running parameters of the engine. In exceptional cases loss of capability to produce full power, black-out and starting problems may also occur. The minimum viscosity of the fuel supplied to the engine is 2.0 cSt. Possible remedial actions against too low viscosity are to specify minimum viscosity when ordering the fuel (LFO) or to design/modify the fuel systems to maintain appropriate minimum viscosity by cooling.

Wärtsilä does not specify any minimum sulphur content for the used fuel. Based on present experience lubricity is not considered a problem for 4-stroke fuel injection components as long as the sulphur (S) content is above ≈ 100 ppm (0.01 %). In some cases lubricity additives are also used by fuel manufacturers and marketers in order to improve lubricity properties of very low sulphur fuels. A common industrial test is also available, based on the ISO 12156-1 standard “Diesel fuel – Assessment of lubricity using the high-frequency reciprocating rig (HFRR)”. The recommended maximum limit, which is also typically specified in other industrial applications, for this HFRR test is 460 microns.

If the sulphur content is below 100 mg/kg it is also recommended to carefully follow up any signs of increased wear in the fuel injection pumps or exhaust valves / valve seats. If exhaust valve clearances need more frequent adjustments compared to earlier experience, it is a possible sign that fuel lubricity is not optimal. In this way a possible problems can also be detected before an excessive wear will occur.

02.1.6. General advice

V3

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 limits of fuel characteristics given in the chapter 02., section 02.1.2.

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 centrifuging capacity. The best and most disturbance-free results are obtained with the 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. 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 or exceeding 991 kg/m^3 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.

See also section 02.2.6., Handling of oil samples.

02.2. Lubricating oil

02.2.1. Lubricating oil qualities

V3

Lubricating oil is an integrated engine component and thus the quality of it is upmost important. All lubricating oils, which have been approved for use in Wärtsilä Vasa 32 & 32LN, engine type, have gone through an approval test according to the engine manufacturer's procedure.

The use of approved lubricating oil qualities during the warranty period is mandatory and is also strongly recommended after the warranty period.

The list of approved lubricating oils can be found in the end of this chapter.

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

Note!
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.

02.2.2. Maintenance and control of the lubricating oil V4

a) **Centrifuging of the system oil** is recommended in order to separate water and insolubles from the oil. Water must not be added when centrifuging ("washing"). The oil should be pre-heated to 80 - 95 °C. Many oil manufacturers recommend a separation temperature of 90 - 95 °C for an effective separation. Please check with the supplier of your lubricating oil what the optimal temperature is. Use the highest recommended temperature. For efficient centrifuging, use only about 20% of the rated flow capacity of the separator. For optimum conditions the centrifuge should be capable of passing the entire oil quantity in circulation 4 - 5 times every 24 hour at 20% of rated flow. Gravity disc should be chosen acc. to oil density at separation temperature. Follow the operation instructions given by the separator manufacturer for optimal performance of the separator.

Note!
The lubricating oil separation efficiency influences the condition of the lubricating oil and the change interval of the lubricating oil batch. Depending on type of application and from the different lubricating oil system arrangements point of view, the following separation routines are adviced:- Continous running of the separator(s) when the engine(s) is running, recommended in the first place.- Periodical separation of auxiliary engine in stand-by or running mode in installation equipped with one or more separator(s), which treats lubricating oil of more than one engine.

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

b) **During the first year of operation** it is advisable to take samples of the lubricating oil at 500 operating hours intervals. The sample should be sent to the oil supplier for analysis. On the basis of the results it is possible to determine suitable intervals between oil changes. Frequent oil analysis at 500 - 1000 operating hours intervals is also recommended after the first year of operation to ensure safe engine operation. See also section 02.2.6., Handling of oil samples. 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 decrease by more than 20% and not rise by more than 25% above the guidance value at 100 °C.Should not decrease by more than 25 % and not rise by more than 45% above the guidance value at 40 °C.

Flash point. Should not fall by more than 50 °C below the guidance value. Min. permissible flash point 190 °C (open cup) and 170 °C (closed cup) . At 150 °C risk of crankcase explosion.

Water content. Should not exceed 0.3%. A value higher than 0.3% can not be accepted for longer periods, but measures must be taken; either centrifuging or oil change.

BN (Base Number).

- Fuel category A and B:The minimum allowable BN value of a used oil is 50% of the nominal value of a new oil.
- Fuel categories C and D:The minimum allowable value of used oil is BN 20.

Insolubles. The quantity allowed depends on various factors. The oil supplier's recommendations should be followed. However, an n-Pentane 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 max. 10% new oil at a time. Adding larger quantities can disturb the balance of the used oil causing, for example, precipitation of insolubles. Measure and record the quantity added. Attention to the lubricating oil consumption may give valuable information about the engine condition. A continuous increase may indicate that piston rings, pistons and cylinder liners are getting worn, and a sudden increase motivates pulling the pistons, if no other reason is found.

d) **Guidance values for oil change intervals** are to be found in chapter 04, Maintenance Schedule. Intervals between changes are influenced by system size (oil volume), 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 engine manufacturer's limits during the whole oil change interval.

02.2.2.1. Changing lubricating oil

V6

When changing lubricating oil the following procedure is recommended:

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

2 **Clean all oil spaces with a high quality fibre free and lint free cloth.** Clean also the 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, Main Data, Operating data and General Design. Oil samples taken at regular intervals analyzed by the oil supplier, and the analysis results plotted as a function of operating hours is an efficient way of predicting oil change intervals. Send or ask the oil supplier to send copies of oil analyses to the engine manufacturer who will then assist in the evaluation. In order to minimize the risk of lubricating oil foaming, deposit formation, blocking of lubricating oil filters, damage of engine components, etc., the following procedure should be followed when lubricating oil brand is changed from one to another:

- If possible, change the lubricating oil brand in connection with an engine (piston) overhaul.
- Drain old lubricating oil from the lubricating oil system.
- Clean the lubricating oil system in case of an excessive amount of deposits on the surfaces of engine components, like crankcase, camshaft compartment, etc.
- Fill the lubricating oil system with fresh lubricating oil.

If the procedure described above is not followed, responsibility of possible damage and malfunctions caused by lubricating oil change should always be agreed between the oil company and customer.

02.2.3. Lubricating oil for the governor

V6

See the Instruction Book for the governor, attached. An oil of viscosity class SAE 30 or SAE 40 is suitable, and the same oil can be used as in the engine. Turbocharger oil can also be used in the governor. In low ambient conditions it may be necessary to use multigrade oil (e.g. SAE 5W-40) to get a good control during start-up. Oil change interval, see maintenance schedule chapter 04.

Condensed water, high temperature or leaking drive shaft seal may cause the oil to deteriorate, or internal surfaces of the governor to collect deposits. If the reason cannot be clarified and rectified, a shorter oil change interval or change of oil type should be considered.

The governor should be flushed with the oil in use or gasoil if heavy contamination of the oil is evident.

Examples of suitable lubricating oils for governor can be found from the end of this chapter, where the lists of approved lubricating oils for an engine and turbocharger are available.

- If the system is equipped with a start booster, then this should also be emptied when changing oil.
- In installations whereby the actuator is equipped with a filter, it has to be cleaned when changing oil.
- Depending on the governor type, oil should be separately emptied from the power cylinder. This is done by removing the plug in the bottom of the power cylinder.
- Some governors are equipped with a magnetic oil plug, this plug should be cleaned in connection with an oil change.

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

02.2.4. Lubricating oils for turbochargers

V5

Please note that different types of turbochargers can be used for the engine. The lubricating system is different for the different turbocharger. One type of chargers has a common lubricating oil system with the engine, see chapter 15, while the other type of chargers has an internal lubricating system for the bearings, see chapter 15. See the Instruction Book for the turbocharger, attached.

Note!
In the ABB VTR..4 series turbochargers the use of synthetic low friction lubricating oils is strongly recommended by the engine and the turbocharger manufacturers!

Oil change interval is1500 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.

The list of approved lubricating oils for the ABB VTR..4 series turbochargers can be found in the end of this chapter. These lubricating oils are, regarding viscosity and quality, according to the recommendations.

02.2.5. Lubricating oils for engine turning device

V1

It is recommended to use EP-gear oils, viscosity 400-500 cSt at 40 °C=ISO VG 460 as lubricating oils for the turning device.

The list of lubricating oils for the engine turning device approved by the turning device manufacturer can be found in the end of this chapter.

02.2.6. Handling of oil samples

V1

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 significantly dependent on proper sampling and the results will only be as good as the quality of the 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 need to be 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/lubricating 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.

02.2.6.1. Lubricating oil sampling V1

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.

02.2.6.2. Fuel oil sampling V1

Fuel oil samples can be drawn from different places in the fuel oil system. Fuel samples "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, since these will probably contain high levels of water and sediment and thus the samples will not be representative of the bulk phase.

02.2.7. Dispatch and transportation V2

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 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, if necessary. 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 interpretation of the analysis results and advice on possible corrective actions is available from Wärtsilä, if needed.

02.3. Cooling water

V1

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 meet the specification found in the end of this chapter. Further, the use of an approved cooling water additive or treatment system 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 freezing occurs, please contact the engine manufacturer for use of anti-freeze chemicals.

Fresh water generated by a reverse osmosis plant onboard often has a high chloride content (higher than the permitted 80 mg/l) causing corrosion.

Caution!
The use of glycol in the cooling water is not recommended, if it is not necessary. Since glycol alone does not protect the engine against corrosion, additionally an approved cooling water additive must always be used!

02.3.1. Additives

V4

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

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

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.

Warning!
Sodium nitrite is toxic.

Corrosion rate as a function of nitrite concentration

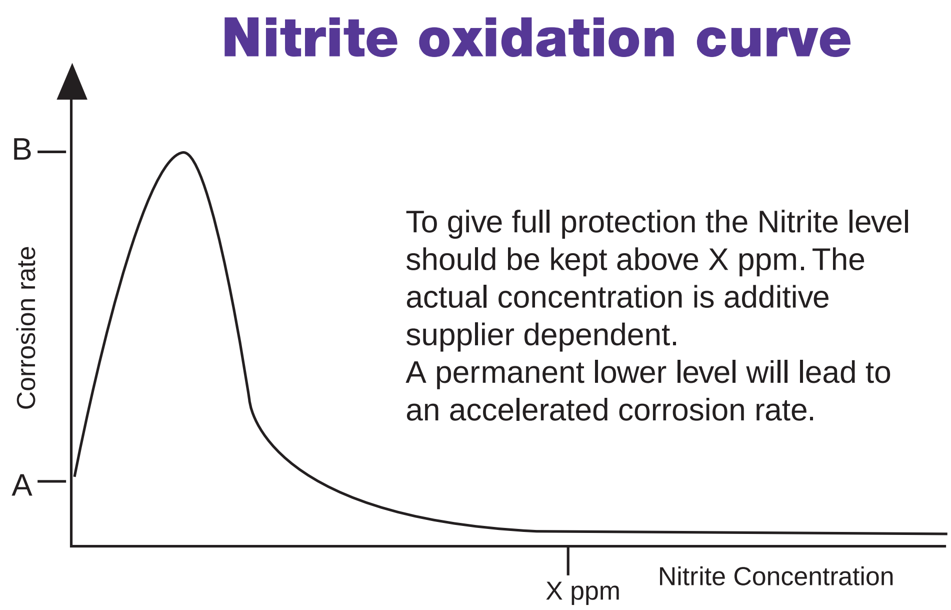


Fig 02-5

320260 V1

Nitrite based cooling water additives are so called anodic inhibitors and require proper dosing and maintenance in order to serve as intended. The nitrite of the additive is as such a salt and it will increase the conductivity of the water. The conductivity is on the other hand one of the main parameters affecting the corrosion rate once a corrosion process gets started, the higher the conductivity the higher the corrosion rate.

If the conditions (nitrite level, chlorides, pH, etc.) in the systems are such that the nitrite based additive is no longer able to protect the entire surface of the system there may occur a rapid, local corrosion in the areas that are not protected. The corrosion rate at the attacked areas will even be much greater than it would be with no additive at all present in the system, see schematic graph of the corrosion rate as a function of the nitrite dosage in Fig 02-5. Observe that the position of the curve peak on the x-axis (= dangerous condition for corrosion) is not stable, but will shift depending on temperature, pH, chlorides and sulphates contents, etc. in the cooling water.

The table below shows shows examples of the most common cooling water additive types.

Summary of the most common cooling water additives		
Additive	Advantages	Disadvantages
Sodium nitrite	- good efficiency, if dosage is controlled carefully - small active quantities, 0.5 % by mass - cheap	- suitable as additive except in air cooled heat exchangers with large soft solder surfaces - toxic - risk of spot corrosion when too low concentration
Nitrite + borate	- no increased risk of corrosion at over doses - innocuous for the skin	- tendency to attack zinc coverings and soft solderings - toxic: lethal dosage 3 - 4 g solid nitrite - risk of spot corrosion when too low concentration
Sodium silicate	- not toxic - harmless to handle	- not active when water velocity exceeds 2 m/s - commercial products very expensive - increased risk of corrosion when too low concentration; spot corrosion - limited suitability
Sodium molybdate	- not toxic - harmless to handle	- more expensive than toxic additives - increased risk of corrosion, if unsufficently dosed - can cause deposit formation (molybdates can collect to ferrous sulphates)
Organic and inorcanic synergistic based	- not toxic	- more expensive than sodium nitrite and molybdate based additives - big active quantitives by mass

02.3.2. Treatment

V2

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

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

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

The list of approved cooling water additives and treatment systems can be found in the end of this chapter.

Note!
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.

Additionally a frequent laboratory analysis of cooling water at 3 months interval is recommended to ensure safe engine operation. For further information and recommendations on cooling water treatment and analysis, see chapter 02B, Raw Water Quality.

02A. Environmental Hazards

V2

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.1. Fuel oils

V2

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, and present a risk of fire and explosion, may cause long-term harm and damage in water environments, and present a risk contamination of the soil and the ground water. Take every appropriate measure to prevent water and soil contamination.

02A.1.1. Handling

V3

- Isolate from ignition sources, such as, sparks from static electricity.
- Avoid breathing evaporated fumes (which may contain hydrogen sulphide, etc.) during the 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. Great risk of suffocating when entering tanks.
- 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 authorised disposal plants.

02A.1.2. Personal protection equipment

V2

- **Respiratory organs protection:** Oil mist: Use respirator with combined particle and gas filter. Evaporated fumes (hydrogen sulphide, etc.): Use respirator with 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 protective clothing if hot product is handled.

02A.1.3. First aid measures

V2

- **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 to avoid the risk of 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.2. Natural gas

V2

Natural gas is non-toxic and will not harm anyone breathing in the low concentrations near minor fuel leaks. Heavy concentrations, however, can cause drowsiness and eventual suffocation.

In a gas engine installation, gas may be dangerous. Particularly serious are fires and explosions, caused by gas leakage into the engine room, and explosions caused by unburned gas in the exhaust system.

If a gas explosion occurs, it is important to protect people, equipment and environment from damage. Damage is caused by the shock wave and the burning effect of the expanding and partly burning gases. Damage can be avoided by preventing pressure build up in equipment and extracting the released gas to an open area.

Read the Gas Safety Manual that can be found at the end of chapter 03 for gas engine installations.

02A.3. Lubricating oils

V2

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. There is a 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

V3

When handling lubrication oils:

- Ensure adequate ventilation if there is a risk of release of vapours, mists or aerosols. Do not breathe vapours, fumes or mist.
- Keep the oil away from flammable materials and oxidants.
- Keep the oil 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.

Note also the following:

- 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 authorised disposal plants.

02A.3.2. Personal protection equipment

V2

- **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 protective clothing if hot product is handled.

02A.3.3. First aid measures

V2

- **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 to avoid the risk of 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

V3

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 with the undiluted product can produce intense irritation. Diluted solutions may be moderately irritating.

02A.4.1. Handling

V3

- 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 up 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

V2

- **Respiratory protection:** Not normally required. Avoid exposure to product mists.
- **Hand 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 minimise splashing. Use safety footwear when handling barrels.

02A.4.3. First aid measures

V1

- **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. Fly ashes and exhaust gas dust contaminated components

V3

When handling fly ashes, exhaust gas dusts or any contaminated components, observe carefully the following minimum requirements:

Note!
Inhaling, eye contacts, skin contacts and swallowing of fly ashes and dusts must be avoided.

Employees must be required to study the safety instructions before they start to overhaul the exhaust gas system or engine components that have been in contact with exhaust gases.

Note!
Spreading and spillage of the fly ashes and dusts to the environment must be avoided.

When opening the manholes of the exhaust gas system and specially the Selective Catalytic Reduction (SCR) avoid spreading the dust in the surrounding area. During replacement of components in the exhaust gas system and during handling as well as during normal operation of the system, dust spreading must be avoided.

Appropriate flue gas dust spillage disposal instructions must be applied. The dust collected from the exhaust gas system must be considered as hazardous waste and must be treated according to the local regulations and legislation.

02A.5.1. Personal protection equipment

V3

- **Respiratory organ protection:** Toxic particles: Use P3 filter respirator. For work inside the SCR or other places in the exhaust gas system, where the dust concentration is high, a respiration mask with fresh filtered compressed air supply is recommended.
- **Hand protection:** Gloves.
- **Eye protection:** Wear goggles.
- **Skin and body protection:** Wear cover clothing.

Also when machining or cleaning engine components that have been in contact with exhaust gases, proper protection according to the above must be used.

Consideration must also be given to whether the ventilation is suitable for collecting dust from the machining and cleaning of the components.

02A.5.2. First aid measures

V2

- **Inhalation of ashes:** 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.
- **Skin contact:** Hot ash 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 ash 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 to avoid the risk of aspiration into respiratory organs. Seek medical advice.

02A.6. Lead in bearings

V2

Lead has valuable lubricating properties and therefore it is incorporated into many bearing alloys.

The bearings in Wärtsilä engines contain lead and therefore are toxic. Lead containing bearings that are to be scrapped must be disposed of according to the local authority regulations.

02A.7. Fluoride rubber products

02A.7.1. Handling instructions - normal sealing applications

V2

In normal sealing applications the use of fluoride rubber products does not cause any health hazards. The products can be handled without any risk provided that normal industrial hygiene is applied.

02A.7.2. Handling instructions in case of overheated seats and valve blow-by

V2

When changing O-rings, for instance after a valve blow-by, operators handling the remains of burnt fluoride rubber must wear impenetrable acid-proof gloves to protect the skin from the highly corrosive remains. Appropriate glove materials are neoprene or PVC. All liquid remains must be considered to be extremely corrosive.

The remains can be neutralized with large amounts of calcium hydroxide solution (lime water). Used gloves must be disposed off.

02A.7.2.1. Use of fluoride rubber products at temperatures above 275°C (527°F)

V2

Fluoride rubber can be used in most applications (up to 275°C) without any substantial degradation or health hazard. Use of or test of fluoride rubber at temperatures above 275°C must be avoided. If the material is exposed to higher temperatures there is a risk that the temperature will rise out of control.

02A.7.3. Special conditions

02A.7.3.1. Grinding dust

V2

Dust and particles which originate from the grinding or abrasion (wear) of fluoride rubber can cause the formation of toxic degradation products when burned (incinerated). Smoking must therefore be prohibited in areas where there is fluoride rubber dust and particles present.

02A.7.3.2. Fire

V1

In case of a fire, burning fluoride rubber can cause the formation of toxic and corrosive degradation products (e.g. hydrofluoric acid, carbonyl fluoride, carbon monoxide and carbon fluoride fragments of low molecular weight).

Burning (incineration) of fluoride rubber is allowed only when using approved incinerators equipped with gas emission reduction systems.

02A.7.3.3. Decontamination

V2

Operators handling the remains of burnt fluoride rubber must wear impenetrable acid-proof gloves to protect the skin from the highly corrosive remains of burnt fluoride rubber. Appropriate glove materials are neoprene or PVC. All liquid state remains must be considered to be extremely corrosive.

02A.7.4. Personal protection equipment

V2

- **Hand protection:** Impenetrable acid-proof gloves (neoprene or PVC).
- **Inhalation protection:** Breathing mask.

02A.7.5. First aid measures for accidents with fluoride rubber products

V3

Inhaling:	Move the victim from the danger zone. Make the victim blow his nose. Seek medical advice.
Eye contact:	Rinse immediately with water. Seek medical advice.

Skin contact: Rinse immediately with water. Put a 2 % solution of calcium gluconate gel on the exposed skin. If calcium gluconate gel is not available, continue to rinse with water. Seek medical advice.

02B. Oil requirements & oil quality

02B.1. Requirements and oil quality

V1

SYSTEM OIL REQUIREMENTS AND QUALITY FOR WÄRTSILÄ VASA 32 ENGINES

Viscosity

Viscosity class SAE 30 or 40 (SAE 40 is preferred)

Viscosity Index (VI)

Min. 95

Alkalinity (BN)

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 975-01, BS MA 100: 1996 CIMAC 2003 ISO 8217: 2005(E)	GRADE NO. 1-D, 2-D DMX, DMA DX, DA ISO-F-DMX, DMA	10 -30
B	BS MA 100: 1996 CIMAC 2003 ISO 8217: 2005(E)	DMB DB ISO-F-DMB	15 - 30
C	ASTM D 975-01, ASTM D 396-04, BS MA 100: 1996 CIMAC 2003 ISO 8217: 2005(E)	GRADE NO. 4-D GRADE NO. 5-6 DMC, RMA10-RMK55 DC, A30-K700 ISO-F-DMC, RMA10-RMK55	30 - 55
D	CRUDE OIL (CRO)		30 - 55
F	LIQUID BIO FUEL (LBF)		10 - 20

In case a low sulphur (S max. 0.2 % m/m) distillate fuel is used, it's recommended to use a lubricating oil with BN of 10 – 15.

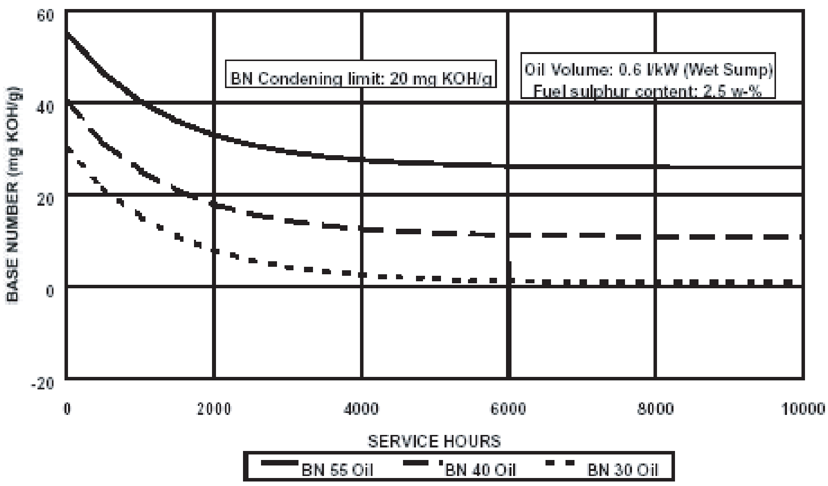
It is recommended to use in the first place BN 50-55 lubricants when operating on heavy fuel. This recommendation is valid especially for engines having wet lubricating oil sump and using heavy fuel with sulphur content above 2.0 % mass. BN 40 lubricants can be used when operating on heavy fuel as well if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.

BN 30 lubricants are recommended to be used only in special cases, such as installations equipped with an SCR catalyst. Lower BN products eventually have a positive influence on cleanliness of the SCR catalyst. With BN 30 oils lubricating oil change intervals may be rather short, but lower total operating costs may be achieved because of better plant availability provided that the maintenance intervals of the SCR catalyst can be increased. BN 30 oils are also a recommended alternative when operating on crude oil having low sulphur content. Though crude oils many times have low sulphur content, they can contain other acid compounds and thus an adequate alkali reserve is important. With crude oils having higher sulphur content BN 40 – 55 lubricating oils should be used.

If both distillate fuel and residual fuel are used periodically as fuel, lubricating oil quality has to be chosen according to instructions being valid for residual fuel operation, i.e. BN 30 is the minimum. Optimum BN in this kind of operation depends on the length of operating periods on both fuel qualities as well as of sulphur content of fuels in question. Thus in particular cases BN 40 or even higher BN lubricating oils should be used.

The intervals between lubricating oil changes may be extended by adding oil daily to keep the oil level constantly close to the maximum level.

An example of BN depletion curve with different BN lubricating oils is shown below.



Additives

The oils should contain additives that give good oxidation stability, corrosion protection, load carrying capacity, neutralisation of acid combustion and oxidation residues and should prevent deposit formation on internal engine parts (piston cooling gallery, 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

Base oils

Use of virgin base stocks only is allowed, i.e. recycled or re-refined base oils are not allowed.

02B.2. Condemning limits for used lubricating oil V1

When estimating the condition of used lubricating oil, the following properties along with the corresponding limit values must be noted. If the limits are exceeded, measures must be taken. Compare also with guidance values for fresh lubricating of the brand used.

Property	Unit	Limit	Test method
Viscosity	cSt at 40 °C	max. 25% decrease max. 45% increase	ASTM D 445
Viscosity	cSt at 100 °C	max. 20% decrease max. 25% increase	ASTM D 445
Water	% V/V	max. 0.30	ASTM D 95 or D 1744
Base Number	mg KOH/g	min. 20 in HFO operation, max. 50% depletion in LFO operation	ASTM D 2896
Insolubles	% m/m in n-Pentane	max. 2.0	ASTM D 893b
Flash Point, PMCC	°C	min. 170	ASTM D 93
Flash Point, COC	°C	min. 190	ASTM D 92

02B.3. Change of lubricating oil brand V3

In order to minimise the risk of lubricating oil foaming, deposit formation, blocking of lubricating oil filters, damage to engine components, etc., the following procedure should be followed when lubricating oil brand is changed from one to another:

- If possible, change the lubricating oil brand in connection with an engine (piston) overhaul
- Drain old lubricating oil from the lubricating oil system
- Clean the lubricating oil system in case of an excessive amount of deposits on the surfaces of engine components, like crankcase, camshaft compartment, etc.
- Fill the lubricating oil system with fresh lubricating oil

If the procedure described above is not followed, responsibility of possible damage and malfunctions caused by lubricating oil change should always be agreed between the oil company and customer.

02B.4. Approved lubricating oil qualities for Vasa 32 engines V1

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Should unapproved lubricating oils be used during the engine warranty period, and there exist no agreement with the engine manufacturer about testing, the engine guarantee does not hold.

GAS OIL, MARINE DIESEL OIL AND LIQUID BIO FUEL OPERATION

If gas oil, marine diesel oil or liquid bio fuel is used as fuel, lubricating oils with a BN of 10-20 are recommended to be used. Also BN 30 lubricating oils included in Table 3 can be used in gas oil and marine diesel oil fuelled engines.

Table 1.

Approved system oils - fuel categories A and B, recommended in the first place in gas oil, marine diesel oil or liquid bio fuel installations:

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
Adnoc-Fod	Marine Engine Oil X324	SAE 30	24	A,B
	Marine Engine Oil X424	SAE 40	24	A,B
BP	Energol HPDX 30	SAE 30	12	A,F
	Energol HPDX 40	SAE 40	12	A,F
	Energol DS3-153	SAE 30	15	A,F
	Energol DS3-154	SAE 40	15	A,F
	Energol IC-HFX 203	SAE 30	20	A,B,F
	Energol IC-HFX 204	SAE 40	20	A,B,F
Castrol	HLX 30	SAE 30	12	A,F
	HLX 40	SAE 40	12	A,F
	MLC 30	SAE 30	12	A,F
	MLC 40	SAE 40	12	A,F
	MHP 153	SAE 30	15	A,B,F
	MHP 154	SAE 40	15	A,B,F
	Seamax Extra 30	SAE 30	15	A,B,F
	Seamax Extra 40	SAE 40	15	A,B,F
	TLX Plus 203	SAE 30	20	A,B,F
	TLX Plus 204	SAE 40	20	A,B,F
Chevron (Texaco + Caltex + FAMM)	Delo 1000 Marine 30	SAE 30	12	A,F
	Delo 1000 Marine 40	SAE 40	12	A,F
	Delo 2000 Marine 30	SAE 30	20	A,B,F
	Delo 2000 Marine 40	SAE 40	20	A,B,F
	Taro 12 XD 30	SAE 30	12	A,F
	Taro 12 XD 40	SAE 40	12	A,F
	Taro 16 XD 30	SAE 30	16	A,B,F
	Taro 16 XD 40	SAE 40	16	A,B,F
	Taro 20 DP 30	SAE 30	20	A,B,F
	Taro 20 DP 40	SAE 40	20	A,B,F

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
ExxonMobil	Exxmar 12 TP 30	SAE 30	12	A,F
	Exxmar 12 TP 40	SAE 40	12	A,F
	Exxmar 24 TP 30	SAE 30	24	A,B
	Exxmar 24 TP 40	SAE 40	24	A,B
	Delvac 1630	SAE 30	12	A,F
	Delvac 1640	SAE 40	12	A,F
	Mobilgard ADL 30	SAE 30	15	A,B,F
	Mobilgard ADL 40	SAE 40	15	A,B,F
	Mobilgard 312	SAE 40	15	A,B,F
	Mobilgard 412	SAE 30	15	A,B,F
	Mobilgard 1 SHC	SAE 40	15	A,B,F
Indian Oil Corporation	Servo Marine 1030	SAE 30	10	A,F
	Servo Marine 1040	SAE 40	10	A,F
	Servo Marine 2030	SAE 30	20	A,B,F
	Servo Marine 2040	SAE 40	20	A,B,F
Kuwait Petroleum	Q8 Mozart HPM 30	SAE 30	12	A,F
	Q8 Mozart HPM 40	SAE 40	12	A,F
Nippon Oil Corporation	SL 230	SAE 30	22	A
	SL 240	SAE 40	22	A
Petrobras	Marbrax CCD-410-AP	SAE 40	12	A,F
	Marbrax CCD-415	SAE 40	15	A,B,F
	Marbrax CCD-420	SAE 40	20	A,B,F
	Marbrax CCD-410	SAE 40	12	A,F
Saudi Arabian Lubricating oil Company (Petrolube)	Petromin Petromar 2-30	SAE 30	30	A,B
	Petromin Petromar 2-40	SAE 40	30	A,B
	Petromin Petromar 3-30	SAE 30	40	A,B
	Petromin Petromar 3-40	SAE 40	40	A,B
Shell	Gadinia Oil 30	SAE 30	12	A,F
	Gadinia Oil 40	SAE 40	12	A,F
Statoil	MarWay 1030	SAE 30	10.6	A,F
	MarWay 1040	SAE 40	10.6	A,F
Total / Lubmarine	Disola M 3015	SAE 30	14	A,F
	Disola M 4015	SAE 40	14	A,F
	Disola M 3020	SAE 30	20	A,B,F
	Disola M 4020	SAE 40	20	A,B,F

HEAVY FUEL AND CRUDE OIL OPERATION

Today's modern trunk piston diesel engines are stressing the lubricating oils heavily due to a.o. low specific lubricating oil consumption. Also ingress of residual fuel combustion products into the lubricating oil can cause deposit formation on the surface of certain engine components resulting in severe operating problems. Due to this many lubricating oil suppliers have developed new lubricating oil formulations with better fuel and lubricating oil compatibility.

Table 2.

Approved system oils - fuel categories C and D, recommended in the first place when operating on heavy fuel, on crude oil having high sulphur content in order to reach full service intervals. BN 50-55 lubricating oils are preferred in the first place.

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
BP	Energol IC-HFX 403	SAE 30	40	C,D
	Energol IC-HFX 404	SAE 40	40	C,D
	Energol IC-HFX 504	SAE 40	50	C,D
Castrol	TLX Plus 403	SAE 30	40	C,D
	TLX Plus 404	SAE 40	40	C,D
	TLX Plus 504	SAE 40	50	C,D
	TLX Plus 554	SAE 40	55	C,D
Cepsa	Troncoil 4040 PLUS	SAE 40	40	C,D,
	Troncoil 5040 PLUS	SAE 40	50	C,D,
	Ertoil Koral 4040 SHF	SAE 40	40	C,D,
	Ertoil Koral 5040 SHF	SAE 40	50	C,D
Chevron (Texaco + Caltex + FAMM)	Taro 40 XL 40	SAE 40	40	C,D
	Taro 50 XL 40	SAE 40	50	C,D
	Delo 3400 Marine 30	SAE 30	40	C,D
	Delo 3400 Marine 40	SAE 40	40	C,D
	Delo 3550 Marine 40	SAE 40	55	C,D
Chinese Petroleum Corporation	Marilube Oil W 404	SAE 40	40	C,D
	Marilube Oil W 504	SAE 40	50	C,D
ENI S.p.A.	Cladium 400 S SAE 30	SAE 30	40	C,D
	Cladium 400 S SAE 40	SAE 40	40	C,D
	Cladium 500 S SAE 30	SAE 30	50	C,D
	Cladium 500 S SAE 40	SAE 40	50	C,D
	Cladium 550 S SAE 30	SAE 30	55	C,D
	Cladium 550 S SAE 40	SAE 40	55	C,D

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
ExxonMobil	Exxmar 40 TP 30	SAE 30	40	C,D
	Exxmar 40 TP 40	SAE 40	40	C,D
	Exxmar 50 TP 40	SAE 40	50	C,D
	Mobilgard M 340	SAE 30	40	C,D
	Mobilgard M 440	SAE 40	40	C,D
	Mobilgard M50	SAE 40	50	C,D
FL Selenia S.p.A.	MAEO 4040	SAE 40	40	C,D
	MAEO 4050	SAE 40	50	C,D
Fuchs	Titan PSW 40 SAE 40	SAE 40	40	C,D
	Titan PSW 55 SAE 40	SAE 40	55	C,D
Indian Oil Corporation	Servo Marine 4030	SAE 30	40	C,D
	Servo Marine 4040	SAE 40	40	C,D
	Servo Marine 5040	SAE 40	50	C,D
	Servo Marine 5540	SAE 40	55	C,D
	Servo Marine K-4030	SAE 30	40	C,D
	Servo Marine K-4040	SAE 40	40	C,D
	Servo Marine K-5040	SAE 40	50	C,D
	Servo Marine K-5540	SAE 40	55	C,D
Morris Lubricants	Aquamor 140MD	SAE 40	40	C,D
	Aquamor 150MD	SAE 40	50	C,D
Nippon Oil Corporation	Marine T404	SAE 40	40	C,D
	Marine T504	SAE 40	50	C,D
Pertamina	Martron 440	SAE 40	40	C,D
	Martron 450	SAE 40	50	C,D
	Salyx 440	SAE 40	40	C,D
	Salyx 450	SAE 40	50	C,D
Petrobras	Marbrax CCD-440	SAE 40	40	C,D
	Marbrax CCD-450	SAE 40	50	C,D
Petron	Petromar XC 4030	SAE 30	40	C,D
	Petromar XC 4040	SAE 40	40	C,D
	Petromar XC 5540	SAE 40	55	C,D
Petronas	Disrol 400 SAE 30	SAE 30	40	C,D
	Disrol 400 SAE 40	SAE 40	40	C,D
	Disrol 500 SAE 30	SAE 30	50	C,D
	Disrol 500 SAE 40	SAE 40	50	C,D

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
Repsol YPF	Neptuno W NT 4000 SAE 30	SAE 30	40	C,D
	Neptuno W NT 4000 SAE 40	SAE 40	40	C,D
	Neptuno W NT 5500 SAE 30	SAE 30	55	C,D
	Neptuno W NT 5500 SAE 40	SAE 40	55	C,D
Saudi Arabian Lubricating Oil Company (Petrolube)	Petromin Petropower 3-30	SAE 30	40	C,D
	Petromin Petropower 3-40	SAE 40	40	C,D
	Petromin Petropower 4-40	SAE 40	55	C,D
Shell	Argina X 40	SAE 40	40	C,D
	Argina XL 40	SAE 40	50	C,D
Total / Lubmarine	Aurelia XL 3040	SAE 30	40	C,D
	Aurelia XL 3055	SAE 30	55	C,D
	Aurelia XL 4040	SAE 40	40	C,D
	Aurelia XL 4055	SAE 40	55	C,D
	Aurelia TI 3040	SAE 30	40	C,D
	Aurelia TI 3055	SAE 30	55	C,D
	Aurelia TI 4040	SAE 40	40	C,D
	Aurelia TI 4055	SAE 40	55	C,D

Table 3.

Approved system oils - fuel categories A, B, C and D. Lubricating oils with BN 30 included in Table 3 are designed to be used when operating on crude oil with low sulphur content (< 1 % m/m). Further, on heavy fuelled installations BN 30 lubricants have eventually a positive influence on cleanliness of the SCR catalyst.

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
BP	Energol IC-HFX 303	SAE 30	30	A,B,C,D
	Energol IC-HFX 304	SAE 40	30	A,B,C,D
Castrol	TLX Plus 303	SAE 30	30	A,B,C,D
	TLX Plus 304	SAE 40	30	A,B,C,D
Cepsa	Troncoil 3040 PLUS	SAE 40	30	A,B,C,D
	Ertoil Koral 3040 SHF	SAE 40	30	A,B,C,D
Chevron (Texaco + Caltex + FAMM	Taro 30 DP 30	SAE 30	30	A,B,C,D
	Taro 30 DP 40	SAE 40	30	A,B,C,D
	Delo 3000 Marine 30	SAE 30	30	A,B,C,D
	Delo 3000 Marine 40	SAE 40	30	A,B,C,D
Chinese Petroleum Corporation	Marilube Oil W 304	SAE 40	30	A,B,C,D
ENI S.p.A.	Cladium 300 S SAE 30	SAE 30	30	A,B,C,D
	Cladium 300 S SAE 40	SAE 40	30	A,B,C,D

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
ExxonMobil	Exxmar 30 TP 30	SAE 30	30	A,B,C,D
	Exxmar 30 TP 40	SAE 40	30	A,B,C,D
	Mobilgard M 330	SAE 30	30	A,B,C,D
	Mobilgard M 430	SAE 40	30	A,B,C,D
Indian Oil Corporation	Servo Marine 3030	SAE 30	30	A,B,C,D
	Servo Marine 3040	SAE 40	30	A,B,C,D
	Servo Marine K-3030	SAE 30	30	A,B,C,D
	Servo Marine K-3040	SAE 40	30	A,B,C,D
Morris Lubricants	Aquamor 130MD	SAE 40	30	A,B,C,D
Nippon Oil Corporation	Marine T303	SAE 30	30	A,B,C,D
	Marine T304	SAE 40	30	A,B,C,D
Pertamina	Martron 430	SAE 40	30	A,B,C,D
	Salyx 430	SAE 40	30	A,B,C,D
Petrobras	Marbrax CCD-330	SAE 30	30	A,B,C,D
	Marbrax CCD-430	SAE 40	30	A,B,C,D
Petron	Petromar XC 3030	SAE 30	30	A,B,C,D
	Petromar XC 3040	SAE 40	30	A,B,C,D
Petronas	Disrol 300 SAE 30	SAE 30	30	A,B,C,D
	Disrol 300 SAE 40	SAE 40	30	A,B,C,D
Saudi Arabian Lubricating Oil Company (Petrolube)	Petromin Petropower 2-30	SAE 30	30	A,B,C,D
	Petromin Petropower 2-40	SAE 40	30	A,B,C,D
Shell	Argina T 30	SAE 30	30	A,B,C,D
	Argina T 40	SAE 40	30	A,B,C,D
Total / Lubmarine	Aurelia XL 3030	SAE 30	30	A,B,C,D
	Aurelia XL 4030	SAE 40	30	A,B,C,D
	Aurelia TI 3030	SAE 30	30	A,B,C,D
	Aurelia TI 4030	SAE 40	30	A,B,C,D

Table 4.

Approved system oils - fuel categories A, B and C. Some lubricating oils with older type of detergent / dispersant chemistries are still available and are listed in Table 4. These brands are, however, likely to cause shorter service intervals.

LUBRICATING OILS WITH OLDER TYPE OF DETERGENT/DISPERSANT ADDITIVE CHEMISTRY				
SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
ADNOC-Fod	Marine Engine Oil X330	SAE 30	30	A,B,C
	Marine Engine Oil X430	SAE 40	30	A,B,C
ENI S.p.A.	Cladium 400 SAE 30	SAE 30	40	A,B,C
	Cladium 400 SAE 40	SAE 40	40	A,B,C
Neste	NST 30	SAE 30	30	A,B,C
	NST 40	SAE 40	30	A,B,C
Petrogal	GALP Marine MH 4040	SAE 40	40	A,B,C
Teboil	Ward L 30 T SAE 30	SAE 30	30	A,B,C
	Ward L 30 T SAE 40	SAE 40	30	A,B,C
	Ward L 40 T SAE 30	SAE 30	40	A,B,C
	Ward L 40 T SAE 40	SAE 40	40	A,B,C

Before using a lubricating oil not listed in Tables 1-4, the engine manufacturer must be contacted. Lubricating oils that are not approved have to be tested according to engine manufacturer’s procedures.

APPROVED LUBRICATING OILS FOR ABB VTR-TURBOCHARGERS

SPECIAL LOW FRICTION SYNTHETIC OILS: CHANGE INTERVAL: 1500 hours (ABB´s List 2b)				
MANUFACTURER	BRAND NAME	VISCOSITY cSt at 40 °C	VISCOSITY cSt at 100 °C	VI
Shell	Corena AP 68	68	8.5	94

SPECIAL LOW FRICTION SYNTHETIC OILS: CHANGE INTERVAL: 2500 hours (ABB´s List 3b)				
MANUFACTURER	BRAND NAME	VISCOSITY cSt at 40 °C	VISCOSITY cSt at 100 °C	VI
BP	Enersyn TC-S 68	68	8.5	98
Chevron (Texaco + Caltex + FAMM)	Cetus PAO 68	68	10.3	138
Castrol	Aircol SR 68	68	10.5	142
ENI S.p.A.	Dicrea SX 68	71.6	10.5	134

SPECIAL LOW FRICTION SYNTHETIC OILS: CHANGE INTERVAL: 2500 hours (ABB´s List 3b)				
MANUFACTURER	BRAND NAME	VISCOSITY cSt at 40 °C	VISCOSITY cSt at 100 °C	VI
ExxonMobil	Compressor Oil RS 68	67	10	135
	Rarus SHC 1026	66.8	10.4	144
	SHC 626	69.9	10.9	147
Shell	Corena AS 68	67.8	10.1	145
Total / Lubmarine	Barelf SM 68	73.8	11.4	147

APPROVED LUBRICATING OILS FOR ENGINE TURNING DEVICE

It is recommended to use EP-gear oils, viscosity 400-500 cSt at 40 °C = ISO VG 460 as lubricating oils for turning device.

LUBRICATING OILS FOR ENGINE TURNING DEVICE				
SUPPLIER	BRAND NAME	VISCOSITY cSt at 40 °C	VISCOSITY cSt at 100 °C	VISCOSITY INDEX (VI)
BP	Energol GR-XP 460	460	30.5	95
Castrol	Alpha SP 460	460	30.5	95
Chevron (Texaco + Caltex + FAMM)	Meropa 460	460	31.6	100
ENI S.p.A.	Blasia 320	300	23.0	95
ExxonMobil	Mobilgear 600 XP 460	460	30.6	96
	Mobilgear 634	437	27.8	96
Shell	Omala Oil 460	460	30.8	97
Total / Lubmarine	Epona Z 460	470	30.3	93

LUBRICATING OILS FOR GOVERNOR / ACTUATOR

An oil of viscosity class SAE 30 or SAE 40 is suitable and usually the same oil can be used as in the engine. Turbocharger oil can also be used in the governor. In low ambient conditions it may be necessary to use a multigrade oil (e.g. SAE 5W-40) to get a good control during start-up. Oil change interval: 2000 service hours.

LUBRICATING OILS FOR STARTING MOTOR

According to starting device manufacturer Gali International, S.A., the following lubricating oils are recommended to be used.

LUBRICATING OILS FOR GALI STARTING MOTOR, TYPE A45 (Normal ambient conditions)	
SUPPLIER	BRAND NAME
BP	Energol HLP-HH32
Chevron (Texaco + Caltex + FAMM)	Rando HD 32
ExxonMobil	Mobil DTE 24 Esso Nuto H32
Klüber Lubrication	Lamora HLP 32 Klüberoil GEM 1-32
Shell	Tellus 32
Total / Lubmarine	Visga FP32

LUBRICATING OILS FOR GALI STARTING MOTOR, TYPE A45 (Cold / hot ambient conditions)	
SUPPLIER	BRAND NAME
Chevron (Texaco + Caltex + FAMM)	Rando HD 32
ExxonMobil	Mobil DTE 13M
Shell	Tellus 32
Total / Lubmarine	Visga 32

02C. Raw water quality

02C.1. Raw water quality and approved cooling water additives

V7

Revision: e
Document No:
4V92A0765

FOR WÄRTSILÄ VASA 32/32LN, ENGINE TYPES

02C.2. Raw water quality

V3

Raw water for the closed cooling water circuits of engines has to meet the following specification:

Property	Limit
pH	min. 6.5
Hardness	max. 10 °dH
Chlorides	max. 80 mg/l
Sulphates	max. 150 mg/l

For raw water, evaporated water and a good quality tap water are normally recommended. Water from a reverse osmosis process may also be used if it meets the specifications. Untreated sea water, fresh water and rain water are unsuitable.

02C.3. Approved cooling water additives

V5

Manufacturer	Additive name
S.A. Arteco N.V. Technologiepark-Zwijnaarde 2 B-9052 Ghent/Zwijnaarde, Belgium	Havoline XLi
Ashland Specialty Chemical Drew Industrial One Drew Plaza Boonton, NJ 07005, USA	Drewgard 4109
Ashland Specialty Chemical Drew Marine One Drew Plaza Boonton, NJ 07005, USA	DEWT-NC powder Liquidewt Maxigard
Chevron Global Lubricants 6101 Bollinger Canyon Road San Ramon, CA 94583	Havoline XLi
GE Water and Process Technologies Interleuvenlaan 25 B-3001 Heverlee, Belgium GE Water and Process Technologies 4636 Somerton Road Trevose PA 19053, United States	CorrShield NT 4293 CorrShield NT 4200
Houseman Ltd The Priory, Burnham Slough SL1 7LS, UK	Cooltreat 651
Kuwait Petroleum (Danmark) AS Hummetoftveij 49 DK-2830 Virum, Denmark	Q8 Corrosion Inhibitor Long-Life
Maritech AB Box 143 S-29122 Kristianstad, Sweden	Marisol CW
Nalco Chemical Company One Nalco Centre Naperville, Illinois 60566-1024 USA	Trac 102 (ex-Nalcool 2000)

Manufacturer	Additive name
Nalfleet Marine Chemicals PO Box 11 Winnington Avenue, Northwich Cheshire, CW8 4DX, UK	Trac 102 (ex-Nalcool 2000) Nalfleet EWT 9-108
Rohm & Haas La Tour de Lyon 185, Rue de Bercy 75579 Paris, Cedex 12, France	RD11 RD11M RD25
Suomen KL-Lämpö Oy Keisarinviitta 22 33960 Pirkkala, Finland	Korrostop KV
Total Diamant B, 16, rue de la République 92922 Paris La Défense Cedex, France	WT Supra
Unitor ASA P.O. Box 300 Skøyen N-0212 Oslo, Norway	Dieselguard NB Rocor NB liquid Cooltreat AL
Vecom Holding BV PO Box 27 3140 AA Maassluis, The Netherlands	Vecom CWT Diesel QC-2

In order to prevent corrosion in the cooling water system, the instructions of right dosage and concentration of active corrosion inhibitors should always be followed. The information can be found in the table below.

Product designation	Dosage per 1 m³ of system capacity	Concentration of active corrosion inhibitor
Corrshield NT 4293 CorrShield NT 4200	10 litres	670 - 1000 ppm as NO_2
Drewgard 4109	16 - 30 li-tres	640 - 1200 ppm as NO_2
DEWT-NC powder Drewgard 4109 Liquidewt Maxigard	3 - 4.5 kg 16 - 30 litres 8 - 12 litres 16 - 30 litres	1500 - 2250 ppm as NO_2 640 - 1200 ppm as NO_2 470 - 700 ppm as NO_2 640 - 1200 ppm as NO_2
Cooltreat 651	5 litres	800 ppm as NO_2
Q8 Corrosion Inhibitor Long-Life	50 - 100 litres	1.8 - 3.7 Brix° of active compounds measured with a supplier's refrac-tometer

Product designation	Dosage per 1 m³ of system capacity	Concentration of active corrosion inhibitor
Maricol CW	6 - 9 litres	1000 - 1500 ppm as NO_2
Trac 102 (ex-Nalcool 2000) Nalfleet EWT 9 - 108	32 - 48 litres 2.25 - 3.4 litres	1000 - 1500 ppm as NO_2 670 - 1000 ppm as NO_2
Korrostop KV	20 - 25 litres	120 - 150 ppm as Mo
RD11 (RD11M) RD25	5 kg 50 litres	1250 ppm as NO_2 710 ppm as Mo
Havoline XLi	50 - 100 litres	1.8 - 3.7 Brix° of active compounds measured with a supplier's refrac-tometer
WT Supra	50 - 100 litres	1.8 - 3.7 Brix° of active compounds measured with a supplier's refrac-tometer
Dieselguard NB Rocor NB Liquid Cooltreat AL	2.0 - 4.8 kg 9.5 - 24 litres 50 - 100 litres	1000 - 2400 ppm as NO_2 1000 - 2400 ppm as NO_2 1.8 - 3.7 Brix° of active compounds measured with a supplier's refrac-tometer
Vecom CWT Diesel QC-2	6 - 10 litres	1500 – 2500 ppm as NO_2

Note!
For many products the recommended minimum and maximum limits are listed in the table above. Since the amount of active corrosion inhibitors, especially nitrites, decreases during service, the engine manufacturer recommends to start the dosage from the upper level of indicated range.

Note!
The nitrite content of nitrite-based cooling water additives tends to decrease in use. The risk of local corrosion increases substantially when nitrite content goes below the recommended limit.

Note!
Cooling water additive manufacturers can indicate the required nitrite content measured either as sodium nitrite, $NaNO_2$ or as nitrite, NO_2. 1 mg/l as NO_2 is equivalent to 1.5 mg/l as $NaNO_2$.

02C.4. Use of glycol

V3

If a freezing risk exists, glycol needs to be added to cooling water. Since glycol alone does not protect the engine and cooling water system against corrosion, an approved cooling water additive must also be used. All approved cooling water additives are compatible with glycol.

Ready-to-use mixtures containing both glycol and corrosion inhibitors are not permitted since the concentration of each component cannot be individually optimized. Usually, if the inhibitor concentration is correct, the glycol concentration will be unnecessarily high. No reduction in the glycol concentration is possible without increasing the risk of corrosion.

The amount of glycol in a closed cooling water systems should always be minimized since glycol adversely affects the heat transfer properties of water. Therefore it may be necessary to de-rate the engine if glycol is used; see document DAAE062266 for more information.

Two types of glycol are available: monopropylene glycol (MPG) and monoethyleneglycol (MEG). So called industrial qualities of both glycol types can be used, but MPG is considered to be less harmful to the environment.

03. Start, Stop and Operation

03.1. Turning of crankshaft V2

Turning is performed by means of an electrically driven turning device built on the engine. Four and six cylinder engines have, as standard, a manual turning device while the other cylinder numbers have electrically driven devices. Also the four and six cylinder engines can be provided with electrically driven turning devices.

03.1.1. Electrically driven turning device V2

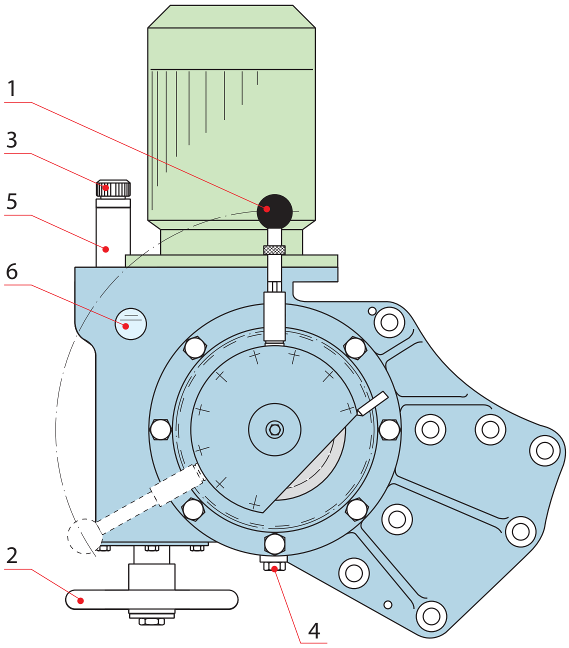
The turning device consists of an electric motor which drives the turning gear through a gear drive and a worm gear. There is a control box available, including a cable, which allows the turning to be accomplished from any position near the engine. The turning speed is about 4.8 RPM.

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

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

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

Electrically driven turning device



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

Fig 03-1 V1

03.1.2. Slow turning device V2

As additional equipment the engine can be provided with a system for slow turning of the engine before starting.

03.2. Start V2

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).
- Both cooling water system circuits, LT and HT water circuit, are in running order (correct pressures, circulating water preheated and pre-circulated sufficiently to heat the engine).
- The oil level in the governor and turbocharger(s) is correct.

- The starting air pressure exceeds 15 bar (normally, 10 bar is still sufficient to start the engine).
- The starting air system is drained of condensate.
- The drain pipe of the air cooler casing is open, no leakage.

Caution!
Before starting the engine, make sure that all covers and shields are in place and firmly fastened. Covers may only be removed when the engine is stopped for e.g. maintenance work, and must be replaced as soon as the work is finished.

Caution!
Before starting the engine, make sure that all maintenace or other work on the engine or auxiliary equipment is finished.

Caution!
Hot box covers may be removed temporarily while the engine is running for measurements and checks, but they must immediately be mounted again.

03.2.1. Manual start

V2

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

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

3 **Turn the crankshaft two revolutions** by using the turning device 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 waterlocks is eliminated.

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

5 **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.

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

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

03.2.2. Remote and automatic start

V1

See installation specific instructions.

03.3. Stop

03.3.1. Manual stop

V2

1 **Engines with built-on cooling water pump:** Idle the engine 1 min. before stopping. The pre-heating pump to be started.

Engines with separate cooling water pump: 1 min. idling will be enough, but the water pump should run for some 5 min more.

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

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. Make also sure that the starting air shut-off valve located before main starting valve is closed. Otherwise it might cause engine damage and/or personal injury.

Move 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 operating the pre-lubricating pump for a few minutes. At the same time, turn the crankshaft a few revolutions to ensure proper lubrication and protect the engine from corrosion.

Blow the engine with open indicator valves and start the engine once a week to check that everything is in order.

03.3.2. Prolonged stop

V2

Valid for an engine which has been started up, but has to be stopped for several months or longer.

Cooling water and lubricating oil remain in engine/system.

Caution!
The lubricating oil should not be kept warm, e.g. by separating if the engine is not preheated to normal preheating temperature.

The reason is that water which may be present in the lubricating oil in the engine sump will evaporate. The water mist will condensate on the colder parts in the crankcase causing liquid water, which may cause corrosion damages to engine parts e.g. camshaft, rollers, tappets, cylinderliners, piston (rings), gudgeon pin, crankshaft, gears and bearings.

03.3.2.1. Initial protection at beginning of stoppage period V1

- Water system

  Before stoppage, water treatment has to be added so that the level (concentration of inhibitor) is on the upper limit or slightly higher. A lower concentration may cause local corrosion, especially in areas like cylinder liners and exhaust valve seats.

- Fuel system

  If the engine has run on heavy fuel oil (HFO), the engine should run on light fuel oil (LFO) for a period of 15 minutes, on at least 50% load, to rinse the system from HFO before stopping.

- Cylinder liners

  The nozzle holders should be removed and 300ml rust protection Shell Ensis Fluid G or similar sprayed into the cylinders. Mount the nozzle holders after protection.

- Outside protection

  The outside protection is dependent of how severe the ambient condition are. The injection pumps, pipes, fuel racks and other unpainted surfaces in the hot box should be protected with a thin grease (spray) e.g. Tectyl 502EH.

- Turbocharger

  It is recommended that the suction branch is removed so that the rotor can be turned at the same time as the lube oil priming pump is running. Blind off the inlet with a suitable plywood plate or similar.

- General

  Close the indicator valves and blind off the exhaust gas pipes. By using the engine prelubricating pump, circulate the oil through the lubricating system for about 15 minutes. At the same time turn the crankshaft and the turbocharger rotors a few turns.

03.3.2.2. Monthly follow-up

V1

It is recommended that a monthly visual inspection of crankcase and hotbox is performed and if corrosion is found, more protection to be added.

By using the engine prelubricating pump, circulate the oil through the lubricating oil system for about 15 minutes. At the same time, turn the crankshaft and the turbocharger rotors a few turns.

03.4. Operation at low load and idling

V3

Engine idling

Engine running with no load (idling) is limited as follows:

	Time (mins)
Recommended idling time:	3 – 5
Maximum idling time:	30

If the idling has last longer than 5 minutes, high load running (minimum 70%) is to be followed for minimum 60 minutes to clean up the engine.

Low load operation

Engine running with low load is limited as follows:

	Marine Engines	Power Plants
Low load operation	10 – 20% of rated power	10 – 30% of rated power
Maximum time:	30 hours	10 hours

After running high load (minimum 70%), is to be followed for minimum 60 minutes to clean up the engine.

03.5. Normal operation supervision

V1

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

03.5.1. Every second day or after every 50 running hours

V1

1 **Read all thermometers and pressure gauges** and, at the same time, the load of the engine. All temperatures are more or less dependent on the load, and the lubricating oil, cooling water and raw water pressures (built-on pumps) are dependent on the speed. Therefore, always compare the values read with those at corresponding load and speed in the Acceptance Test Records and curves. **Guidance values are stated in** chapter 01.1 The charge air temperature should, in principle, be as low as possible at loads higher than 60 %, however, not so low that condensation occurs, see Fig 03-2. 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 of the engine decreases. Very low pressure (less than 0.5 bar) before the injection pumps reduces engine performance and may cause uneven load distribution between the cylinders (risk of breakdown!). Too high of a pressure drop may also result in deformation of filter cartridges (risk of injection pump seizure).

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

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

5 **Check the ventilation** (de-aerating) of the engine cooling water system. Check that the leakage from the telltale hole of the cooling water pump and the raw water pump is normal (slight).

6 **Check the quantity of leak-fuel** from the draining pipes and from the telltale hole of the fuel feed pump.

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

8 **Check that the telltale holes** of the oil coolers and the cooling 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.

Condensation in charge air coolers

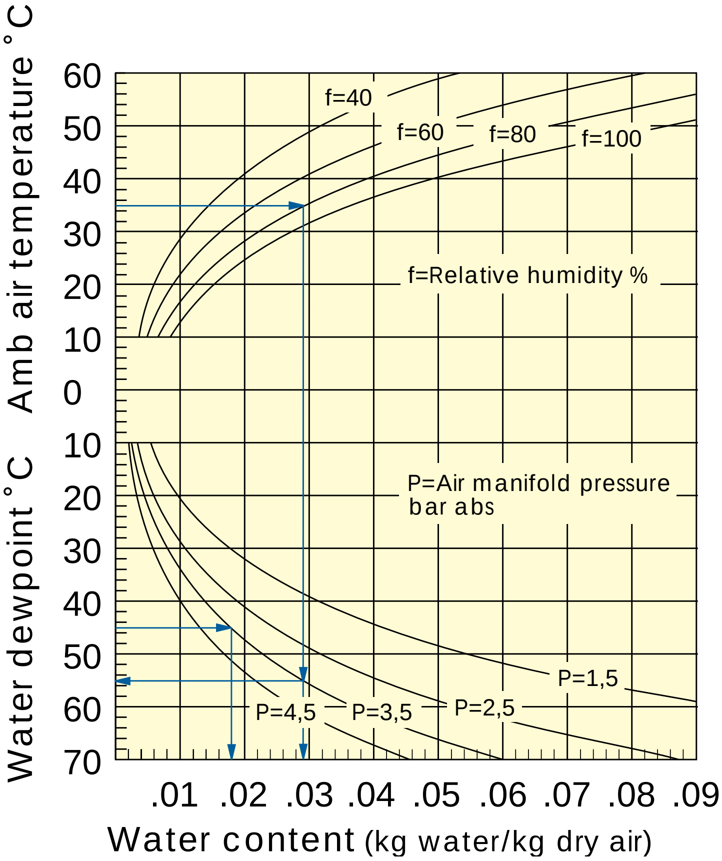


Fig 03-2 V1

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

03.5.2. Other maintenance works

V1

To avoid malfunction of the engine, scheduled maintenance work must be done, see chapter 04.

03.5.3. In connection with maintenance work

V1

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.

03.5.4. General

V2

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

2 **Strong gas blow-by past the pistons** is one of the most dangerous things that can occur in 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!

3 **When checking the firing pressures,** the load of the engine, the exhaust temperatures and all other operation parameters should be entered into Operation Data Record WV98V091GB. The value to be used for firing pressure is the **average peak pressure (p_{av})**. The pressure has to be measured as an average (mean) value (pav) of at least 32 cycles.

Note!
Measurement of firing pressures without simultaneous notation of the other operation parameters is practically worthless.

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 the rated load for one hour before continuing the low load operation or stopping 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 3 minutes before stopping is unnecessary and should be avoided.

03.6. Start after a prolonged stop (more than 8 h)

03.6.1. Manual start

V3

1 Check
- The lubricating oil level.
- The cooling water level in the expansion tank.
- The raw water supply to heat exchangers.
- The fuel oil level in the day tank (troublesome and time consuming job to vent the fuel system if the feed pump has sucked air!)
- The starting air pressure - min. 15 bar.
- That the parts of the fuel control shaft system and the injection pump racks move freely. **Otherwise risk of overspeed.**

2 **Observe all points in** section 03.2.1 Point 3 grows **more important the longer the engine has been stopped.**

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

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

03.7. Start after overhaul

V2

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, that all screw connections are properly locked and the injection pump racks move freely in the pumps.

2 **The speed governor control lever** being in max. 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 5 mm.

3 **If the injection pumps,** camshaft or its driving mechanism have been touched, check the injection timing of one cylinder (on each cylinder bank in a V-engine). See chapter 16 and the engine "Test protocol".

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,** see chapter 12

Note!
If the camshaft or the driving mechanism have been touched, check the valve timing of one cylinder at least (on each cylinder bank in a V-engine). Guidance values, see chapter 06.1.1 and chapter 13.

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

7 **Start the pre-lubricating oil pump.** Vent the lubricating oil filters. Check (as thoroughly as possible) that lubricating oil appears from all bearings and lubricating nozzles, from the piston cooling oil outlet and from the valve mechanism. Check that there is no leakage from the pipe connections inside or outside the engine.

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

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) spare the oil pump and oil filter.

9 **See the instructions** in section 03.1 and section 03.6.1 when starting.

03.8. Operation supervision after overhaul

V1

1 **At the first start,** listen carefully for possible jarring sounds. If anything is 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 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 (de-aerating) of the engine cooling water system.
- Check the quantity of leak fuel.
- Check the telltale holes of the coolers.
- Check the content of additives in the cooling water.
- Check the cylinder pressures.
- Listen for jarring sounds.
- Check the crankcase pressure.
- Check the starting air pipes.
- Vent the filters.

03.9. Running-in

V2

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

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

Note!
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.

Running-in programme

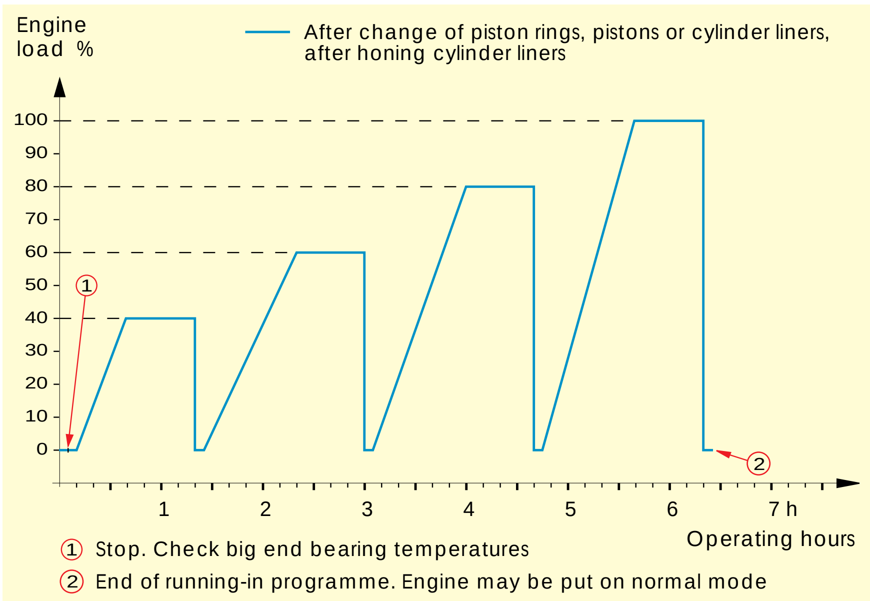


Fig 03-3 V1

03.10. Maintenance of turning device V2

Change the lubricating oil in the turning device once during the first year of operation.

Approved lubricating oils, see section 02.2.5. After that, the oil should be changed according to chapter 04 Check also that the vent hole (3), Fig 03-1 is open.

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

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

3 **Fill the gear box with oil** (according to the table in section 02B.4) through the filling hole (5) until the oil level reaches the level gauge glass (6). Utmost cleanliness should be observed.

4 **Close the oil holes** and operate the turning device a few seconds.

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

04. Maintenance Schedule

V7

The actual operating conditions, and above all the quality of the fuel used, will largely determine the maintenance necessity for the engine. Because of the difficulty in anticipating the various operating conditions that may be encountered in the field, the periods stated in the schedule should be used for guidance purposes only, but must not be exceeded during the warranty period. If there are any indications that the maintenance procedure is required in advance of the recommended time period, prudent industry practice dictates that the suggested maintenance procedure be performed. Additionally, if inspection or observation reveals that a part shows wear or use beyond the prescribed tolerances, then that part should be renewed immediately.

Also see the instruction books of the turbocharger separate instructions for additional equipment and section 03.1.

Note!
Note the Risk Reduction in chapter 00A

Note!
Note the Environmental Hazards in chapter 02A

- **Before any steps are taken,** carefully read the corresponding item in this Manual.
- **During all maintenance work,** observe the utmost cleanliness and order.

Caution!
If a 110 V injector power supply is fitted, it must be disconnected before dismantling any of the cylinder head covers.

- **Before dismantling, drain and depressurize all relevant systems.** After dismantling, immediately cover holes for lubricating oil, fuel oil, gas and air with tape, plugs, clean cloth or the like.
- **When exchanging a worn-out or damaged part** that has 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.
- **Always renew all gaskets, sealing rings and O-rings** during maintenance work.

Note!
The O-rings in the cooling water system must not be lubricated with oil based lubricants, use soap or similar.

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

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 the main starting valve, is closed. Then drain the engine starting air system to avoid engine damage or personal injury.

Caution!
When overhauling the engine, make absolutely sure that the generator breaker is secured and gear box is not engaged to avoid accidental turning of engine.

Caution!
Accidental turning of engine may cause engine damage or personal injury.

04.1. How to select application and fuel quality V1

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).
- NG Natural gas.

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

Fuel characteristics, maximum limits			
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

V3

Every second day, irrespective of the engine being in operation or not		
Automatic prelubrication	Check operation	See chapter 03.2 and 18.9
Crankshaft	**Marine engine:** In a stopped engine, turn the crankshaft into a new position.	See chapter 03.1

04.3. Once a week

V1

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

04.4. Interval: 50 operating hours

V4

Interval: 50 operating hours		
Air coolers	Check draining of air coolers. Check that the draining pipe is open, check if any leakage.	15.4.1 03.5.1
Cooling water system	Check water level in cooling system. Check the water level in the expansion tank(s) and/or the static pressure in the engine cooling circuits.	19.3
Connecting rod	Check tightening of the connecting rod screws. Check the tightening of the connecting rod screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. **Note!** Pump to stated pressure. Tighten if possible. **Do not loosen!**	11.3.4 1 07.3.1
Fuel and lubricating oil filters	Check pressure drop indicators. Change filter cartridges if high pressure drop is indicated.	03.5.1 17.2 18.6
Gauges and indicators	Take readings. Read and record (using eg. form No. WV98V091) all temperature and pressure gauges, and at the same time the load of the engine.	03.5.1
Governor, actuator	Check oil level in governor. Check oil level, and look for leaks	02.2.3 22.4
Injection and fuel system	Check leak fuel quantity. Check the amount of leak fuel from the injection pumps and nozzles.	03.5.1 17
Lubricating oil sump	Check oil level in sump. Check oil level by means of dip stick, compensate for consumption.	18.1 1
Main bearings	Check tightening of main bearing screws. Check the tightening of main bearing screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. **Note!** Pump to stated pressure. Tighten if possible. **Do not loosen!**	10.1.3 07.3.1
Running-in filter	Remove the running-in filter. After the first 50 operating hours, remove the running-in filter and pump up the hydraulic jack.	
Turbocharger	Water cleaning of compressor. Clean the compressor by injecting water.	15.2.4
Turbocharger VTR-chargers	Check turbocharger oil level. Check oil level, and look for leaks. Change oil after the first 100 service hours in both oil spaces.	15.1 02.2.4
Valve mechanism	Check valve clearances. Check the valve clearances after 50 hours' running in new and overhauled engines.	12.1.4 06.1.1 06.1.1

04.5. Interval: 100 operating hours

V1

Interval: 100 operating hours		
Turbocharger	Water cleaning of turbine. Clean the turbine by injecting water; more often if necessary.	15.2.1

04.6. Interval: 500 operating hours

V5

Interval: 500 operating hours		
Centrifugal filter	Clean centrifugal filter(s). Clean more often if necessary. Remember to open the valve before the filter after cleaning.	18.7.1
Control mechanism	Maintenance of control mechanism. Check for free movement, clean and lubricate.	22.2
Cooling water	Check water quality. Check content of additives.	19.6 02.3
Cylinder pressure	Check cylinder pressure. Record firing pressures of all cylinders.	12.1.3 03.5.3
Lubricating oil	Take oil samples. In a new installation and after changing lubricating oil brand, take oil samples for analyzing. To ensure safe engine operation, frequent oil analysis at 500 - 1000 operating hours intervals are also recommended after the first year of operation. Change lubricating oil if the oil analysis results are not within the limits set by the engine manufacturer. When changing oil, clean all oil spaces with a high quality fibre free and lint free cloth. Regardless of the analysis results, the oil should be changed in connection with every piston overhaul, or every fourth year, whichever comes first.	02.2.2
Turbocharger VTR-chargers	Change lubricating oil in turbocharger(s). Lubricating oil change interval according to lubricating oil in use. See section 02.2.4.	02.2.4
	Take care that the turbine oil is not mixed with the engine lubricating oil.	15.1

04.7. Interval: 1000 operating hours

V2

Interval: 1000 operating hours		
Air filter (on-built)	Clean turbocharger air filter. Remove the filter(s) and clean according to instructions of the manufacturer (more often, if necessary).	15.1
Automation	Functional check of automation. Check function of the sensors for the alarm system and automatic stop devices.	01.2
Electrical fuel feed pump	Regrease el. fuel feed pump. Regrease the pump under running condition.	17.5
El. lubricating oil pump	Regrease prelubricating pump. Regrease the pump under running condition.	18.8
Flexible coupling Geislinger (Oil filled)	Oil change/check of the coupling. At first interval, change oil of the coupling. Following (1000 h) intervals, check oil level. See manufacturers instructions.	
Fuel filter	Replace fuel oil filter cartridges. Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced when the pressure difference indicator shows too high pressure drop).	17.6.1 17 17.2
Lubricating oil filter	Replace lub. oil filter cartridges. Drain the filter housings. Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced when the pressure difference indicator shows too high pressure drop.)	18.1
Valves	Check valve condition. Check that the inlet and exhaust valves move freely in their guides. This should preferably be done when the engine has been out of operation for a couple of hours. Check valve clearances. Check cylinder tightness (valves, piston rings) with a pneumatic test.	12.1.4 06.1.1 12A

04.8. Interval: 2000 operating hours

V2

Interval: 2000 operating hours		
Air cooler(s)	Check water side of charge air cooler(s). The first time check and possible cleaning of the waterside. If in good condition and deposits insignificant: future intervals 4000 running hours.	15.4.1
Injection valves	Inspect injection valves. 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. Replace the nozzles if necessary.	16.3.3
Lubricating oil	Change lubricating oil. Change oil in a new installation (wet sump installations). Take samples for analyzing. If the analyzing values are positive and if the oil supplier or engine manufacturer so recommend, the intervals between changes can be prolonged in steps of 500 operating hours. In dry sump installations the oil change intervals may be in the order of 8000 hours or more. Clean all oil spaces when changing lub. oil.	18.1 1
Measuring instruments	Check gauges. Check pressure and temperature gauges. Replace faulty ones.	
Governor	Change oil in governor. Change lubricating oil.	02.2.3 22.4
Mec. overspeed trip device	Check function of mechanical overspeed trip device. Check function and tripping speed	22.5 06.1.3
El.-pneu. overspeed trip device	Check el.-pneumatic overspeed trip device. Check function and tripping speed.	22.6.2 06.1.3

04.9. Interval: 4000 operating hours

V2

Interval: 4000 operating hours		
Air cooler(s)	Clean the charge air cooler(s). Clean and pressure test. Look carefully for corrosion.	15.4.1
Automation	Check connectors and cables. Check mounting and connections. Apply contact lubricant to contact surfaces. Check tightness of connections. Check condition of cables, wires and cable glands. Replace damaged connectors and cables.	
Camshaft	Inspect contact faces of camshaft. Check the contact faces of the cams and tappet rollers. Check that the rollers rotate. Rotate the engine with the turning gear.	14.2 03.1

Interval: 4000 operating hours		
Cooling water spaces	Inspect jacket water spaces on engine with cooled turbocharger. Inspect turbocharger cooling water ducts for possible deposits if the deposits are 1 mm or thicker, clean and inspect the water side of one cylinder liner through the plug in the engine block. If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.1 19.6 19.1 02.3 10.4.1
	Inspect jacket water spaces on engine with uncooled turbocharger. Inspect the water side of one cylinder through the plug in the engine block. If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.1 19.6 19.1 02.3 10.4.1
Control mechanism	Check control mechanism. Check for wear in all connecting links between the governor and all injection pumps.	22.2
Crankshaft	Check crankshaft alignment. Check alignment, use form No. WV98V036. Alignment check is performed on a warm engine.	11.2.1
Crankshaft	Check thrust bearing clearance. Check axial clearance.	11.2.2 06.2
Exhaust manifold	Check for leaks. Check for leaks once a year. Replace parts if necessary.	20
Flexible coupling Geislinger (Oil filled)	Oil change of the coupling. Change oil of the coupling. See manufacturers instructions.	
Fuel system	Check and adjustment of fuel system. Check and adjustment of fuel system once a year.	17
Injection valves	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. **HFO: Recommendation:** Replace the nozzle by new ones on 6000 h at the latest. **DO (LFO): Recommendation:** Replace the nozzle by new ones on 8000 h at the latest	16.3.3
Lube oil coolers	Clean the lube oil cooler. If the lube oil temperature before the engine is within normal operating values (section 01.1), the interval can be prolonged. Unnecessary opening of the plate cooler should be avoided. Clean the lube oil cooler before the alarm limit is reached. Examine carefully for corrosion.	19.6
Starting fuel limiter	Check starting fuel limiter. Check the adjustment and function.	22.7

04.10. Interval: 12000 operating hours

V2

Interval: 12000 operating hours		
Balancing shaft gear 4R32	Inspect balancing shaft gear. Replace parts if necessary.	11.1.1
Governor driving gear	Inspect governor driving gear. Replace parts if necessary.	22.4.1 06.2
Flexible coupling Flexible rubber coupling	Check the flexible coupling. Check flexible rubber elements visually acc. to makers recommendations. Dismantle if necessary.	
HT-water pump	Inspect HT-water pump. Dismantle and check. Replace worn parts.	19.7 19.7.1
HT-water pump driving gear	Inspect HT-water pump driving gear. Replace parts if necessary.	19.7.1 06.2
HT-water thermostatic valve	Clean and inspect HT-water thermostatic valve. Clean and check the thermostatic element, valve cone-casing and sealings.	19
LT-water pump	Inspect LT-water pump. Dismantle and check. Replace worn parts.	19.7 19.7.1
LT-water pump driving gear	Inspect LT-water pump driving gear. Replace parts if necessary.	19.7.1 06.2
LT-water thermostatic valve	Clean and inspect LT-water thermostatic valve. Clean and check the thermostatic element, valve cone-casing, indicator pin and sealings.	19.8
Lubricating oil pump	Inspect the lubricating oil pump. Replace parts if necessary.	18.2.2
Lubricating oil pump driving gear	Inspect lubricating oil pump driving gear Replace parts if necessary.	18.2.3 06.2
Oil thermostatic valve	Clean and inspect oil thermostatic valve. Clean and check the thermostatic element, valve cone-casing and sealings.	18.5
Turbocharger VTR-chargers	Replace turbocharger bearings. See manufacturers instructions.	15.1
Turbocharger Napier Na-chargers	Inspect turbocharger bearings. Check and change if necessary. See manufacturers instructions.	15.1
Turbocharger ABB TPL-chargers	Inspect turbocharger bearings. Check and change if necessary. See manufacturers instructions.	15.1

04.11. Interval: 12 000 – 24 000 h depending on the used fuel

V3

Fuel	Overhaul interval	
	Average load > 75%	Average load < 75%
HFO 2	12000 h	16000 h
HFO 1	16000 h	20000 h
DO	20000 h	240000 h
NG	20 000 h	24 000 h

Interval: See table above		
Connecting rods	Replace big end bearing. Replace big end bearing. Inspect mating surface serrations. Measure the big end bore, use form No. 3211V015 or form No. 3211V012 (LN-engines)	06.2
Connecting rods (not three-piece design)	Replace connecting rod screws.	
	Replace connecting rod screws by new ones on 24 000 h at the latest.	11.3
Connecting rods (three-piece design)	Replace connecting rod screws.	
	Replace connecting rod screws by new ones at **every second overhaul** when doing piston overhauls at 12 - 16000 h intervals and at **every overhaul** when doing piston overhauls at longer intervals than 16000 h.	11.3
Connecting rods (three-piece design)	Replace connecting rod shims.	
	Replace connecting rod shims by new ones at **every second overhaul** when doing piston overhauls at 12 - 16000 h intervals and at **every overhaul** when doing piston overhauls at longer intervals than 16000 h.	11.3
Connecting rods	Inspect the small end bearings.	
	Inspect the small end bearings. Replace if necessary.	11.3 06.2
Cylinder heads	Overhaul of cylinder head. Dismantle and clean the underside, inlet and exhaust valves and ports. Inspect cooling spaces and clean, if necessary. Grind the valves. Inspect the valve rotators. Check rocker arms. Replace the O-rings in the valve guides. Replace the O-rings at bottom of cylinder head screws at **every overhaul**.	12.1.3 12.1.1 12.2.1 14.1.2
Cylinder liners	Inspect the cylinder liners. Measure the bore using form No. 3210V014 or form No. 3210V020 (LN-engines), replace liner if wear limits are exceeded. Hone the liners. Renew the anti-polishing ring.	10.4.1 06.2
Cylinder liners	Inspect cylinder liner water side. 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.	19.6 10.4.1

Interval: See table above		
Pistons	Inspect the pistons. Composite pistons must be dismantled for inspection of mating surfaces between piston skirt and piston crown. Inspect and clean oil spaces.	1
Piston, piston rings	Inspect pistons and piston rings. Pull, inspect and clean. Check the height of the ring grooves, use form No. 3211V016 or form No. 3211V021 (LN-engines). Check the retainer rings of the gudgeon pins. Replace complete set of piston rings. Note the running-in programme.	11.3.2 11.3 06.2 03.9
Lubricating oil	Change oil in connection with every piston overhaul, or every four years (every sixth year if the engine is running less than 1000 h/year), which-ever comes first. Clean all oil spaces with a high quality fibre free and lint free cloth.	section 02.2.2.1
Starting valves	Check starting valves. Check starting valves in cylinder head. Replace parts if necessary.	21.3

04.12. Interval: 16000 operating hours

V3

Interval: 16000 operating hours		
Camshaft driving gear	Inspect intermediate gears. Replace parts if necessary.	13 06.2
Flexible coupling (Oil filled)	Check the flexible coupling. Dismantle and check flexible coupling according to manufacturers in-structions.	
Fuel feed pump	General overhaul of fuel feed pump. Inspect pump and replace gaskets. Replace worn parts.	17.5
Governor drive	Check governor drive bearing. Check governor driving shaft bearing clearance in situ.	22.4.1 06.2
Governor	General overhaul of the governor. Can be sent to engine manufacturer for overhaul.	
Booster servomotor for governor	General overhaul of the booster servomotor. Replace worn parts. See manufacturers instructions.	
Turning device	Change oil in turning device. Regrease the drive shaft.	02.2.5 03.10
Vibration damper Viscous type	Take oil sample from vibration damper. Take oil sample for analyzing.	11.2
Vibration damper Geislinger	Check vibration damper. Dismantle and check vibration damper every 32000 hours.	11.2

04.13. Interval depending on the load

V2

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

Interval: See table above		
Camshaft	Inspect camshaft bearings. Replace if necessary.	10.3.1 06.2
Valve mechanism	Check valve mechanism parts. Check tappets.	14.1.2 06.2
Crankshaft	Inspect main bearings. Inspect one main bearing, if in bad condition, check all the main bearings and change if necessary. Note the type of bearing in use and do the inspection accordingly.	10.1.2 06.2
Hydraulic jack for main bearing caps	Check function. Change O-rings in the hydraulic jack if they are leaking when lifting the main bearing cap.	10.1.1

04.14. Overhaul interval based on the fuel type

V2

Fuel	Overhaul interval
HFO 2	16 000
HFO 1	16 000
DO	24 000
NG	24 000

Interval: See table above		
Injection pumps	Overhaul of injection pumps. Clean and inspect injection pumps, replace worn parts. Replace the erosion plugs.	16.1.4

04.15. Interval: 24000 operating hours

V2

Interval: 24000 operating hours		
Balancing shaft 4R32	Inspect balancing shaft bearing. Take one bush out for inspection. If in bad condition check the other too. Replace if necessary.	11.4.1
Engine fastening bolts	Check tightening of engine fastening bolts. Replace if necessary.	07.3.1
Exhaust manifold	Check expansion bellows. Replace if necessary.	20.1
Flexible coupling (Oil supply from engine)	Check the flexible coupling. Dismantle and check flexible coupling according to manufacturers instructions.	
Main starting valve	General overhaul of main starting valve. Replace worn parts.	21.1
Mec. overspeed trip device	General overhaul of mechanical overspeed trip device. Check function and tripping speed.	22.5.3 22.5.1
Starting air distributor	General overhaul of starting air distributor. Replace worn parts.	
Turbocharger ABB TPL-chargers	Inspect turbocharger bearings. Check and change if necessary. See manufacturers instructions.	15.1

04.16. Interval: 48000 operating hours

V2

Interval: 48000 operating hours		
Balancing shaft gear 4R32	Inspect bearing bushes. Replace parts.	11.4.3
Camshaft driving gear	Inspect intermediate gear bearings. Replace parts.	13 06.2
Crankshaft	Inspect crankshaft.	
	Inspect the crankshaft for wear.	06.2

Interval: 48000 operating hours		
Engine foundation Flexible mounted	Check flexible elements of engine foundation. Replace if necessary.	
Flexible coupling	Check the flexible coupling. Dismantle and check flexible coupling according to manufacturers instructions. Replace spring packs/inner star if necessary.	
Turbocharger	Replace rotor. Lifetime is dependent of operating conditions. See manufacturers instructions.	15.1

05. Maintenance Tools

V1

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

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

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

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

05.1. Use of this list

V1

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

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

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

05.2. Ordering of Maintenance tools

V1

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

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

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

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

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

Main Bearings 100

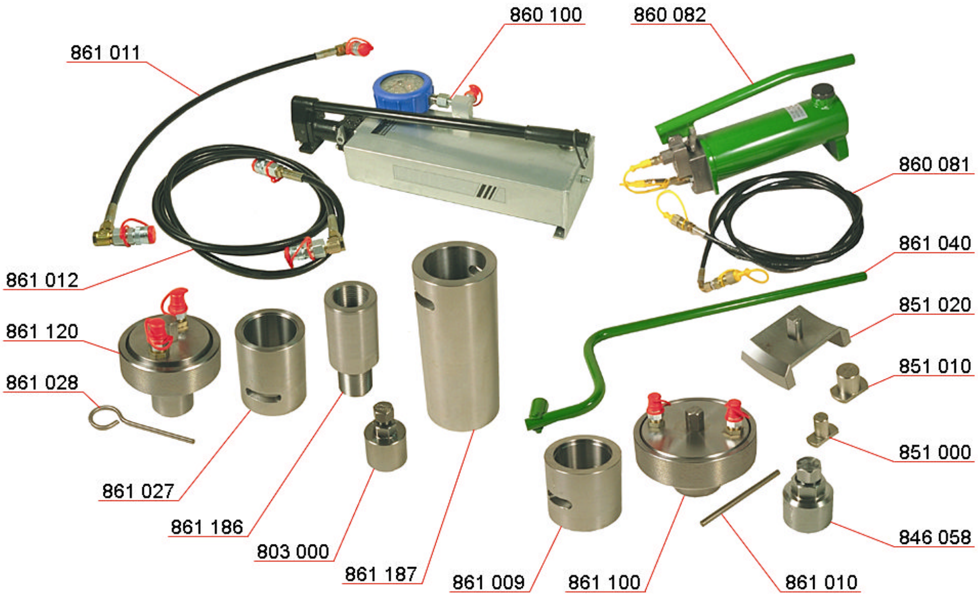


Fig 05-1 V1

Code	Description	Drawing No.
803000	Stud remover M42	4V80D0012
846058	Stud remover M56	3V84G0189
851000	Turning tool for main bearing shell	4V85B0023
851010	Turning tool for main bearing shell	4V85B0016
851020	Turning tool for thrust washers & bearing shell	3V85B0015
860081	Flexible hose 3000 mm, (low p. pump) **(1)**	
860082	Low pressure pump (150 bar) **(1)**	1V86A0018
860100	High pressure pump (1000 bar) **(1)**	4V86A0033

Code	Description	Drawing No.
861009	Distance sleeve M56	3V86B0039
861010	Pin for tightening of nuts M56	4V86B0002
861011	Flexible hose 800 mm (1)	
861012	Flexible hose 3000 mm (1)	
861027	Distance sleeve M42	3V86B0046
861028	Pin for tightening of nuts M42	4V86B0011
861040	Lifting tool for hydraulic cylinders M56	3V86B0052
861100	Hydraulic cylinder M56 (1)	3V86B0079
861120	Hydraulic cylinder M42 (1)	3V86B0078
861186	Extension piece M42 for main bearing side screws (2)	4V86B0133
861187	Extension piece M42 for main bearing side screws (2)	3V86B0134

(1) Including quick couplings

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

Cylinder Liner 100

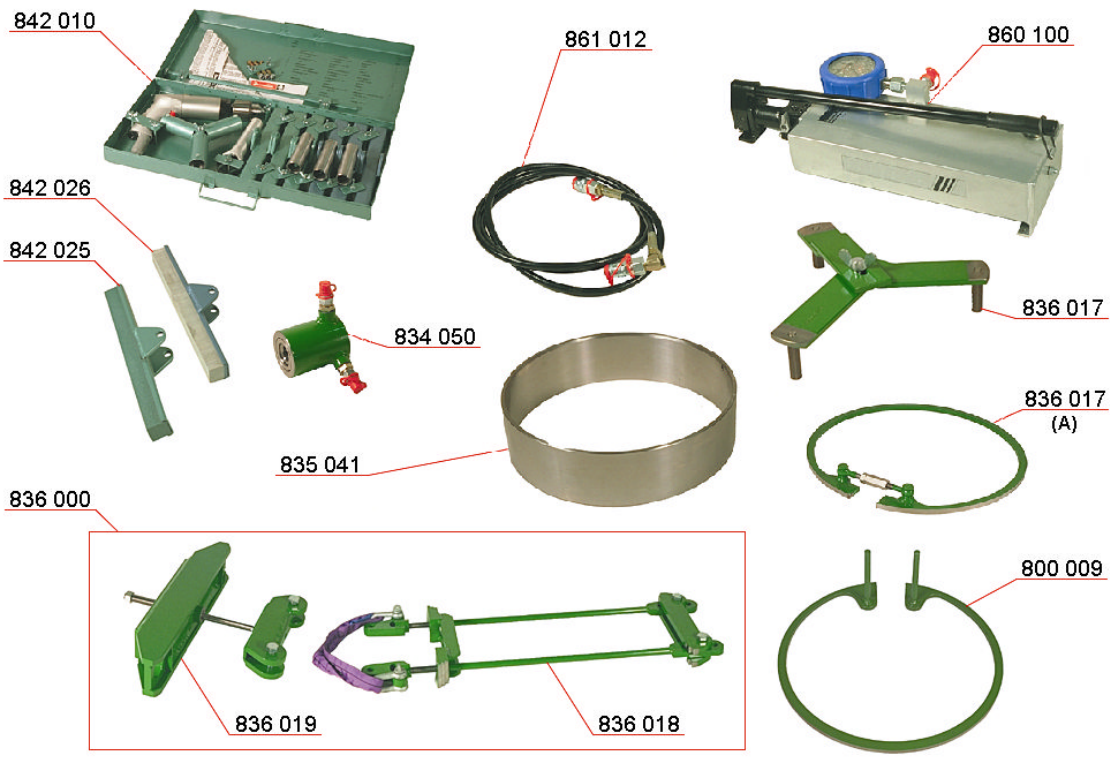


Fig 05-2 V1

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

(1) Only for 32 DF

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

(3) Including quick couplings

Connecting Rod, O-Profile 110

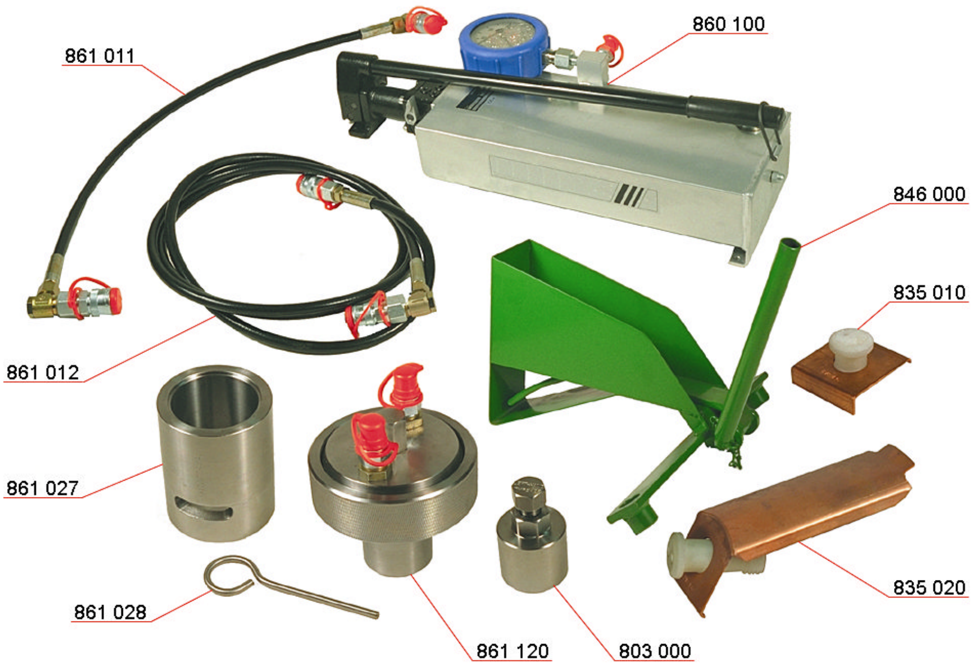


Fig 05-3

V1

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

(1) Only needed for V-engine

(2) Including quick couplings

Connecting Rod, H-Profile 110

Fig 05-4 V1

Code	Description	Drawing No.
803005	Stud remover M45x3	3V80D0020
835010	Protecting sleeve for connecting rod tooth (1)	3V83F0082
835020	Protecting sleeve for connecting rod tooth (1)	2V83F0083
835030	Mounting screw M45x3	3V83F0084

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

(1) Only needed for V-engine

(2) Including quick couplings

(3) Only for In-line engine

Connection Rod, Marine Head 110

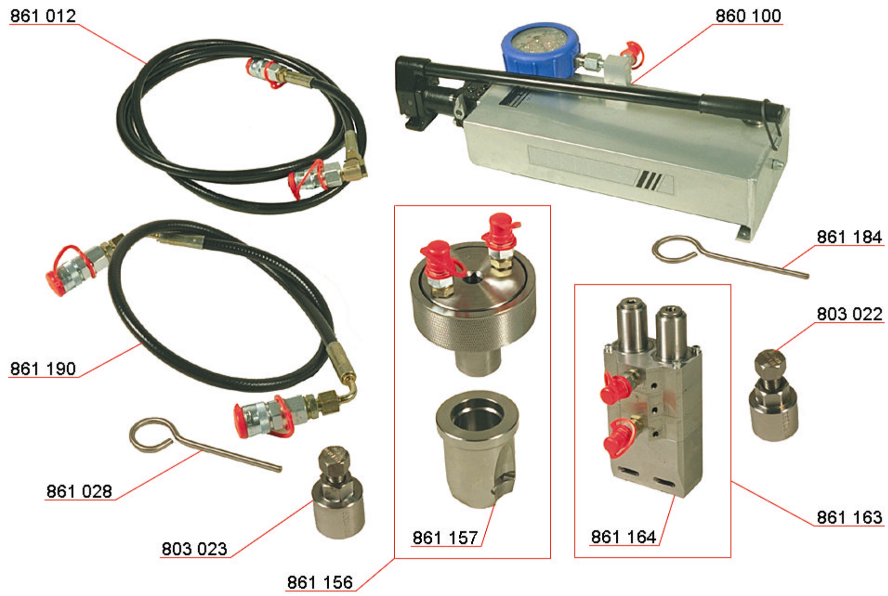


Fig 05-5 V1

Code	Description	Drawing No.
803022	Stud remover M30	4V86G0026
803023	Stud remover M24	4V80D0030
860100	High pressure pump (1000 bar) (1)	4V86A0033

Code	Description	Drawing No.
861012	Flexible hose 3000 mm (1)	
861028	Pin for tightening of nuts M30	4V86B0011
861156	Hydraulic tool M30 (1)	3V86B0186
861157	Distance sleeve M30	2V86B0187
861163	Hydraulic tools M24 (1)	2V86B0201
861164	Distance piece M24	2V86B0204
861184	Pin for tightening of nuts M24	4V86B0034
861190	Flexible hose 1100 mm (1)	

(1) Including quick couplings

Connection Rod, Marine Head, R-eng. 110

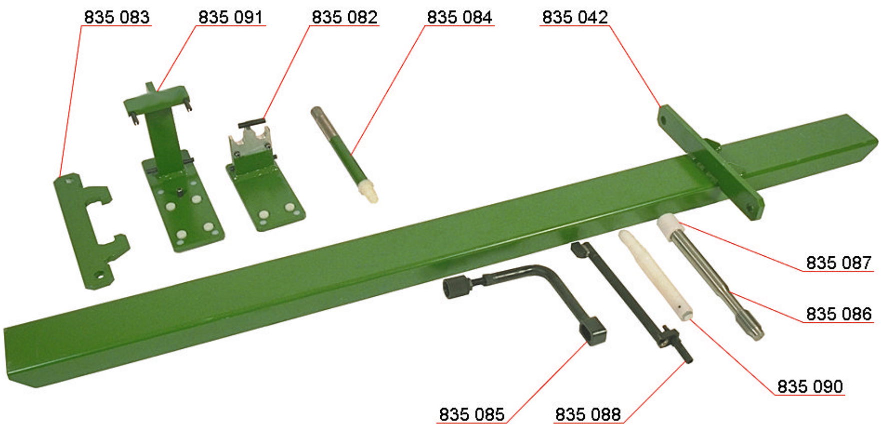


Fig 05-6 V1

Code	Description	Drawing No.
835042	Assembly rail	1V83F0215
835082	Sledge	2V83F0212
835083	Support	2V83F0214
835084	Support arm	3V83F0163
835085	Support arm	3V83F0217
835086	Mounting screw M30	3V83F0180
835087	Protecting cap for screw M30	4V83B0269

Code	Description	Drawing No.
835088	Limiter for piston	3V83F0178
835090	Fastening arm	3V83F0211
835091	Sledge	1V83F0213

Connection Rod, Marine Head, V-eng. 110

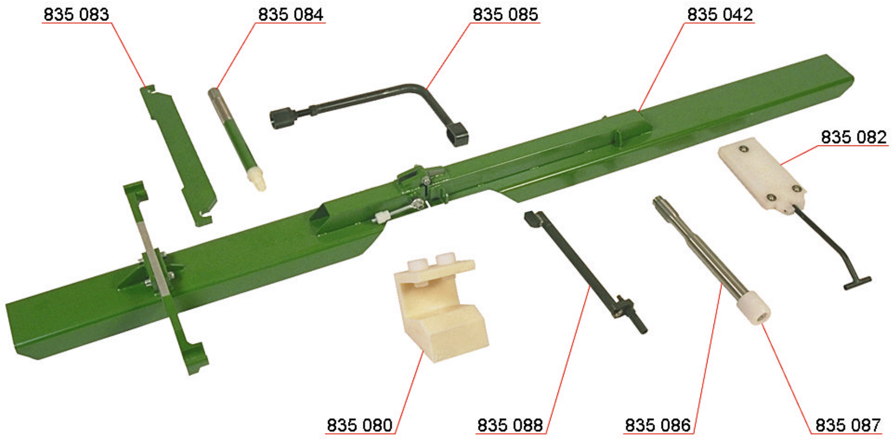


Fig 05-7

V1

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

(1) Not for 32 DF and 34 SG

Piston 110

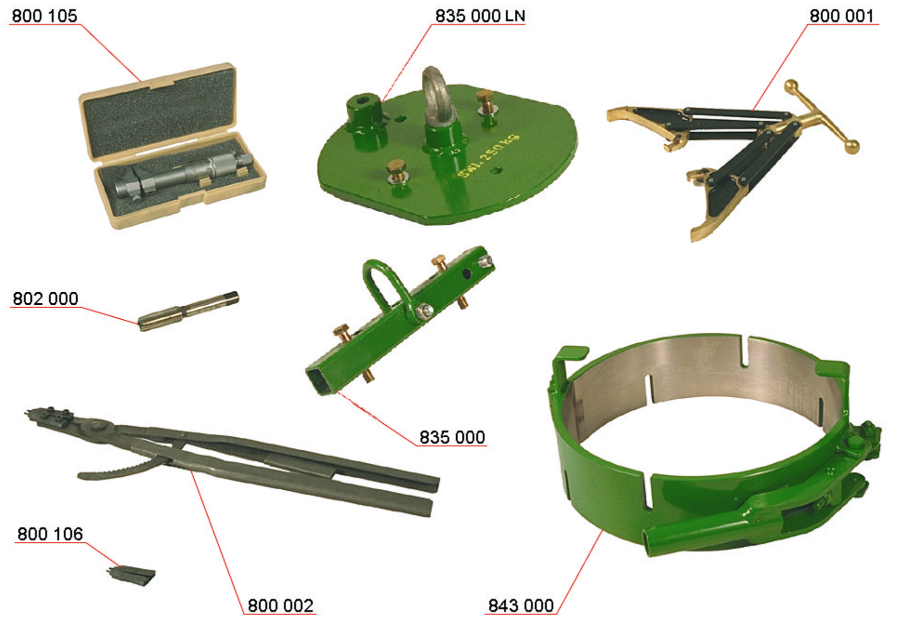


Fig 05-8 V1

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

(1) for 32 and 32 GD

(2) for 32 LN and 32 LNGD

Piston, 32DF and 34SG 110

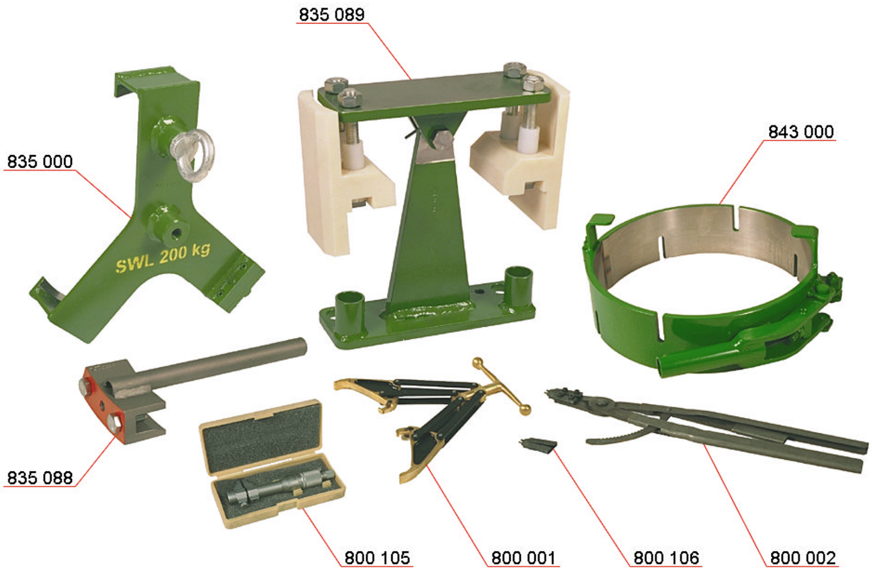


Fig 05-9 V1

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

(1) Only for 34 SG

(2) Only for 32 DF

Cylinder Head 120

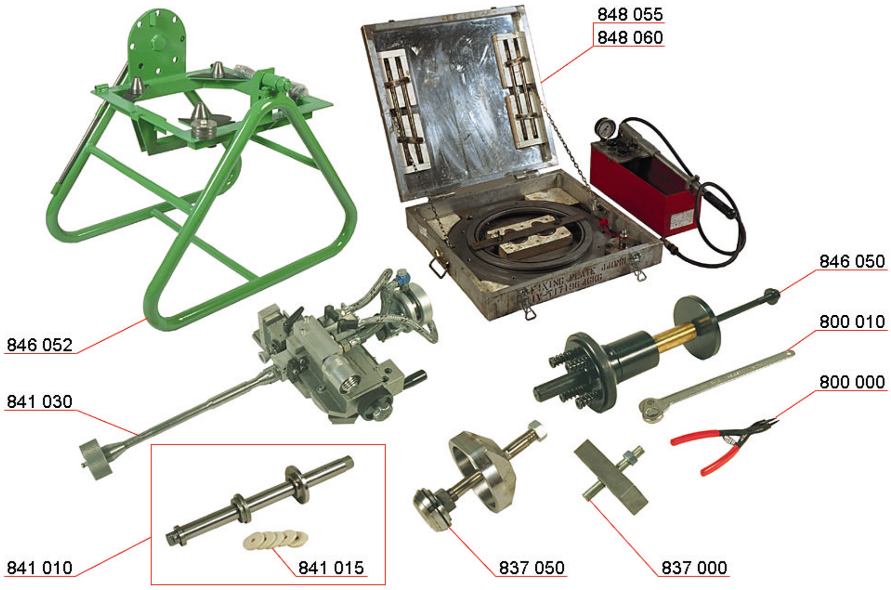


Fig 05-10

V1

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

(1) Not for 32 DF and 34 SG

Cylinder Head 120

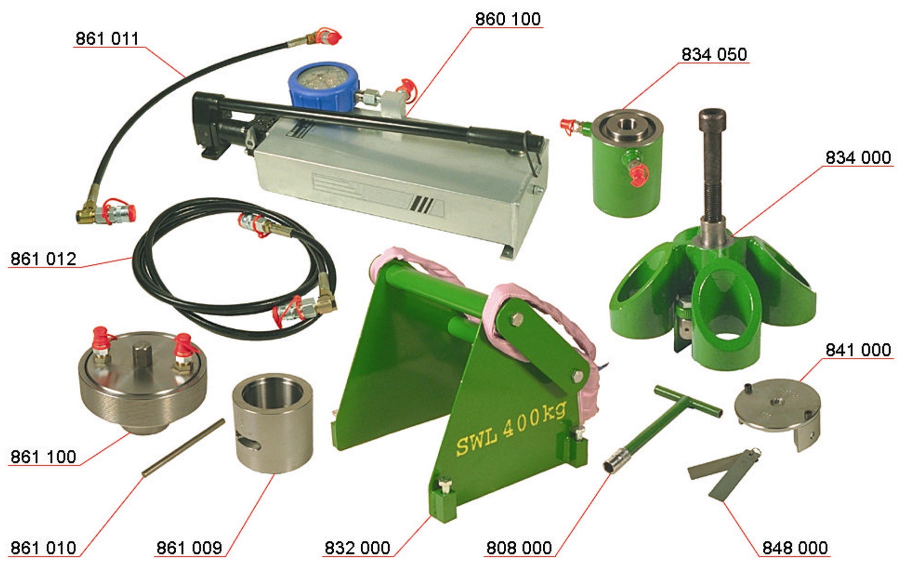


Fig 05-11 V1

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

(1) Not for 32 DF and 34 SG

(2) Including quick couplings

Tools for Pre Chamber, V-engine 120

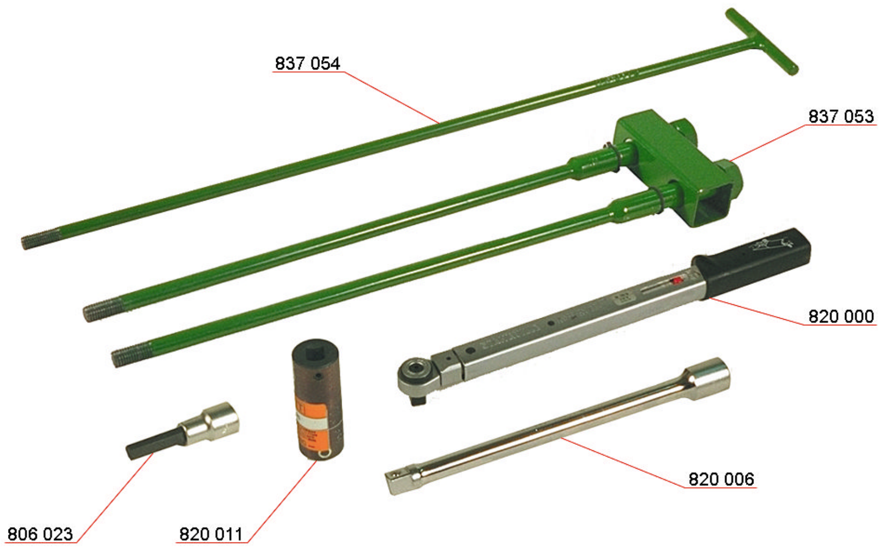


Fig 05-12 V1

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

Tools for Intermediate Gear 130

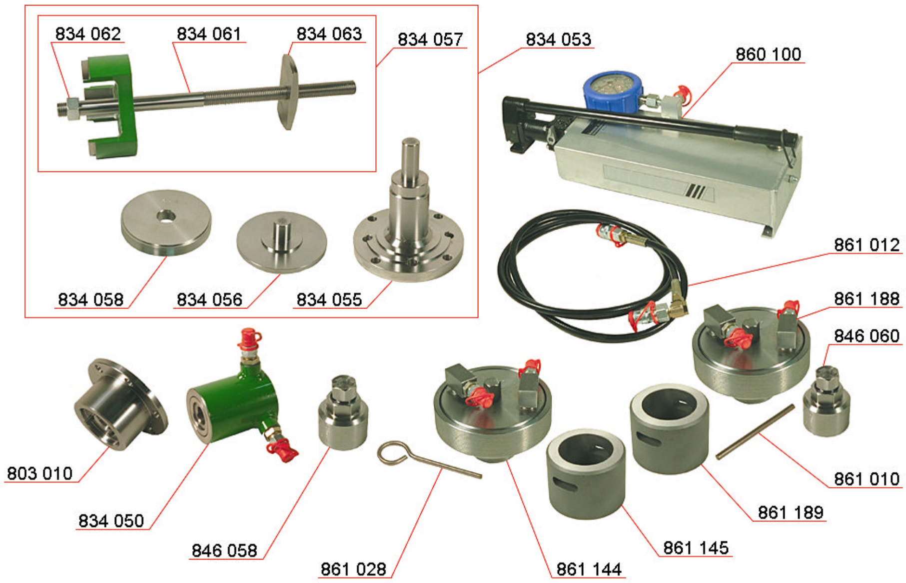


Fig 05-13 V1

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

Code	Description	Drawing No.
861189	Distance sleeve M48	3V86B0125

(1) Including quick couplings

Tools for Planetary Gear, R-engine 130

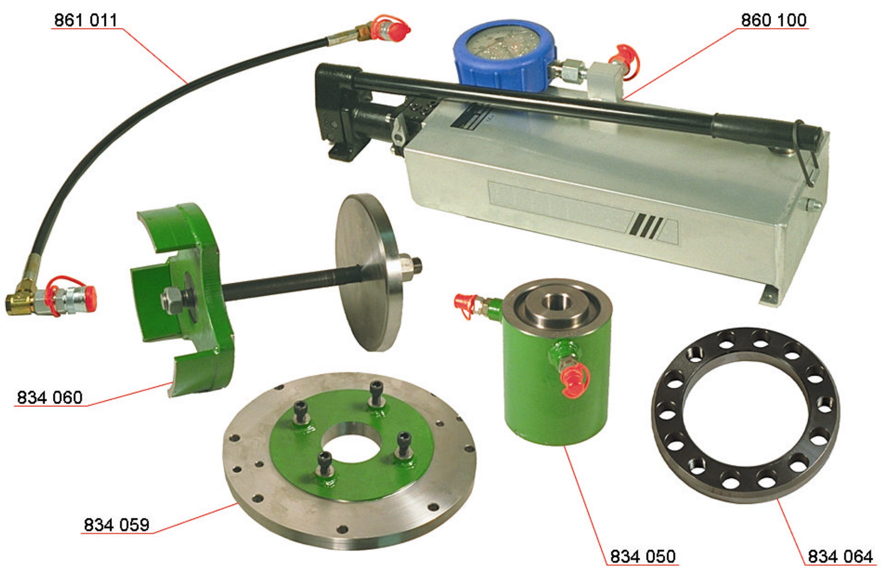


Fig 05-14 V1

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

(1) Including quick couplings

Injection Equipment 160

Fig 05-15 V1

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

(1) Only for 32 LN and 32 LNGD

Tools for Multi-Needle injection Valve 160

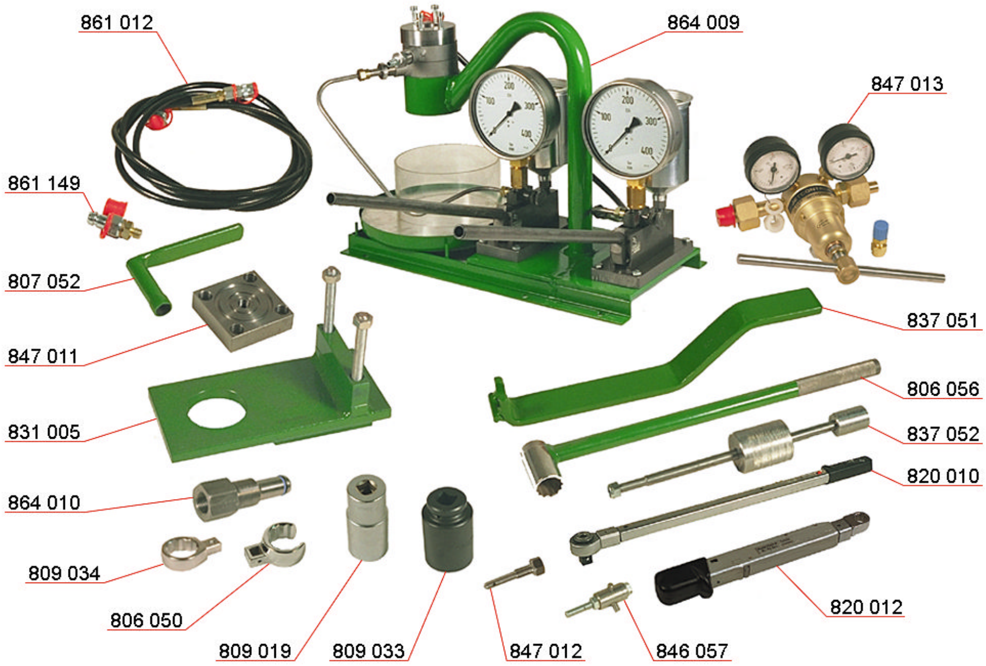


Fig 05-16

V1

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

Code	Description	Drawing No.
864010	Adapter for nitrogen gas fuel connection	4V86E0110

(1) Including quick couplings

Turbocharger 372

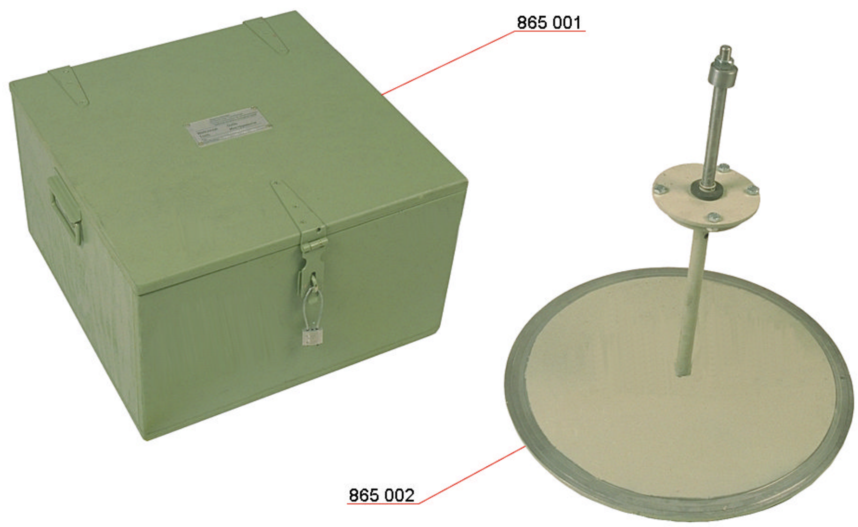


Fig 05-17 V1

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

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

Miscellaneous Tools 900

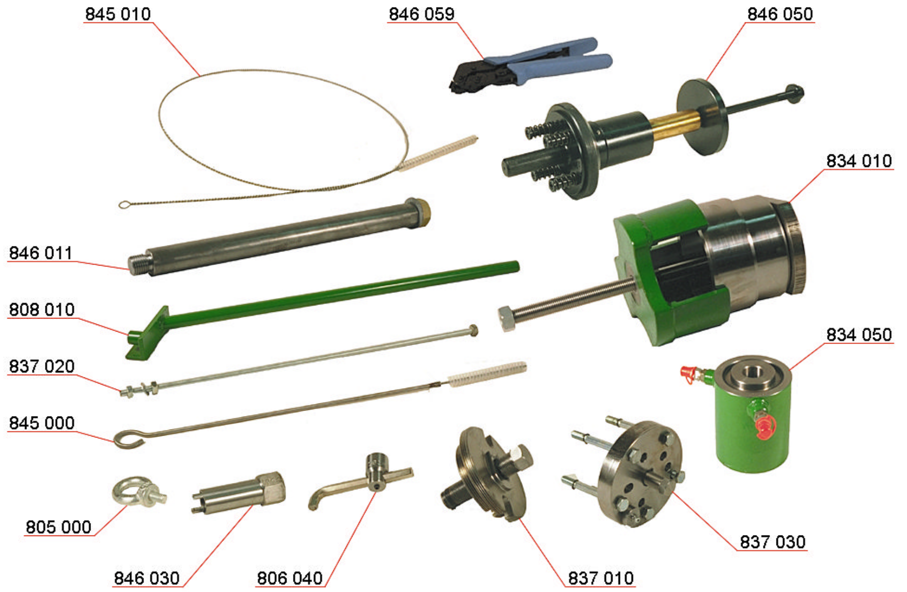


Fig 05-18 V1

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

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

Miscellaneous Tools 900

Fig 05-19 V1

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

(1) Only for 32 and 32 LN

(2) Only for 9R32

(3) Only for 4, 6 ,8R and V-engines

Miscellaneous Tools for 32 DF and 34 SG 900

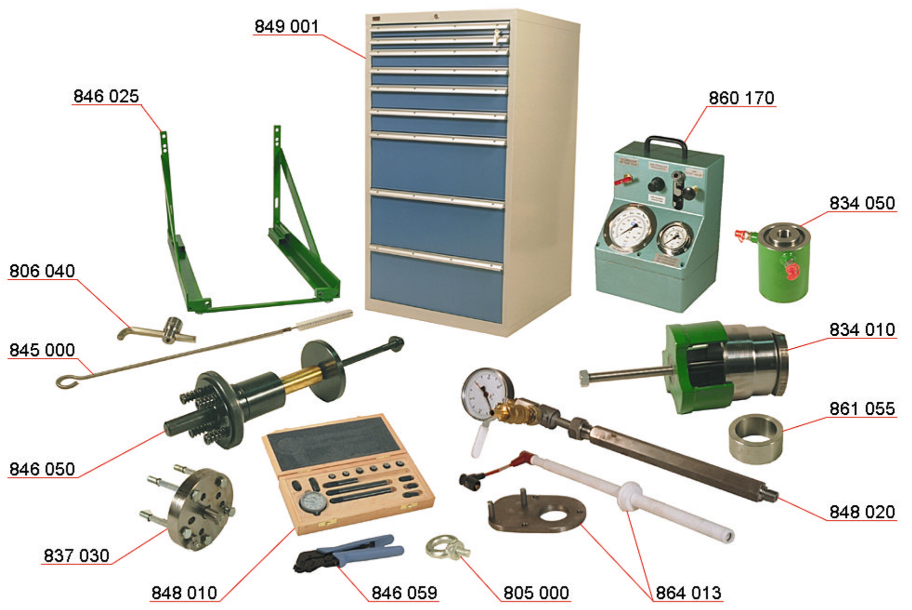


Fig 05-20 V1

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

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

(2) Only for 34 SG

Additional Tools for V-eng. and 4R32 900

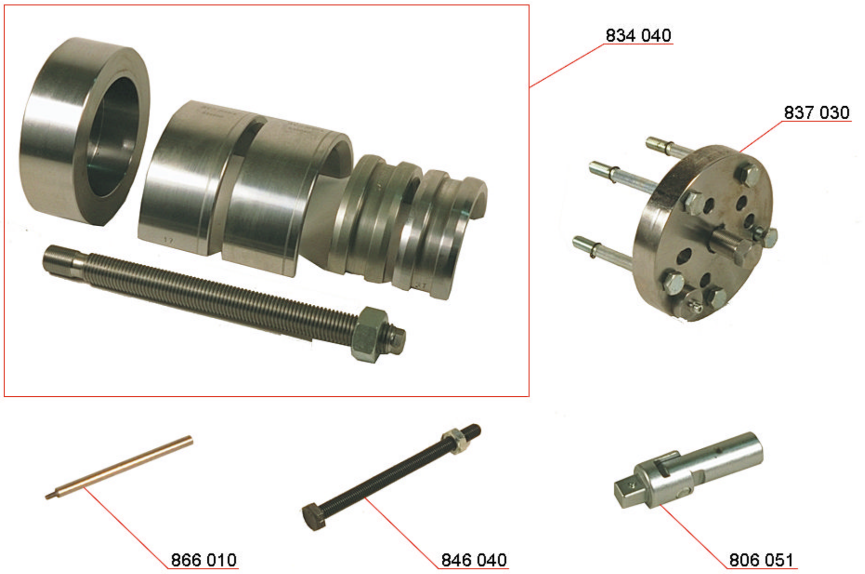


Fig 05-21 V1

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

(1) Only for 4R32

High Pressure Pump 900

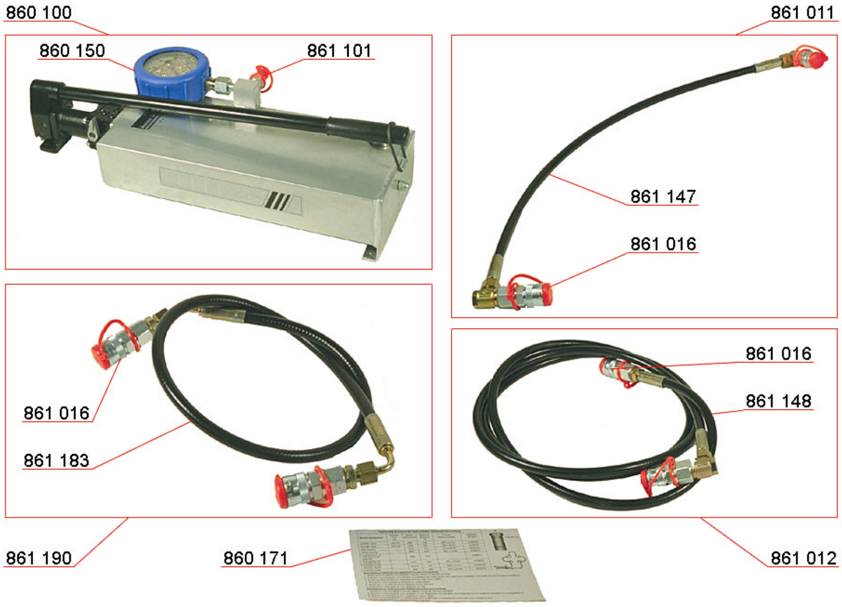


Fig 05-22

V1

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

(1) Including quick couplings

Low Pressure Pump 900

Fig 05-23 V1

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

(1) Including quick couplings

Tightening Tools 900

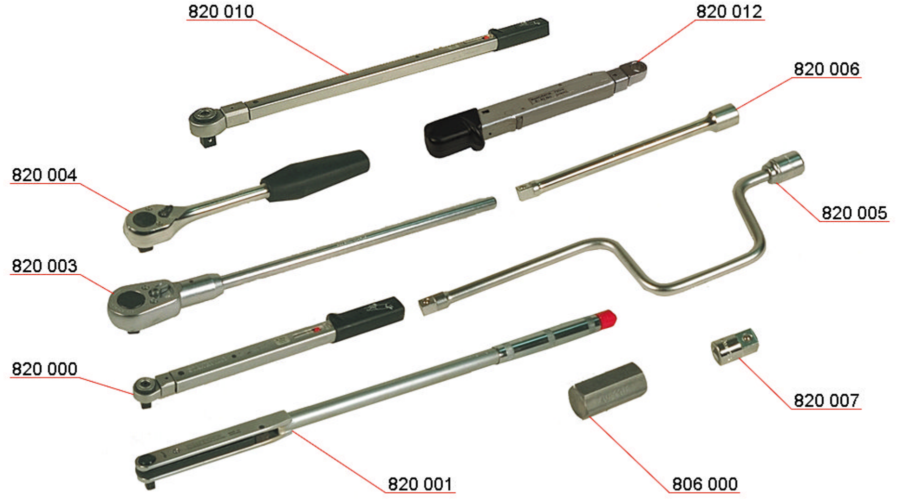


Fig 05-24 V1

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

(1) Only for 32 GD and 32 LNGD

Hand Tools 900

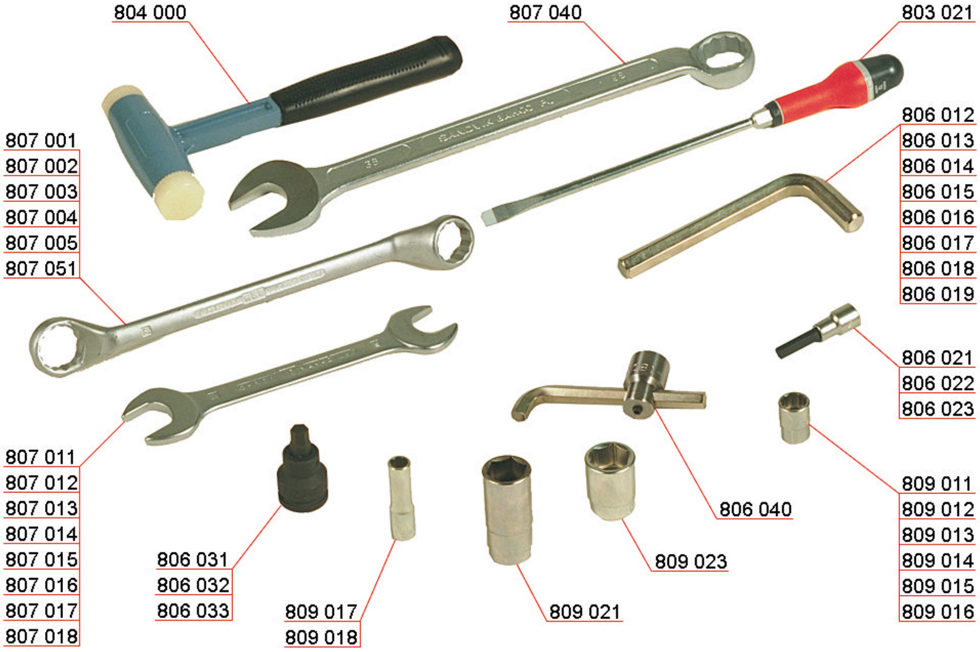


Fig 05-25 V1

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

Code	Description	Drawing No.
809018	Long socket wrench 24 x 12.5L with 1/2" square drive	
809021	Long socket wrench 30 x 20L with 3/4" square drive	
809023	Socket wrench with 30 x 20 3/4" square drive	

Hand Tools 900

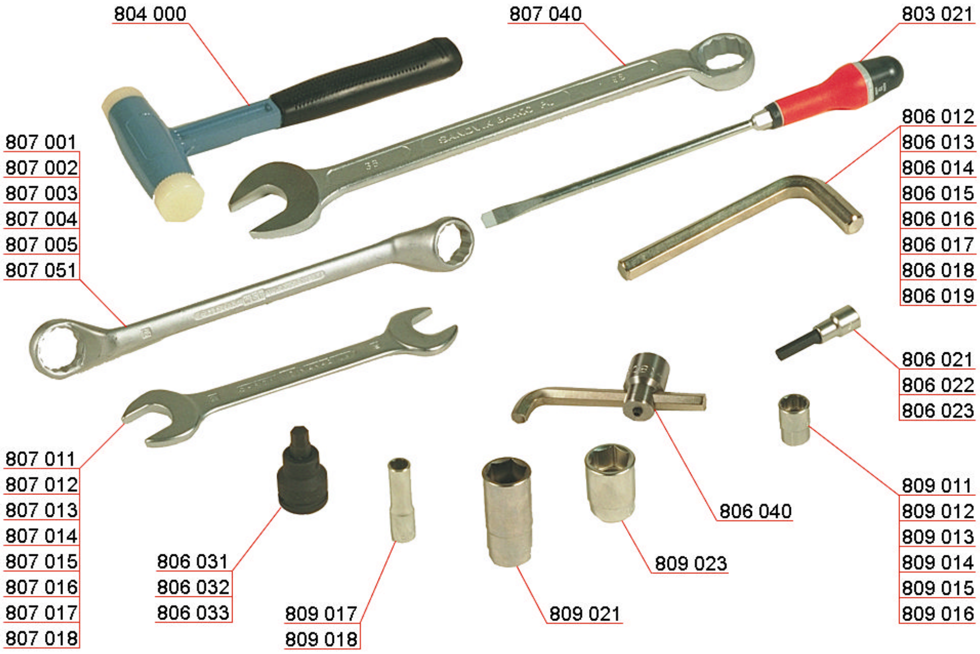


Fig 05-26

V1

Code	Description	Drawing No.
807001	Box wrench 10-11	
807002	Box wrench 12-14	
807003	Box wrench 13-17	
807004	Box wrench 19-22	
807005	Box wrench 30-32	
807011	Engineers wrench 10-11	
807012	Engineers wrench 12-14	
807013	Engineers wrench 13-17	
807014	Engineers wrench 19-22	
807015	Engineers wrench 24-27	
807016	Engineers wrench 30-32	
807017	Engineers wrench 36-41	

Code	Description	Drawing No.
807018	Engineers wrench 46-50	
807040	Combination wrench AL 36	
807051	Box wrench 24-27	
809011	Socket wrench 10 x 12.5 with 1/2" square drive	
809012	Socket wrench 13 x 12.5 with 1/2" square drive	
809013	Socket wrench 17 x 12.5 with 1/2" square drive	
809014	Socket wrench 19 x 12.5 with 1/2" square drive	
809015	Socket wrench 24 x 12.5 with 1/2" square drive	
809016	Socket wrench 27 x 12.5 with 1/2" square drive	

06. Adjustments, Clearances and Wear Limits

V1

06.1. Adjustments

06.1.1. Valve timing

V2

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

Schematic valve timing

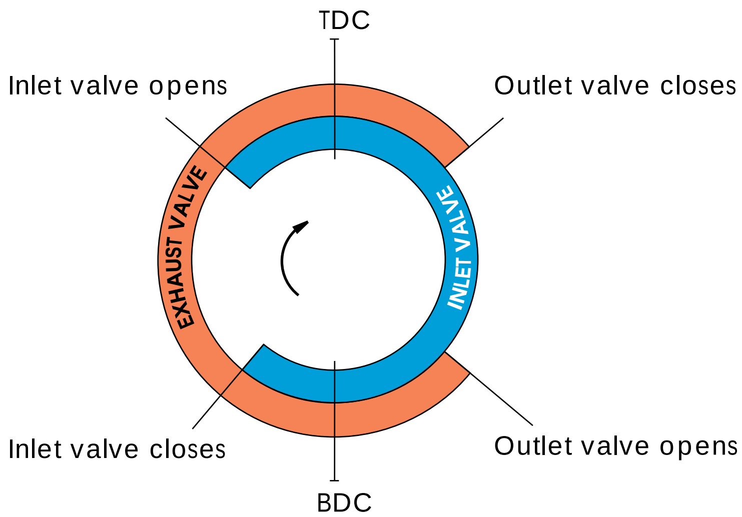


Fig 06-1

V1

Valve clearances, cold engine: .... inlet valves 0.7 mm

.... exhaust valves 1.2 mm

06.1.2. Opening pressures for fuel injection valves

V1

Engines	Opening pressure	Notes
32 LN	500 bar	
32 LN	350 bar	Service LN

32 LNGD (diesel)	320 bar	
32 LNGD (gas)	330 bar	Air pressure 5 bar on gas side

32 DF	350 bar	Main diesel
	900 bar	Pilot diesel supply pressure

- Fuel injection timing: See engine test run records.

06.1.3. Set values for overspeed trip devices

V2

Table 06-4 Power Plant and Marine Main engines

LN and GD engines		
Nominal speed	Electro-pneumatic tripping speed	Mechanical tripping speed
720 RPM	830 ± 10 RPM	850 ± 10 RPM
750 RPM	860 ± 10 RPM	885 ± 10 RPM

Table 06-5 Power Plant and Marine Main engines

DF engines		
Nominal speed	WECS tripping speed	Redundant device tripping speed
720 RPM	828 ± 10 RPM	850 ± 10 RPM
750 RPM	862 ± 10 RPM	885 ± 10 RPM

Table 06-6 Marine Auxiliary engines

Nominal speed	Electro-pneumatic tripping speed	Mechanical tripping speed
720 RPM	815 ± 10 RPM	830 ± 10 RPM
750 RPM	850 ± 10 RPM	860 ± 10 RPM

06.2. Clearances and wear limits (at 20°C)

V1

Part, measuring point		Drawing dimension (mm)		Normal clearance (mm)	Wear limit (mm)
		Max.	Min.		
03	Turning device driving gear backlash drive gear/ flywheel gear rim	1.20	0.30		
10	Main bearing clearance (also flywheel bearing)			0.270-0.374	
	Journal, diameter	300.000	299.968		299.8
	Journal, out of circularity	0.015			0.05
	Journal, taper	0.015/100			0.025/100
	Main bearing shell thickness				10.1.2
	Trimetal shells	7.390	7.370		7.32 mm
	Bimetal shells	7.390	7.370		
	Bore of main bearing housing	315.032	315.000		
	Assembled bearing bore	300.342	300.270		
	Thrust bearing, axial clearance			0.20-0.46	0.7
	Thrust washer thickness	14.850	14.800		14.60
	Camshaft bearing clearance			0.130-0.210	0.36
b.	Camshaft diameter	165.000	164.975		
	Camshaft bearing bush, thickness	7.435	7.420		
	Camshaft bearing housing, bore	180.025	180.00		
	Assembled bearing bore	165.200	165.145		165.25
	Camshaft thrust bearing housing, bore	85.035	85.000		
	Assembled bearing bore	75.125	75.060		75.25
	Camshaft thrust bearing clearance			0.060-0.144	
	Camshaft thrust bearing, axial clearance			0.250-0.700	1.0
	Cylinder liner, diameter	320.107	320.050		top: 320.80 bottom: 320.30
	Cylinder liner, out of cylindricity at TDC	0.03			0.25
	Anti-polishing ring, wall thickness	7.25	7.20		
11	Big end bearing clearance			0.210-0.304	
	Crank pin, diameter	270.000	269.968		269.920
	Crank pin, out of circularity	0.015			0.05
	Crank pin, taper	0.015/100			0.025/100
	Big end bearing shell thickness				11.3.3
	Bimetal shells (Al- based)	5.915	5.900		5.84 mm
	Big end bore	282.032	282.00		281.90
	ovality				0.10
	Assembled bearing bore	270.272	270.210		

	Part, measuring point	Drawing dimension (mm) Max.	Min.	Normal clearance (mm)	Wear limit (mm)
	Gudgeon pin bearing clearance			0.090-0.169	
	Gudgeon pin diameter	150.000	149.986		
	Small end bore	169.955	169.930		
	Assembled bearing bore	150.155	150.090		150.180
	Connecting rod axial clearance in piston			0.5-1.0	
	Small end bearing bush, thickness	9.930	9.910		
	Bore diameter in piston St/Sg	150.070	150.050		150.100
	Clearance gudgeon pin - piston St/Sg			0.05-0.084	
	Compression ring end gaps				
	(C84, C101)			0.70-1.10	
	(C67)			1.25-1.60	
	Oil scraper ring gaps (C79)			1.20-1.50	
	Piston ring height clearance:				
	Compression ring I			0.193-0.245	0.5
	Compression ring II			0.150-0.202	0.5
	Oil scraper ring			0.063-0.115	0.3
	Piston ring groove height: Groove I	8.210	8.180		8.50
	Groove II	6.120	6.090		6.45
	Groove III	8.080	8.050		8.30
	Balancing shaft mechanism for 4R32 , see Fig 06-2 Balancing shaft bearing				
	bearing clearance			0.080-0.157	
	Bearing diameter in situ	100.135	100.080		100.180
	Bearing journal diameter	100.000	99.978		
	Thrust bearing				
	bearing clearance			0.060-0.144	
	axial clearance (gears I-V)			0.37- 0.69	1.00
	Bearing diameter in situ	75.125	75.060		75.170
	Bearing journal diameter	75.000	74.981		
	Balancing shaft backlash:				
	Crankshaft gear wheel (C)/Balance intermediate gear wheel (I)			0.20-0.50	
	Balance intermediate gear wheel (I)/Balance intermediate gear wheel (II)			0.26-0.40	
	Balance interm. gear wheel (II and III)/ Bal. shaft gear wheel (V and IV)			0.26-0.40	

Part, measuring point		Drawing dimension (mm)		Normal clear-ance (mm)	Wear limit (mm)
		Max.	Min.		
12	Valve guide diameter assembled	24.135	24.100		24.25
	Valve stem diameter	24.000	23.979		23.95
	Valve stem clearance			0.100-0.156	0.30
	Valve seat deviation relative guide (max. value)	0.10			
	Inlet valve seat bore in cylinder head	112.022	112.000		
	Exhaust valve seat bore in cylinder head				
	outer bore	122.025	122.000		
	inner bore	110.022	110.000		
13	**Intermediate gear of camshaft drive**				section 10.1.2a
	bearing clearance (34)			0.102-0.179	0.70
	axial clearance			0.33-0.52	
	Bearing diameter in situ	120.157	120.102		
	Bearing journal diameter	120.000	119.978		
	Camshaft driving gear backlash:				
	Crankshaft gear wheel (1)/intermediate gear wheel (3)			0.148-0.716	
	Intermediate gear wheel/large inter-mediate gear wheel (10)			0.178-0.582	
	Small intermediate gear wheel (11)/ camshaft gear wheel (12)			0.178-0.582	
14	Valve tappet, diameter	79.940	79.910		
	Guide diameter	80.046	80.00		
	Diameter clearance			0.060-0.136	
	Tappet roller bore diameter	38.025	38.00		
	Bush diameter, outer	37.975	37.959		37.90
	Bush diameter, bore	30.028	30.007		30.08
	Tappet pin diameter	29.993	29.980		
	Bearing clearance roller-bush bush-tappet pin			0.025-0.066 0.014-0.048	
	Rocker arm bearing diameter, in situ	70.109	70.032		70.4
	Bearing journal diameter	70.000	69.981		
	Bearing clearance			0.032-0.128	
	Yoke pin diameter	29.935	29.922		
	Yoke bore diameter	30.021	30.000		30.1
	Yoke diameter clearance			0.065-0.099	
16	Nozzle needle lift (std Diesel)	0.85	0.80		0.94
	Nozzle needle lift (Diesel DWI)	0.80	0.75		0.85
	Nozzle needle lift (Water DWI))	0.55	0.50		0.65

Part, measuring point		Drawing dimension (mm)		Normal clearance (mm)	Wear limit (mm)
		Max.	Min.		
	Nozzle needle lift (LNGD Diesel)	0.68	0.62		0.76
	Nozzle needle lift (LNGD Gas)	1.56	1.59		1.75
	Nozzle needle lift (DF Main Diesel)	0.70	0.65		0.76
	Nozzle needle lift (DF Pilot Diesel)	0.19	0.16		0.25
17	Fuel feed pump (engine driven) backlash for driving gear - R32			0.79-0.97	
	- V32			0.57-0.76	
18	Lubricating oil pump diameter of shaft	49.92	49.895		
	Bush hole diameter, mounted	50.039	50.000		
	Bearing clearance			0.085-0.190	0.25
	Axial clearance			0.20-0.30	
	Backlash for driving gear - R32			0.35-0.49	
	- V32			0.37-0.57	
	Base tangent length for driving gear-R32	86.662	86.626		
	- V32	86.064	86.016		
19	Water pump backlash for driving gear - R32			0.54-0.68	
	- V32			0.57-0.68	
	Base tangent length - R32	53.801	53.759		53.60
	- V32	61.228	61.186		
21	Backlash for starting motor drive			0.5-0.8	
22	Driving shaft for governor	20.000	19.979		
	Bearing for driving shaft	20.053	20.020		
	Bearing clearance			0.020-0.074	0.15
	Axial clearance			0.10-0.15	
	Backlash for driving gear			0.10-0.20	0.30
	Control shaft	30.000	29.967		
	Control shaft bearing	30.072	30.020		
	Clearance			0.20-0.105	0.25

Numbering system for 4R32 balancing shaft gear wheels

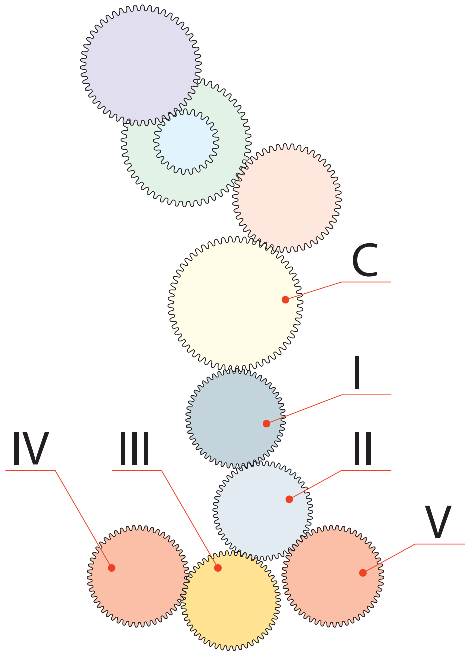


Fig 06-2

V1

07. Tightening Torques and Use of Hydraulic Tools

07.1. Tightening torques for screws and nuts

V1

Note!
See section 07.3.1 for hydraulically tightened connections!

The position numbers in the tables below refer to the corresponding figures A to K, which are located in the engine according to Fig 07-1 Always tighten to stated torque shown in the tables. A loosen screw connection might cause serious damages/human injury. 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.

Note!
Molycote or similar low friction lubricants must not be used for any screws or nuts. Great risk of over tensioning of screws.

1 Nm = 0.102 kpm

Tightening torques

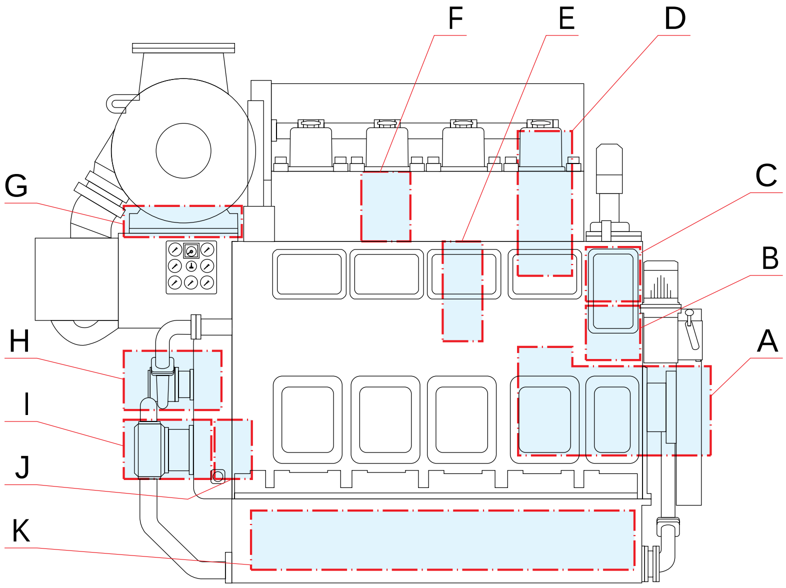
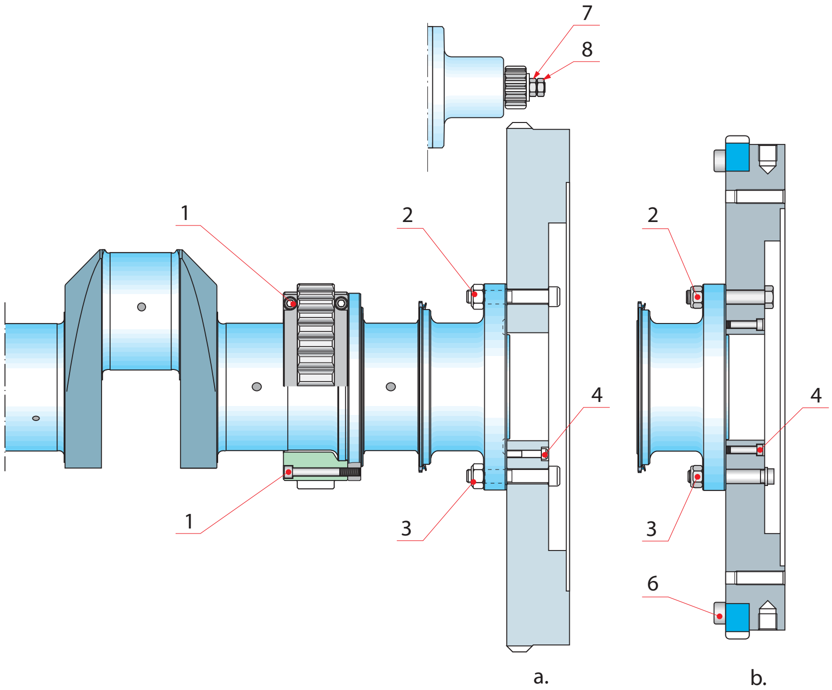


Fig 07-1

V1

07.1.1. A: Crankshaft and flywheel, Starting motor V2

A: Crankshaft and flywheel, Starting motor (4R32)



a. Alternative 1, b. Alternative 2, .

Fig 07-2 V1

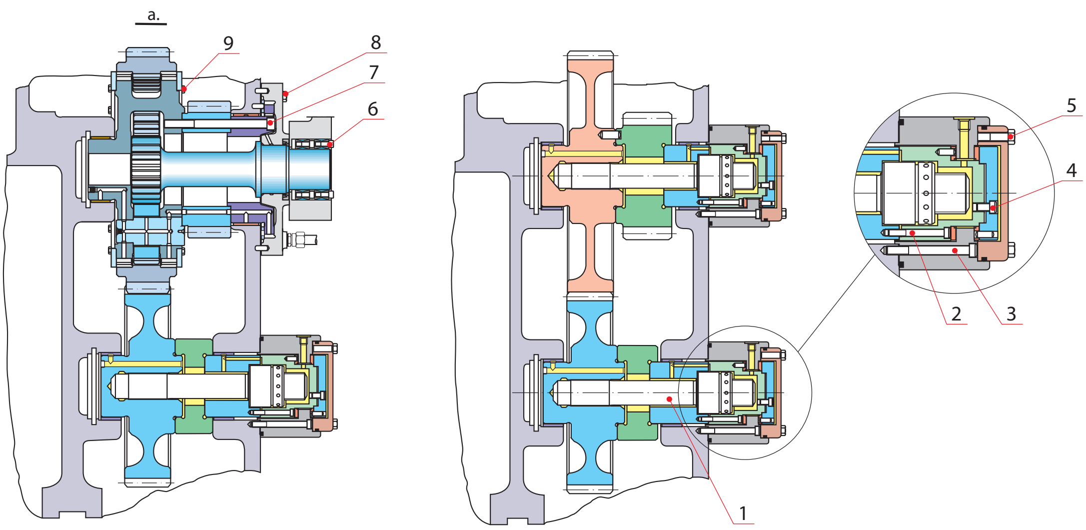
Pos.	Screw connection	Torque (Nm)
1.	Split gear on crankshaft, all M20 screws. **Apply Loctite 262 on threads**, see section 07.2	600±30
2.	Flywheel bolts, M30	1200±60
3.	Flywheel bolts, fitted bolts	650±30
4.	Flywheel bolts, M16	200±15
6.	Gear rim bolts, M12	145±5
7.	Fastening nut for pinion, M16.	100±5
8.	Locking nut, M16	80±5

Note!
If starting motor pinion is fastened with one nut instead of two, tightening torque according to position 7 above.

07.1.2. B: Intermediate gear

V2

Intermediate gear



a. WITH PLANET GEAR.

Fig 07-3

V2

Pos.	Screw connection	Torque (Nm)
1.	Centre screws, M56	200±10
2.	Shaft screws, M8	23±1
3.	Fastening screws, M12	85±5
4.	Shaft plate screws, M10. **Apply Loctite 242 on threads**, see section 07.2	45±5
5.	Cover screws, M10.	45±5
6.	Clamping ring screws. Tighten crosswise in step (25-50-70-70) Nm.	70±5
7.	Fastening screws, M16.	189±10
8.	Cover screws, M12.	85±5
9.	Side screws, M8.	23±1

Note!
See section 07.3.1 for hydraulically tightened connections!

07.1.3. C: Camshaft and control mechanism

V2

Camshaft

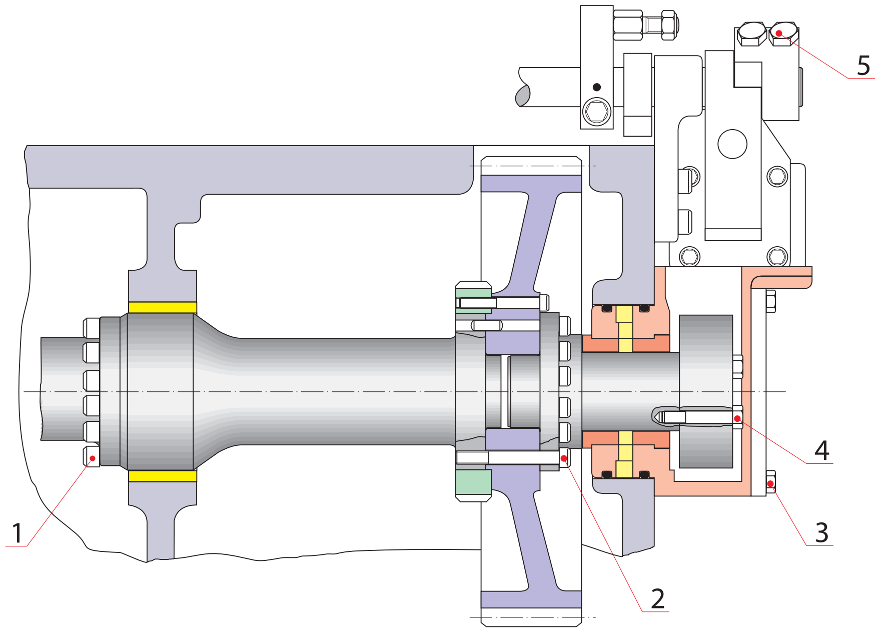


Fig 07-4

V1

Pos.	Screw connection	Torque (Nm)
1.	Camshaft flange connection screws. Torque wrench setting with tool 4V80G17 (806040). The screws are treated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	160±5 **135**
2.	Camshaft gear, flange connection screws. **Apply Loctite 242 on threads,** see section 07.2	130±5
3.	Overspeed trip housing fastening screws	85±5
4.	Overspeed trip device, fastening screws to camshaft. **Apply Loctite 242 on threads,** see section 07.2	45±5
5.	Overspeed trip lever	85±5
6.	Locking screw, M8. **Apply Loctite 242 on threads,** see section 07.2	15±1

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

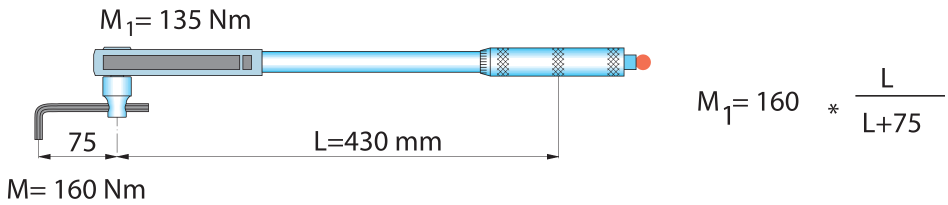


Fig 07-5 V1

Governor drive

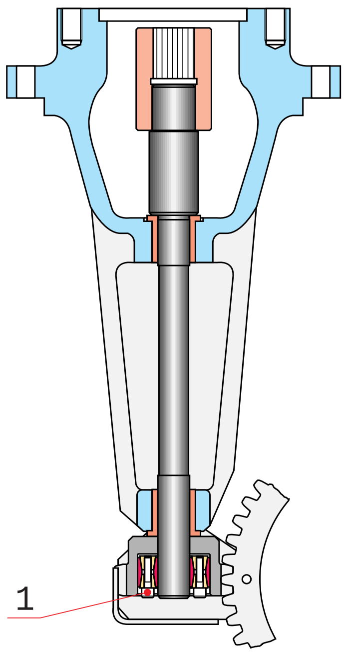


Fig 07-6 V1

Pos.	Screw connection	Torque (Nm)
1.	Screws for clamping ring connection	16±1

07.1.4. D: Cylinder head and flow fuse (DWI)

V2

Cylinder head

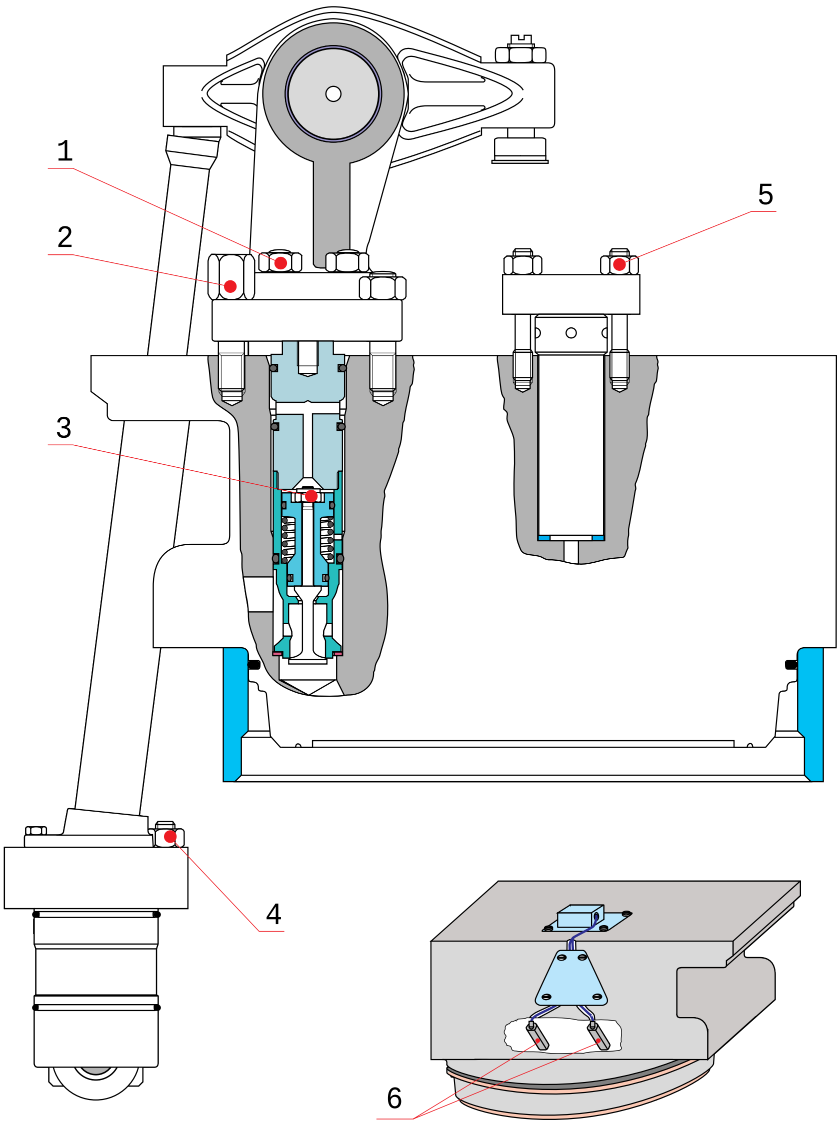


Fig 07-7

V1

Pos.	Screw connection	Torque (Nm)
1.	Rocker arm console, fastening nuts. When re-assembling stud bolts apply Loctite 270 on threads, see section 07.2	250±10
2.	Starting valve fastening nuts	180±10
3.	Nut for starting valve spindle	35±2

Pos.	Screw connection	Torque (Nm)
4.	Nuts for valve tappet guide block **Note! The studs must be locked with Loctite 243.**	200±10
5.	Safety valve in cylinder cover, fastening nuts	50±3
6.	Sensor pockets for exhaust gas temperature (Wencom). **Note! Pockets mounted in the cylinder head.**	10±1

D: Flow fuse (DWI)

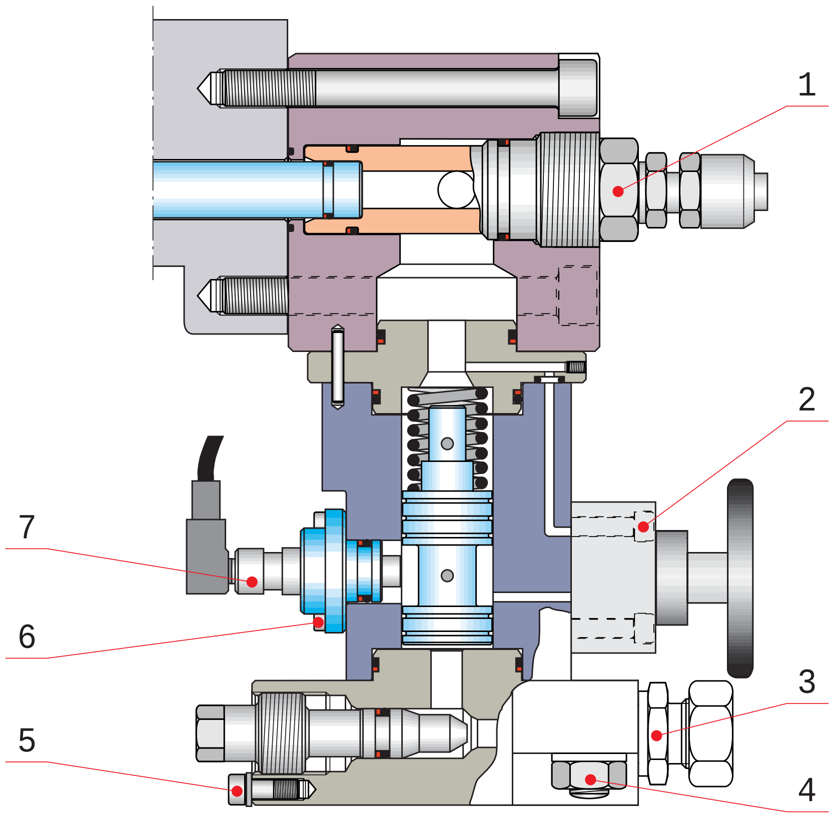


Fig 07-8

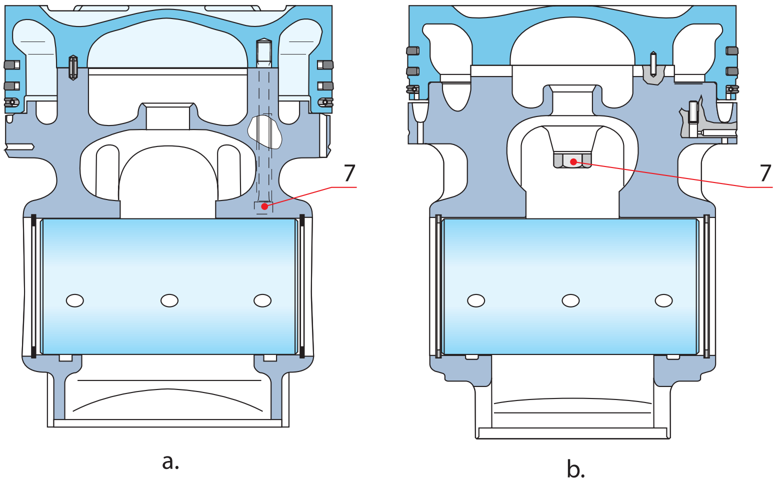
V1

Pos.	Screw connection	Torque (Nm)
1.	Plug for connection piece/deaeration	70±5
2.	Screw for by-pass valve	7±1
3.	Pipe union for water inlet connection	75±5
4.	Fastening nuts	80±5
5.	Limiter screw for shut-off stem	5±1
6.	Fastening screws for proximity switch housing	7±1
7.	Proximity switch	20±1

07.1.5. E: Piston

V2

Piston type I & II



a. Piston of type 1, b. Piston of type 2.

Fig 07-9

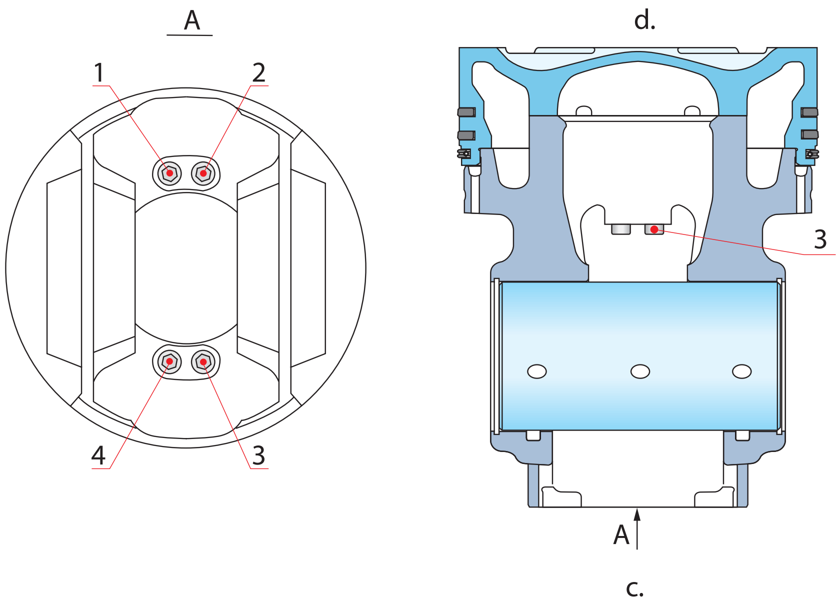
V1

Note!
Pistons of type 1 have four fastening screws for the top, while pistons of type 2 have two fastening screws.

Piston of type 1		
7.	Piston crown connection screws.	
	1. Lubricate threads and contact surfaces with engine oil.	
	2. Tighten the screws crosswise.	
	3. Loosen the screws.	155 Nm
	4. Pre-tighten the screws crosswise.	40 Nm
	5. Tighten the screws further with an angle of	80° ±5°
	6. Test for the right tightness. Screw should not move when tightening by 125 Nm torque.	
	Note! If the free length of the screws exceeds 166 mm the screws must be replaced.	

Piston of type 2		
7.	Piston crown connection screws.	
	1. Lubricate threads and contact surfaces with engine oil.	
	2. Pre-tighten the screws crosswise.	
	3. Loosen the screws.	250 Nm
	4. Pre-tighten the screws crosswise.	80 Nm
	5. Tighten the screws further with an angle of	90° (0°/-10°)
	6. Test for the right tightness. Screws should not move when tightening by 250 Nm torque.	
	Note! If the free length of the screws exceeds 128.5 mm the screws must be replaced.	

Piston type III



c. Piston of type 3, ***d.*** *Piston with 4 screws.*

Fig 07-10 V1

Piston type 3		
Pos.	**Screw connection**	**Torque (Nm)**
3.	Piston crown connection screws. 1. Lubricate threads and contact surfaces with engine oil. 2. Tighten all screws. 3. Tighten all screws further with an angle of 4. Loosen screws 1 and 3. 5. Tighten screws 1 and 3. 6. Tighten screws 1 and 3 further with an angle of 7. Loosen screws 2 and 4. 8. Tighten screws 2 and 4. 9. Tighten screws 2 and 4 further with an angle of 10. Test for the right tightness. Screw should not move when tightening by 165Nm torque. **Note!** When changing piston crown renew all screws	30±1 Nm 96° (+5°/-0°) 30±1 Nm 81° (+5°/-0°) 30±1 Nm 81° (+5°/-0°)

07.1.6. F: Injection pump and valve

V2

Injection pump

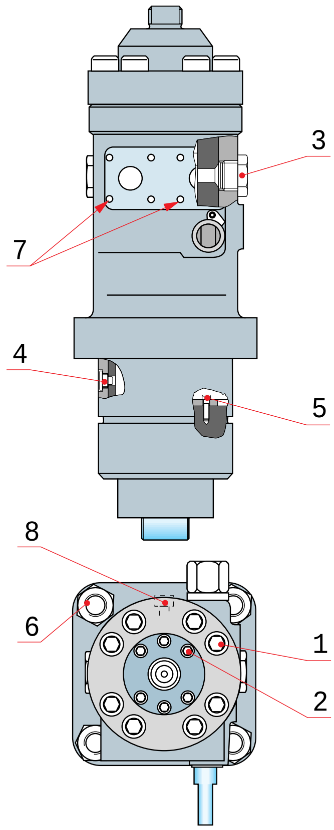


Fig 07-11

V1

Pos.	Screw connection	Torque (Nm)
		L'Orange PEO G052
1.	Screws for pump element flange **Note!** Tighten the screws crosswise in steps	80±5 0..15..40..80
2.	Injection pump, head piece **Note!** Tighten the screws crosswise in steps	100±10 0..20..60..100
3.	Erosion plug **Note! The erosion plug must be secured!**	250±20
4.	Side screw	15±3
5.	Grub screw	12±3

Pos.	Screw connection	Torque (Nm) L'Orange PEO G052
6.	Nuts for injection pump fastening flange **Note! The studs must be locked with Loctite 243.**	250±10
7.	Screws for low pressure fuel pipes	35±2
8.	Air vent screw	22±1

Fuel injection valve

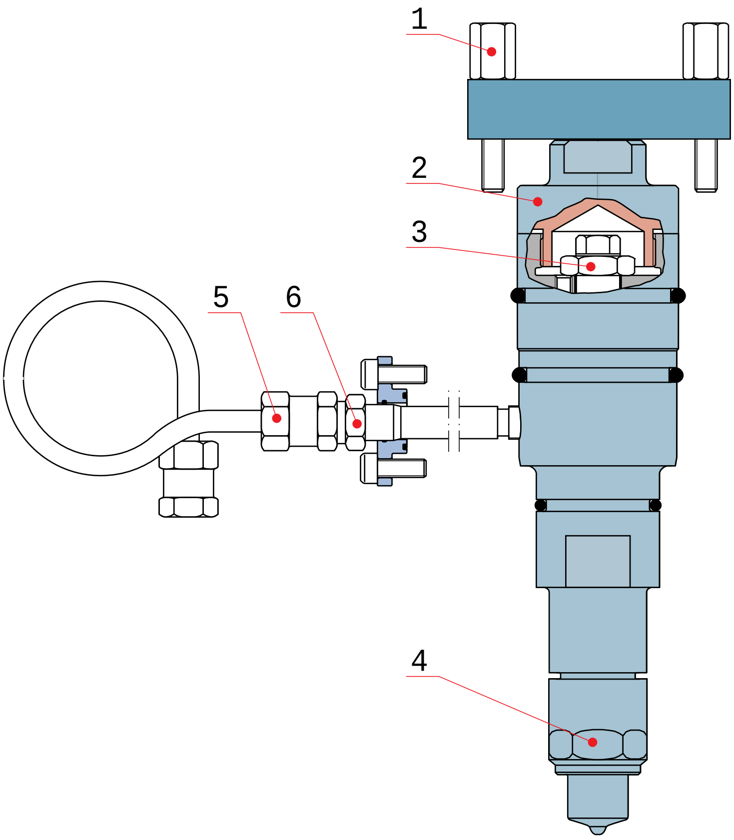


Fig 07-12

V1

Pos.	Screw connection	Torque (Nm) L'Orange
1.	Injection valve fastening nuts	80±5
2.	Injection valve/cap	120±10
3.	Injection valve/counter nut	200±20
4.	Injection nozzle cap nut	320±20
5.	Injection pipe cap nuts	80±5
6.	Connection piece to nozzle holder	95±5

Fuel injection valve and connection pieces (DWI)

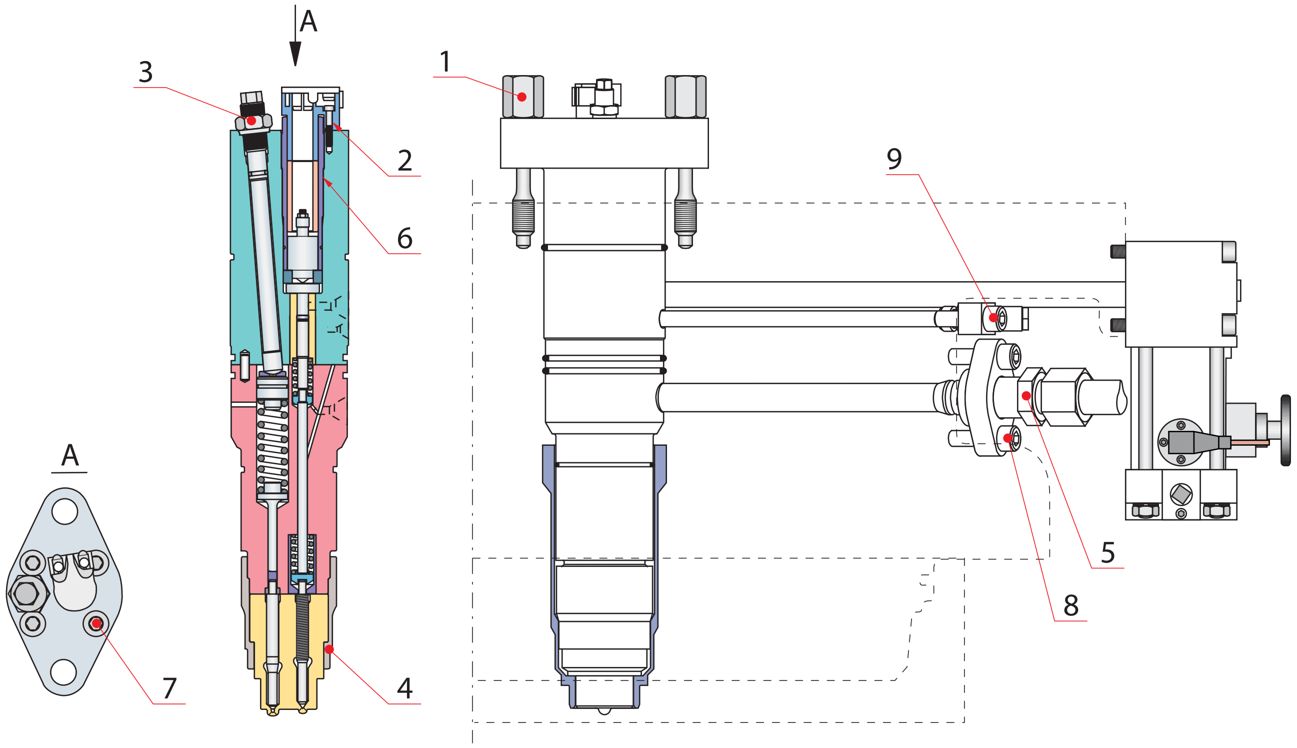


Fig 07-13

V1

Pos.	Screw connection	Torque (Nm)
		Fuel / Water
1.	Injection valve fastening nuts	130±5
2.	Fastening screw for cover	3
3.	Injection valve/counter nut	70±5
4.	Nozzle cap nut	600±20
5.	Injection pipe cap nuts	80±5
6.	Control sleeve	50±5
7.	Fastening screws for top body	70±5
8.	Flange screws	50±5
9.	Fastening screw for drain water connection piece	25±2

07.1.7. G: Turbocharger fastening screws

V1

Turbocharger fastening screws

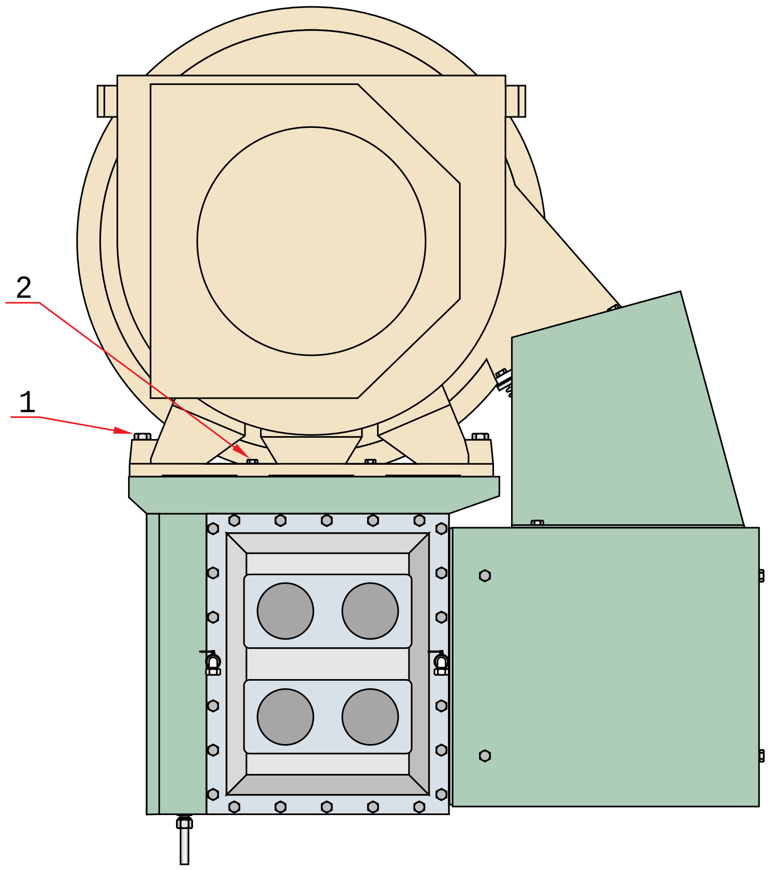


Fig 07-14

V1

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

07.1.8. H & I: Engine driven pumps V1

Engine driven pumps

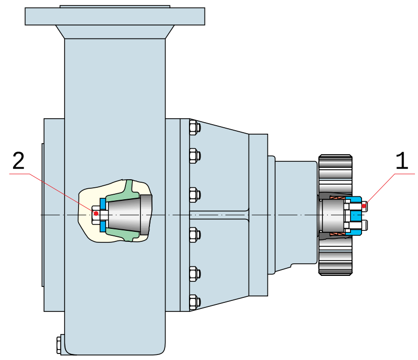


Fig 07-15 V1

Pos.	Screw connection	Torque (Nm)
1.	Driving gear of engine driven pumps: - Water pump in-line engine (*****) - Water pump V-engine (*****) Tighten the screws crosswise (0 - 20 - 40 - 50 Nm) (*****) The screws are treated with locking compound and can be used only once. Replace the screws with new, threated ones.	23±1 50±3
2.	Impeller nut for HT and LT water pump: - In-line engine - V-engine	120±5 150±5

Engine driven pumps, WD-125

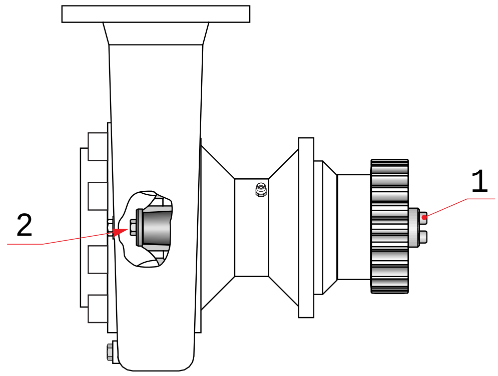


Fig 07-16 V1

Pos.	Screw connection	Torque (Nm)
1.	Driving gear of engine driven pumps: - Water pump V-engine (*) Tighten the screws crosswise (0 - 20 - 40 - 50 Nm) (*) The screws are threated with locking compound and can be used only once. Replace the screws with new, threated ones.	50±3
2.	Impeller screw for HT and LT water pump: -Pump type WD-125: **Apply Loctite 2701 on threads**, see section 07.2.	110±5

Note!
To avoid damaging the threads (Pos. 2), heat up the screws before loosening.

Engine driven pumps

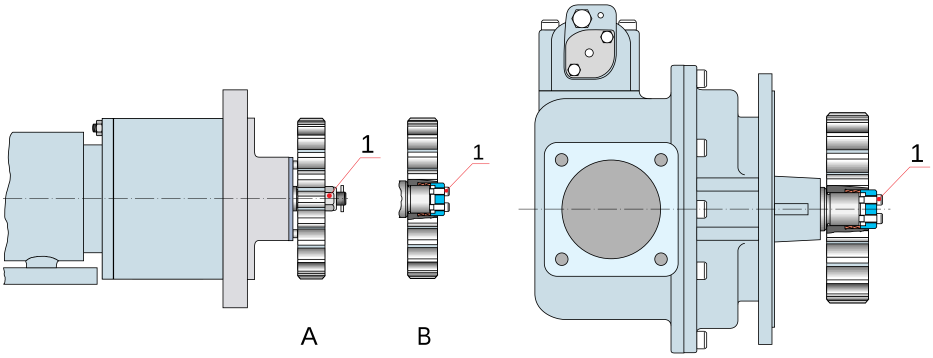


Fig 07-17 V1

Pos.	Screw connection	Torque (Nm)
1.	Driving gear of engine driven pumps: -A) Fuel feed pump -B) Fuel feed pump(*) - Lubricating oil pump (*) Tighten the screws crosswise (0 - 40 - 75 Nm) (*) The screws are threated with locking compound and can be used only once. Replace the screws with new, threated ones.	 180±10 32±2 75±5

07.1.9. J: Free end of crankshaft

V1

Free end of crankshaft

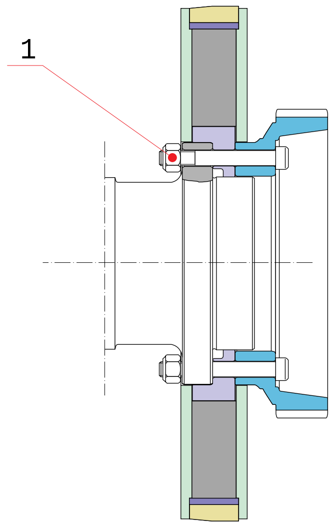


Fig 07-18

V1

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

07.1.10. K: Balancing shafts

V1

Balancing shafts (4R32)

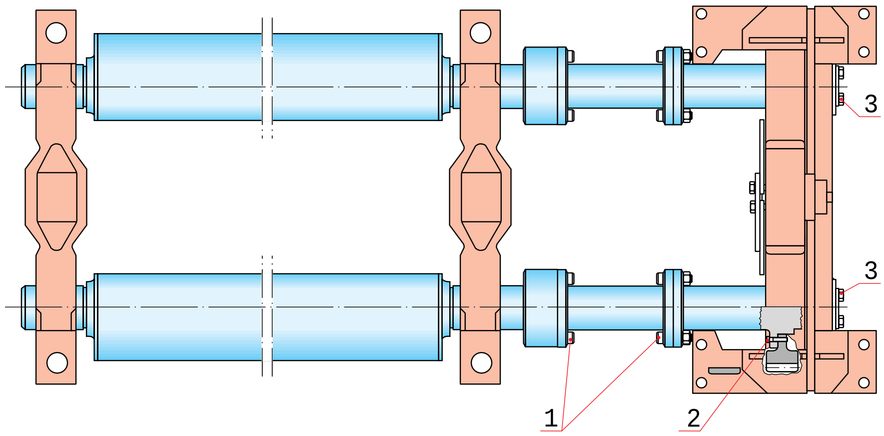


Fig 07-19

V1

Pos.	Screw connection	Torque (Nm)
1.	Balance shafts, flange connection screws	300±10
2.	Drive gear wheel fastening screw. Apply Loctite 242 on threads, see section 07.2	85±5
3.	End flange fastening screws	85±5

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

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

07.2. Use of locking fluid

V1

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

07.3. Hydraulically tightened connections

07.3.1. Tightening pressures for hydraulically tightened connections

V2

Hydraulically tightened connections

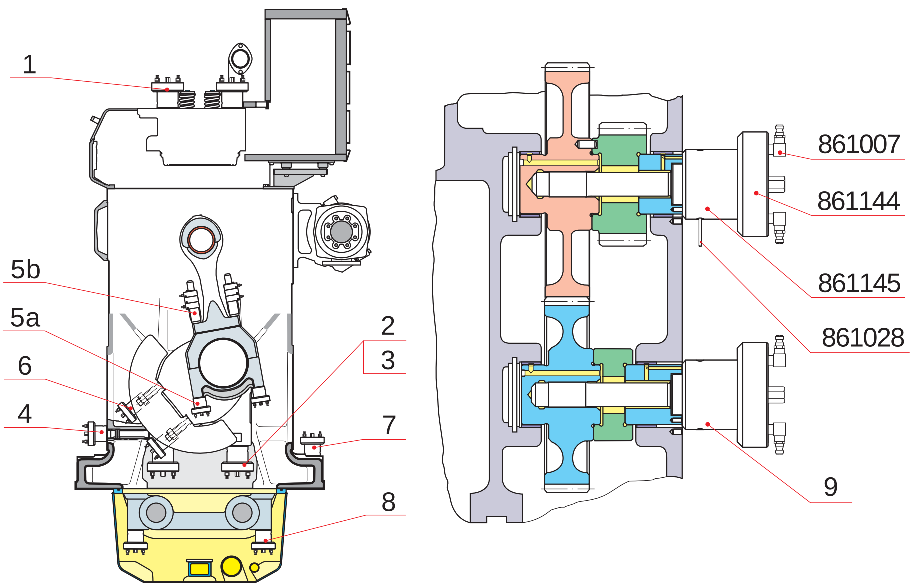


Fig 07-20

V1

Pos.	Screw connection	Max. hydraulic pressure (bar)		Hydraulic cylinder
		tightening	loosening	
1.	Cylinder head screws M56: - outer diameter of cylinder liner 450 mm	500	520	861100
2.	Main bearing screws M56	615	635	861100
3.	Thrust bearing screws M42	615	635	861120
4.	Lateral screws of main bearings and thrust bearing M42	615	635	861120

Pos.	Screw connection	Max. hydraulic pressure (bar)		Hydraulic cylinder
		tightening	loosening	
5.	Connecting rod screws : 5a. M30 tightening in two steps First step Second step 5b. M24 tightening in two steps First step Second step	300 600 400 750	620 770	861156 861163
6.	Counterweight screws M42	600	620	861120
7.	Engine fastening screws M42	x)		861120
8.	Fastening screws M42 for balancing shaft bearing bracket	715	735	861120
9.	Intermediate gears M56	660	680	861144

x) Pos. 7 see installation instructions.

The stud bolts are tightened to the casting at the following torques:

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

Note!
Screws acc. to pos. 4 and 7.

Pos. 4 see chapter 10, section 10.1.3

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

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

07.3.2. Hydraulic Tool Safety Instructions

V1

Since the hydraulic tools operate under high pressure and produce great force, proper safety precautions must be taken to reduce the risk of injury to persons and damage to material during work on the engine and in the workshop,

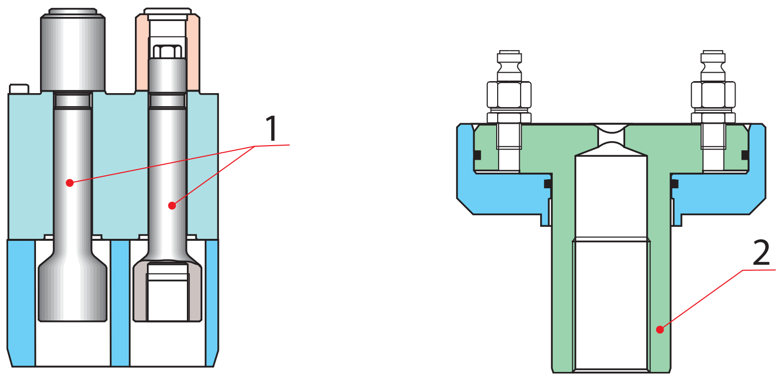
Read also appendix 00A "Risk Reduction".

Hydraulic tool lifetime	
Tool	Load cycles (approx.)
Piston in cylindrical hydraulic tools (see Fig 07-21)	1 000
Screws in "twin cylinder" hydraulic tool (see Fig 07-21)	1 000
Hydraulic hoses and couplings	10 000

If the hydraulically tensioned nuts can not easily be turned when the maximum hydraulic pressure is reached: check for corrosion in threads; check tool condition and manometer error.

If the amount of load cycles is not known, we strongly recommend that the components are changed immediately.

Cylindrical hydraulic tool



1. Screw, 2. Piston.

Fig 07-21

V1

Note!
Familiarity and proper training is required for the safe operation of hydraulic tools.

Warning!
Check the hoses for deep cuts or exposed braiding and replace if necessary.

Warning!
Do not raise the pressure over the value stated in the engine manual. Keep an eye on the pressure gauge at all times.

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

V1

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

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

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

- In the high pressure hydraulic tool set it is recommended to use a special hydraulic oil or in any case an oil with a viscosity of about 2°E at 20°C.
- During the filling of the container of the high pressure pump it is recommendable to couple the set according to scheme B, Fig 07-22. Before filling, open the release valve (2) and empty the cylinders (4) by pressing the piston and cylinder together. After that, drain the oil and re-fill through the filling plug (1).
- After filling, vent the system by pressing in, with a finger, the centre pin of the female part of the last quick-coupling, the coupling being disconnected from the pressure gauge. Keep on pumping until airfree oil emerges from the coupling.
- Check the pressure gauge of the hydraulic tool set regularly. For this purpose a comparison pressure gauge is delivered. This pressure gauge can be connected to the plug hole (7), the outlet hose of the pump being connected direct to the pressure gauges.

07.3.3.1. Instructions for high pressure hydraulic tools V1

Caution!
Pay special attention to cleanliness and carefulness when using and maintaining the hydraulic high pressure tools.

- When the hoses are pressurised, any maintenance, adjustments nor repairing are allowed, not even tightening of the connections.
- Before rising the pressure in the high pressure tool, all hydraulic parts (pump, pipes, hoses, regulating units) has to be vented.
- The weakest parts maximum allowed pressure must not be exceeded.
- Keep a logbook or similar of the hydraulic tools.

07.3.4. Dismantling hydraulically tightened screw connections V1

1 **Attach distance sleeves and hydraulic cylinders** according to Fig 07-22A. Screw on cylinders by hand.

2 **Connect the hoses to the pump and cylinders** according to scheme Fig 07-22B. Open the release valve (2) and screw cylinders in clockwise direction to expel possible oil.

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

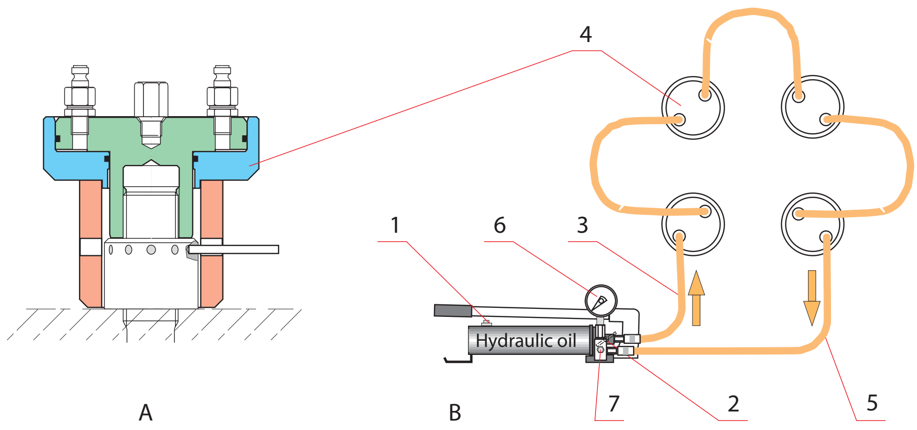
4 **Close the release valve and pump pressure** to the stated value.

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

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

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

Hydraulic cylinder



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

Fig 07-22 V1

07.3.5. Reassembling hydraulically tightened screw connections V1

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

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

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

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

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

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

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

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

07.3.6. Hydraulic tool for connecting rod shank screws

V1

Hydraulic tool, hose connection and tool section

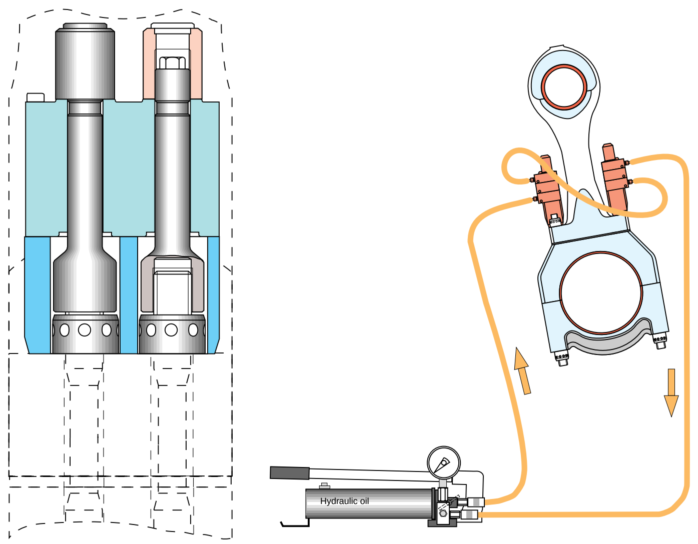


Fig 07-23

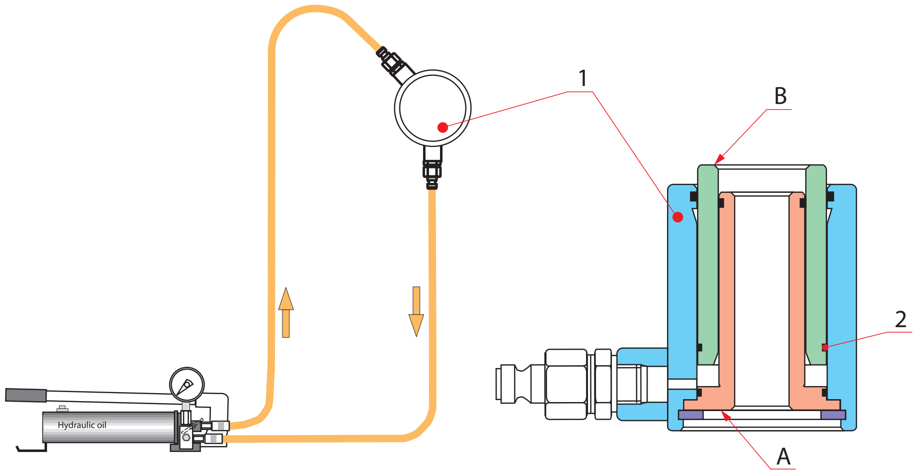
V1

07.4. Use of hydraulic extractor cylinder

V1

For some power demanding operations a hydraulic extractor cylinder is used. In connection with this cylinder, the hydraulic high pressure hand pump is utilized, coupling scheme acc. to Fig 07-24.

Hydraulic extractor cylinder



1. Hydraulic cylinder, 2. Expansion ring.

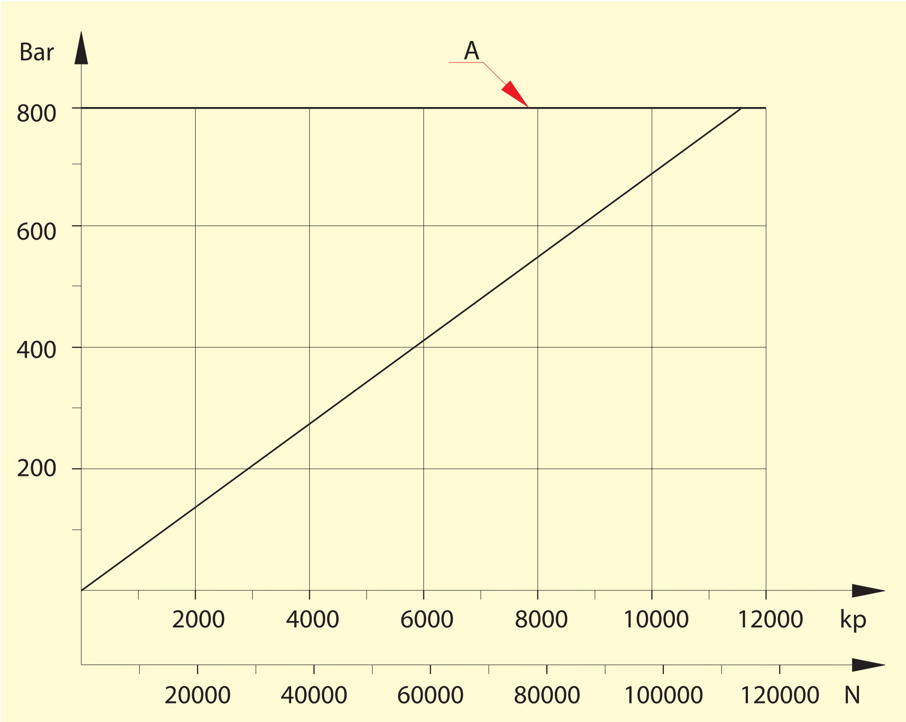
Fig 07-24 V1

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

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

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

Relation between pressure and force



A. *Max. pressure*

Fig 07-25 V1

07.5. Low pressure pump for main bearing cap hydraulic jack in the crankcase V1

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

08. Operating Troubles, Emergency Operation

08.1. Troubleshooting

V4

Preventive measures, see section 03.1 and chapter 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)	Turning device is connected. **NOTE!** Engine cannot be started when turning device is connected. However, before starting, always check that turning device is removed.	11.2, 21
b)	Starting air pressure too low, shut-off valve on starting air inlet pipe closed	21, 21.4
c)	Jamming of starting valve in cylinder head	21.3
d)	Jamming of starting air distributor piston	21.2
e)	Starting air solenoid valve faulty	21.1
f)	Inlet or exhaust valve jamming when open. "Negative" valve clearance (strong blowing noise).	12.
g)	Starting automation outside engine faulty	03.2, 23.1.1.
h)	4R32: Starting motor faulty	21.
2.	**Crankshaft rotates but engine fails to fire**	
a)	Too low speed (1b),	
b)	Automatic shut-down device is not in start position	23.1.1.
c)	Load limit of control shaft or of governor is set at too low a value	Fig 22-1
d)	Overspeed trip device has tripped	22.5, 22.6
e)	Starting fuel limiter wrongly adjusted	22.3.1, 22.7
f)	Some part of fuel control mechanism jamming and prevents fuel admission	22.1.
g)	Fuel and injection system not vented, pipe connections between injection pumps and valves not tightened	17.3
h)	Fuel filter clogged	17.6, 17
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	17.6, 17
k)	Very low air and engine temperatures (preheat circulating water!)in connection with fuel of low ignition quality	02.1
l)	Fuel insufficiently preheated or precirculated	02.1, Fig 02-2

	Trouble Possible reason	See chapter, section
m)	Too low compression pressure (1f)	
3.	**Engine fires irregularly, some cylinders do not fire at all**	
a)	See point 1f, 2f, g, h, k, l, 4d	
b)	Injection pump control rack wrongly adjusted	22.3.1
c)	Injection pump control sleeve does not mesh properly with rack (may cause overspeed if set in direction towards increased fuel quantity)	16.1.4
d)	Injection pump faulty (plunger or tappet sticking; delivery valve spring broken, delivery valve sticking, constant pressure relief valve leaking)	16.
e)	Injection valve faulty; nozzle holes clogged	16.
f)	Piston rings ruined; too low compression pressure	11.3.3
g)	8...18-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)	22.1.
b)	See point 2f	
c)	Fuel feed pressure too low	01.2
d)	Water in preheated fuel (vapour lock in injection pumps)	
e)	Loading automation (e.g. controllable pitch propeller) outside engine faulty	23.1.1.
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, 11.3.4 1
b)	Valve springs or injection pump tappet spring broken	12, 16.
c)	Inlet or exhaust valve jamming when open	
d)	Too large valve clearances	06.1.1 , 12.1.4
e)	One or more cylinders badly overloaded (3b, c)	
f)	Injection pump or valve tappet guide block loose	16.1.2, 14.1.3, 07.13.1
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)	06.2, 16.1.3, 13.1.2

	Trouble Possible reason	See chapter, section
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 15.1 15.1,
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)	03.5, 11.3.2
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	
c)	Charge air temperature too high - charge air cooler clogged on water side or dirty on air side - water temperature to air cooler too high, water quantity insufficient - engine room temperature abnormally high	Test Rec, 01.2 , 01.3 01.3
d)	Excessive deposits in cylinder head inlet or exhaust ports	
e)	Exhaust pipe pressure after turbine high	, , 15.2.1
9.	**Exhaust gas temperature of one cylinder above normal**	**Test Records**
a)	Faulty exhaust gas thermometer	23.1.2, 03.5.1
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	06.1.1 16.3.3
d)	Late injection	06.1.1, 16.1.3
e)	Fuel supply insufficient (filter clogged)	
f)	Injection pump faulty , fuel rack sticking in high	
10.	**Exhaust gas temperature of one cylinder below normal**	

	Trouble Possible reason	See chapter, section
a)	Faulty exhaust gas thermometer	23.1.2, 03.5.1
b)	See points 2f, h, 3b, c, d, e	
c)	Leaky injection pipe or pipe fittings	16.2
d)	When idling, see point 3g	03.5.1
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.	01.2
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 120°C.	
12.	**Lubricating oil pressure lacking or too low**	01.2
a)	Faulty pressure gauge, gauge pipe clogged	23.1.1
b)	Lubricating oil level in oil sump too low	01.1, 18.1
c)	Lubricating oil pressure control valve out of adjustment or jamming	18.3
d)	Three-way cock of lubricating oil filter wrongly set	18.6
e)	Leakage in lubricating oil suction pipe connections	18
f)	Lubricating oil badly diluted with diesel oil, viscosity of oil too low	1, 02.2.2
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**	01.2
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	
d)	Faulty thermostat valve	18.5
15.	**Abnormally high cooling water outlet temperature, difference between cooling water inlet and outlet temperatures too large**	01.2
a)	One of thermometers faulty	
b)	Circulating water cooler clogged, deposits on tubes	
c)	Insufficient flow of cooling water through engine (circulating water pump faulty), air in system, valves closed	19.7, 19.8 03.5.1
d)	Thermostat valve faulty	
16.	**Water in lubricating oil**	02.2.2, 03.5.1

	Trouble Possible reason	See chapter, section
a)	Leaky oil cooler	
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!	02.2.2
17.	**Water in charge air receiver** **(escapes through drain pipe in air cooler housing)**	
a)	Leaky air coolers	
b)	Condensation (too low charge air cooling water temperature)	03.5.1, Fig 03-2
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 22-1 pos. 13
b)	See points 2c, f, g, h, i	
c)	See points 4c, d, 5g, 20d	
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	22.1.
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 max. fuel admission 2) the stop lever and the overspeed trip being in work position and the speed governor in stop position. This control should be done always when the control mechanism or the injection pumps have been touched.	22.3.1

08.2. Emergency operation

08.2.1. Operation with defective air cooler(s)

V1

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 03-2). 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:

a) **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.

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

c) **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)

V1

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

If one turbocharger on a V-engine is defective and must be blocked, the other charger has to be blocked too. The air connection between the turbocharger and the air cooler housing should be removed and the engine will operate as a naturally aspirated engine. Available load from the engine with blocked turbocharger(s) is about 20 % of full load. The engine output must, however, be limited so that the normal full load exhaust temperatures are not exceeded.

Note!
Both turbochargers on a V-engine must be locked or blanked if one of them fails.

08.2.3. Operation with defective cams

V2

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.

Note!
Concerning torsional vibrations and other vibrations, see 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.

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.

Note!
Concerning torsional vibrations and other vibrations, see 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

V2

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

Note!
Concerning torsional vibrations and other vibrations, see 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) surges, reduce load further to avoid continuous surging.

Operation with removed piston and connecting rod, from one or more cylinders, 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 V1

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, dependant 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.

09. Specific Installation Data

09.1. Marine installations

V2

Chapter 09 is reserved for specific installation data.

Depending on installation, the specific installation data may also be found in the separate "Attachments" binder.

09.2. Power installations

V2

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

10. Engine Block with Bearings, Cylinder and Oil Sump

V1

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

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

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

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

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

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

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

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

10.1. Main bearings

10.1.1. Dismantling of the main bearing

V1

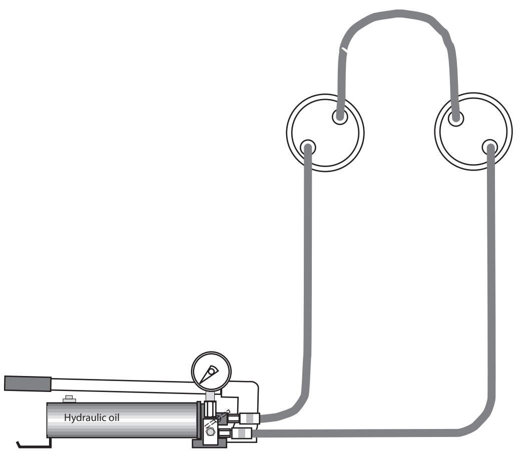
1 **Remove two crankcase covers** on each side of the bearing, on both sides of the engine.

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

3 **Lift the distance sleeve** 861027 into position on the side screw. One or two nuts can be loosened simultaneously.

4 **Screw on the hydraulic tool** 861120 and proceed with opening of the side screw nuts (A).

Dismantling with hydraulic tools

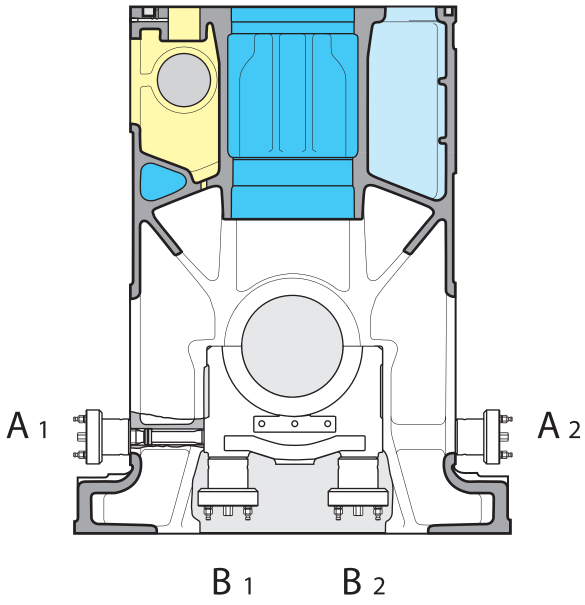


1. *Mount the cylinders.* 2. *Connect the hoses and open the pressure release valve. Tighten the cylinders to expel oil out of these.* 3. *Turn the cylinders 180 counter-clockwise.* 4. *Close the valve and pump pressure according to stated value.* 5. *Open the nuts about half a turn.* 6. *Open the release valve and remove the tool.*

Fig 10-1 HYD2A V2

5 **Loosen the nuts of the main bearing screws** on the bearing in question as shown in Fig 10-2 (B).

Use of hydraulic cylinders



1. *Rear side.*

Fig 10-2 V1

Table 10-1 Hydraulic cylinder combination

Hydraulic cylinder combination			
Screw	A1 A2	B1 B2	
Hydraulic tool	Main bearing and thrust bearing screws	Main bearing screws	Main bearing screws
Cylinder	3V86B78	3V86B79	3V86B78
Sleeve	3V86B46	3V86B39	3V86B46
Pin	4V86B11	4V86B02	4V86B11

Table 10-2 Loosening/Tightening screws

Action/Screw		Comments	Hydraulic pressure
Loosening	A1 A2	One by one in order according to free choice. Two nuts per side can be loosened simultaneously.	615...635 bar
	B1 B2	Always loosened simultaneously.	615...635 bar

Action/Screw		Comments	Hydraulic pressure
Tightening	B1 B2	Simultaneously handtight with pin 4V86B02 (B11) only.	
	A2	A2 bolt tensioned first with 200 bar hydraulic pressure and the nut turned with pin to contact.	200 bar
	B1 B2	Tightened simultaneously with full hydraulic pressure.	615 bar
	A1 A2	Tightened one by one in order according to free choice with full hydraulic pressure.	615 bar

6 **Lift the distance sleeves** 861009 into position and insert the pins 861028.

7 **Lift the hydraulic tool 861100 into position** by using the tool 861040 and proceed with opening of the main bearing nuts (B).

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

9 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked DOWN, see Fig 10-3.

10 **Unscrew the side screws of the main bearing cap** to be lowered. Use the stud tool 803000.

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

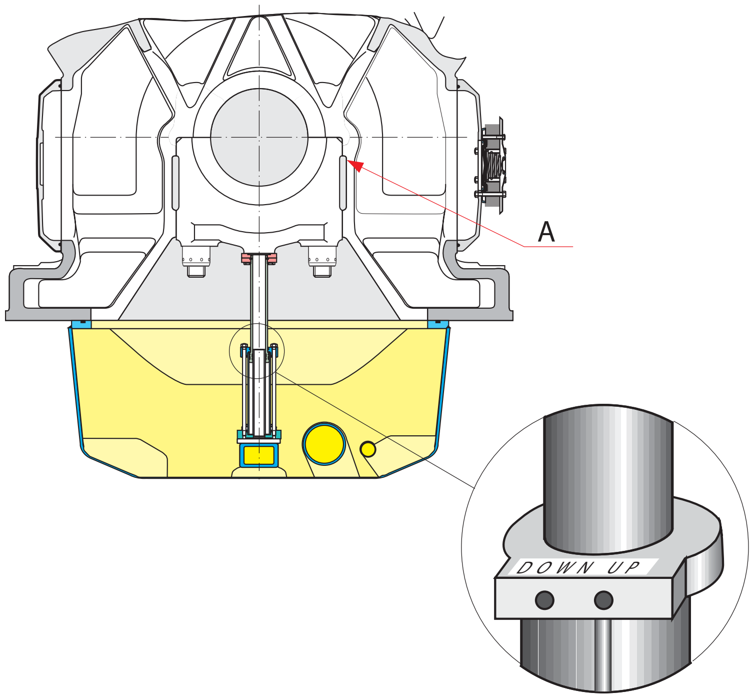
12 **Remove the lower bearing shell.**

13 **Insert the turning tool** 851000 (in-line engine) or 851010 (V-engine) into the main bearing journal radial oil hole.

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

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

Hydraulic jack



A. *Straight side of main bearing cap.*

Fig 10-3 V1

10.1.2. Inspection of main bearings and journals V1

Clean the bearing shells and check for wear, scoring and other damages.

a) Trimetal bearings can be used until the overlay is partially worn off. When the under-laying nickel-barrier or the lining material is exposed in any area, the bearing must be replaced.

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

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

Note!
Mark the new bearings with the bearing numbers.

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

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

10.1.3. Assembling of main bearing

V1

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

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

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

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

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

5 **Insert the turning tool** 851000 (in-line engine) or 851010 (V-engine) into the main bearing journal radial oil hole and turn the crankshaft **carefully** until the bearing shell has turned into position. Take care that the bearing shell lug slides into the oil groove without being damaged.

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

6 **Remove the turning tool.**

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

8 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked UP, see Fig 10-3.

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

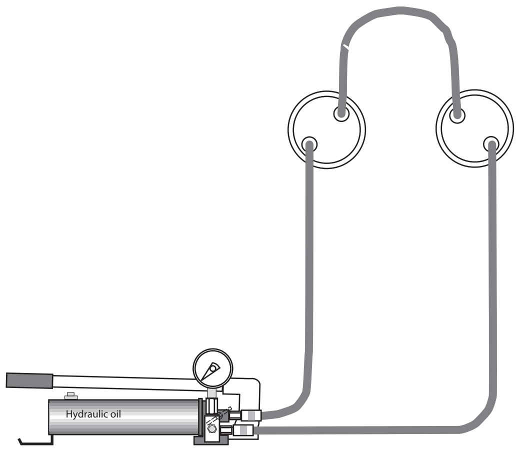
10 **Lubricate the threads of the side screws** (the threads towards the bearing cap) and tighten the screws to the bottom or use the stud tool 803000.

11 **Tighten the nuts by hand.**

12 **Lift the distance sleeves 861027 into position** on the side screws on the **rear side on an in-line engine, or B-bank on an V-engine.** One or two nuts can be tightened simultaneously, Fig 10-2 (A_2).

13 **Screw on the hydraulic tool 861120.**

Reassembly with hydraulic tools



1. *Mount the nuts, the distance sleeves and the cylinders.* 2. *Connect the hoses, open the pressure release valve. Tighten the cylinders to expel oil out of these.* 3. *Close the valve and pump pressure to stated value for step 1.* 4. *Turn the nuts until close contact is reached.* 5. *Release the pressure by opening the valve.* 6. *Close the valve and pump pressure to the full stated value.*7. *Turn the nuts until close contact is reached.* 8. *Open the valve and remove the tool set.*

Fig 10-4 HYD2A V2

14 **Tighten the nut** by the pin 861028 when the hydraulic pressure is **200 bar.**

15 **Lift the distance sleeves 861009 into position** on the bearing cap screws and insert the pins 861028, see Fig 10-2 (B).

16 **Lift the hydraulic tool 861100 into position** by using the tool 861040 and proceed with tightening of the main bearing screws (B).

17 **Lift the distance sleeves 861027 into position** on the side screws on the **rear side on an in-line engine, or B-bank on an V-engine,** straight side of the bearing cap! One or two nuts can be tightened simultaneously, Fig 10-2 (A_2).

18 **Screw on the hydraulic tool 861120** and proceed with tightening of side screw nut (A_2). Tighten to full, stated pressure.

19 **Lift the distance sleeves 861027 into position** on the opposite manoeuvering side screws. One or two nuts can be tightened simultaneously, Fig 10-2 (A_1).

20 **Screw on the hydraulic tool 861120** and proceed with tightening of side screw nuts (A_1). Tighten to full stated pressure.

10.2. Flywheel/thrust bearing

10.2.1. Dismantling of flywheel/thrust bearing

V1

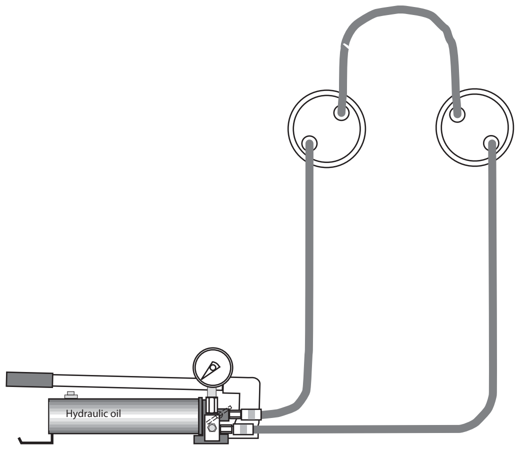
1 **Remove the two crankcase covers** next to the flywheel end, on both sides of the engine. On 4R32, remove the divided end cover inside the flywheel.

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

3 **Lift the distance sleeve 861027 into position** on the side screw. Two nuts can be loosened simultaneously.

4 **Screw on the hydraulic tool** 861120 and proceed with opening of the side screw nuts (A).

Dismantling with hydraulic tools



1. *Mount the cylinders.* 2. *Connect the hoses and open the pressure release valve.Tighten the cylinders to expel oil out of these.* 3. *Turn the cylinders 180 counter-clockwise.* 4. *Close the valve and pump pressure according to stated value.* 5. *Open the nuts about half a turn.* 6. *Open the release valve and remove the tool.*

Fig 10-5 HYD2A V2

5 **Loosen the nuts of the flywheel/thrust bearing screws** as shown in Fig 10-2 (B).

6 **Lift the distance sleeves 861027 into position** and insert the pins 861028.

7 **Screw on the hydraulic tools** 861120. If necessary, use the lifting tool 861040. Proceed with opening of bearing screws (B).

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

9 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked DOWN, see Fig 10-3.

10 **Unscrew the side screws of the flywheel/thrust bearing cap.** Use the stud tool 803000.

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

12 **Remove the lower bearing shell and the thrust washers.** To remove the thrust washer next to the driving end, an M6 screw can be fitted to each end of the washer, see Fig 10-6.

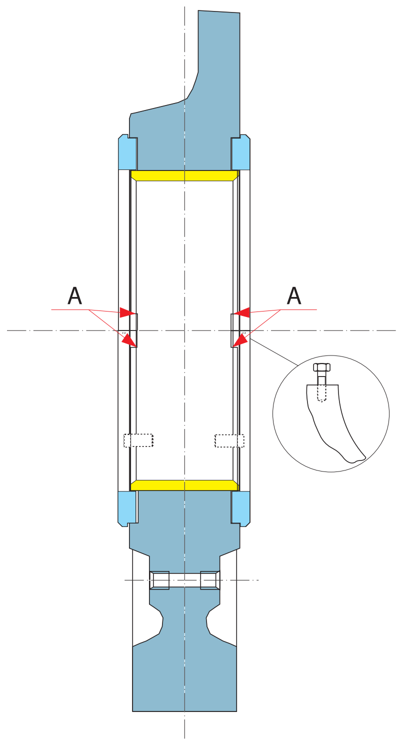
13 **Insert the turning tool** 851020 into the bearing journal radial oil hole.

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

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

16 **Check the bearing** in the same way as the main bearings, section 10.1.2. The thrust washers on the same side have to be changed in pairs.

Thrust bearing



A. *End recesses.*

Fig 10-6 V1

10.2.2. Assembling of flywheel/thrust bearing

V1

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

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

3 **Lubricate the bearing surface,** back side and both ends of the upper bearing shell with clean lubricating oil and place the end of the bearing shell in the slot between the journal and the bearing bore. The axial location of the shell is to be secured by keeping the bearing shell end recesses at level with the axial faces in the engine block, see Fig 10-6.

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

5 **Insert the turning tool** 851020 into the bearing journal radial oil hole and turn the crankshaft carefully until the bearing shell has turned into position.

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

6 **Remove the turning tool.**

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

8 **Lubricate the bearing surfaces** of the lower thrust washers and push them into position on the guiding pins in the bearing cap. For mounting the thrust washer next to the driving end an M6 screw can be fitted to each end of the washer, see Fig 10-6.

9 **Lubricate the bearing surface** of the lower bearing shell with clean lubricating oil and place the shell in bearing cap. The axial location of the shell is to be secured by keeping the bearing shell end recesses at level with the axial faces in the cap, see Fig 10-6.

10 **Connect the hoses of the hydraulic pump** 1V86A18 to the hydraulic jack, the supplying hose set to the side marked UP, see Fig 10-3.

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

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

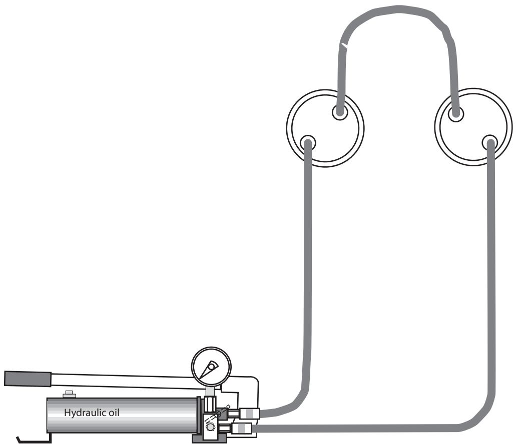
13 **Tighten the side screws** to the bottom or by using the stud tool 803000.

14 **Tighten the nuts of the side screws** on the rear side of the engine as shown in Fig 10-2 (A).

15 **Lift the distance sleeves 861027 into position** on the flywheel/thrust bearing screws and insert the pins 861028, see Fig 10-2 (B).

16 **Screw on the hydraulic tools** 861120. If necessary, use the lifting tool 861040. Proceed with tightening of the bearing screw nuts (B).

Reassembly with hydraulic tools



1. *Mount the nuts, the distance sleeves and the cylinders.* 2. *Connect the hoses, open the pressure release valve. Tighten the cylinders to expel oil out of these.* 3. *Close the valve and pump pressure to stated value for step 1.* 4. *Turn the nuts until close contact is reached.* 5. *Release the pressure by opening the valve.* 6. *Close the valve and pump pressure to the full stated value.*7. *Turn the nuts until close contact is reached.* 8. *Open the valve and remove the tool set.*

Fig 10-7 HYD2A V2

17 **Lift the distance sleeve 861027 into position** on the side screw. Two nuts can be tightened simultaneously.

18 **Screw on the hydraulic tool 861120** and proceed with tightening of side screw nuts (A).

10.3. Camshaft bearings

10.3.1. Inspection of the camshaft bearing bush

V2

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

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

2 **Remove the cover (6)** from the starting air distributor, see chapter 14.1, Fig 14-2.

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

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

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

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

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

10.3.2. Removing of camshaft bearing bush

V2

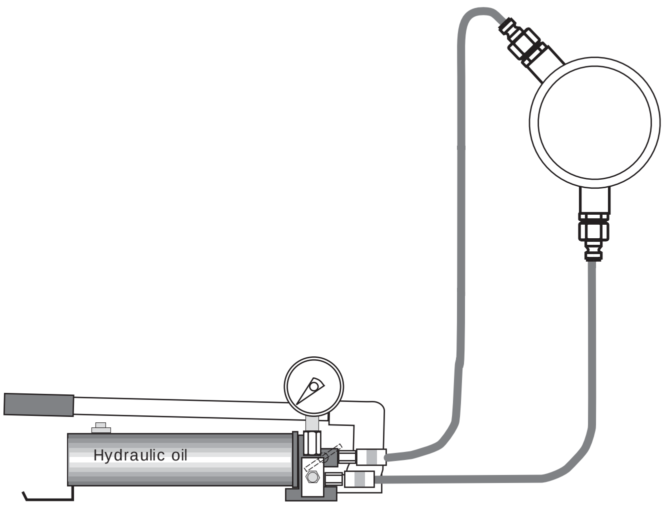
1 **Remove the camshaft cover,** injection pump, guide block and camshaft piece from the two cylinders adjacent to the bearing concerned. If it is the question of an end bearing, the respective camshaft end piece has to be removed.

2 **Remove the camshaft bearing journal.**

3 **Assemble the removing device** 834010 according to Fig 10-9. Notice the difference in tool assembly for the bearing next to the free end of the engine. When it is a question of an end bearing, insert the guide sleeve 834011, the thicker part being directed towards the middle of the engine.

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

Dismantling with hydraulic tools



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

Fig 10-8

HYD V1

5 **Connect the hoses of the hydraulic pump** 860100 to the hydraulic tool.

6 **Pump pressure to the hydraulic tool** to withdraw the bearing bush. **The pressure must not exceed the value stated in** section 07.3.1. If the bearing bush does not move when this pressure is achieved, a light knock on the end flange 834012 can be necessary.

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

Removing of camshaft bearing bush

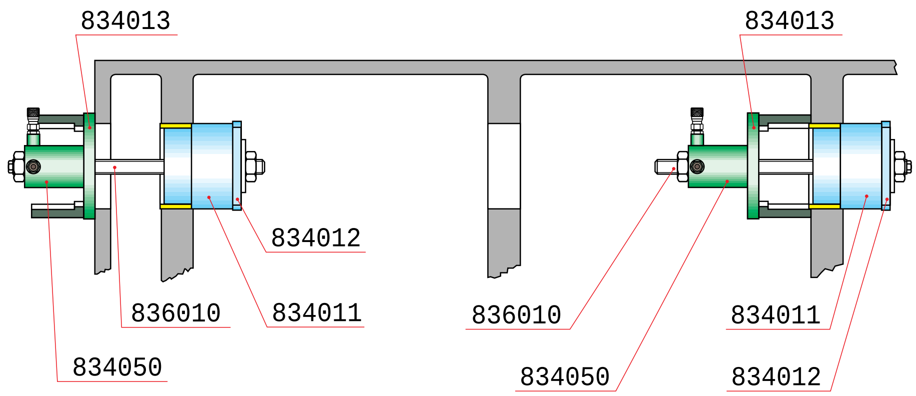


Fig 10-9

V1

10.3.3. Mounting of camshaft bearing bush

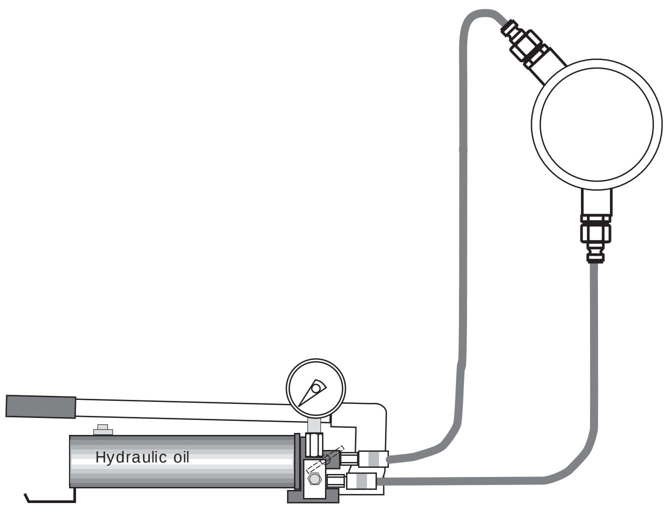
V2

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

2 **Assemble the mounting device** 834010 according to Fig 10-11. Notice the difference in tool assembly for the bearing next to the free end of the engine. When it is a question of an end bearing, insert the guide sleeve 834011, the thinner part being directed towards the middle of the engine.

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

Reassembly with hydraulic tools



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

Fig 10-10

HYD V1

4 **Connect the hoses of the hydraulic pump** 860100 to the hydraulic tool.

5 **Pump pressure to the hydraulic tool** to mount the bearing bush. **The pressure must not exceed the value stated in section 07.3.1.**

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

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

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

Mounting of camshaft bearing bush

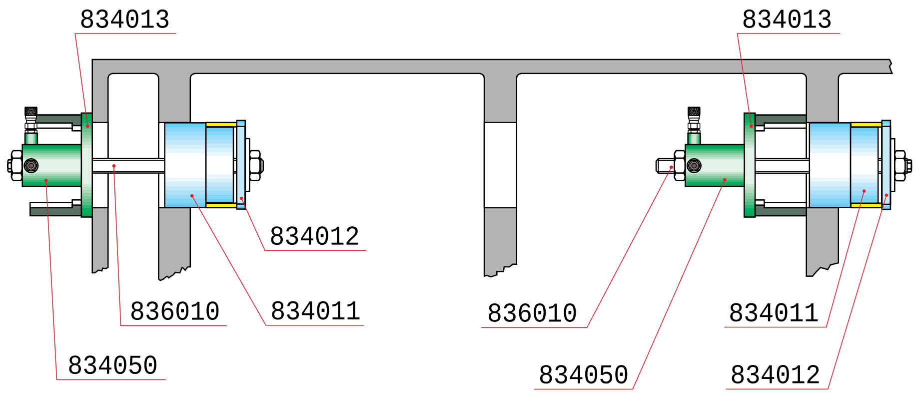


Fig 10-11

V1

10.4. Cylinder liner

10.4.1. Maintenance of cylinder liner

V1

a) **Honing of cylinder liner bore**

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

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

The honing equipment is delivered with the engine.

b) **Check the inner diameter of the cylinder liner,** use form No. 3210V014 or form No. 3210V020 (LN-engines).

c) **Cleaning of the cylinder liner water side**

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

10.4.2. Removing cylinder liner

V2

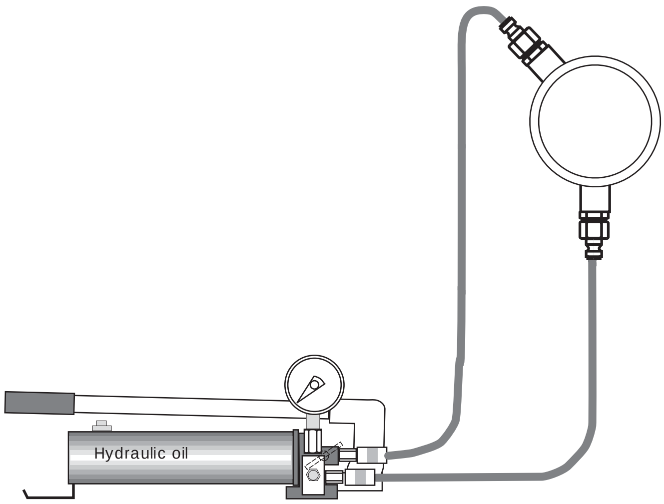
1 **Drain the engine cooling water** and remove the cylinder head and piston with connecting rod.

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

3 **Assemble the removing device** 836000 and the hydraulic tool 834050 according to Fig 10-13.

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

Dismantling with hydraulic tools



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

Fig 10-12

HYD V1

5 **Connect the hoses** of the hydraulic pump 860100 to the hydraulic tool.

6 **Pump pressure to the hydraulic tool** to withdraw the cylinder liner. **The pressure must not exceed the value stated in section 07.3.1**

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

8 **Use the part of the removing device** intended for this purpose to lift the cylinder liner, see Fig 10-13.

10.4.3. Mounting of cylinder liner

V1

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

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

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

4 **Lubricate the lower O-rings and the sealing faces** with grease and assemble the lifting device, see Fig 10-13.

5 **Lower the liner carefully into the bore** of the engine block. When the lowest O-ring touches the engine block, align the liner so that the mark (3, in Fig 10-13) on the liner is directed towards the driving end of the engine, on the V-engine B-bank towards the free end of the engine. Lower further and press liner into position by hand.

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

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

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

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

Removing and lifting of cylinder liner

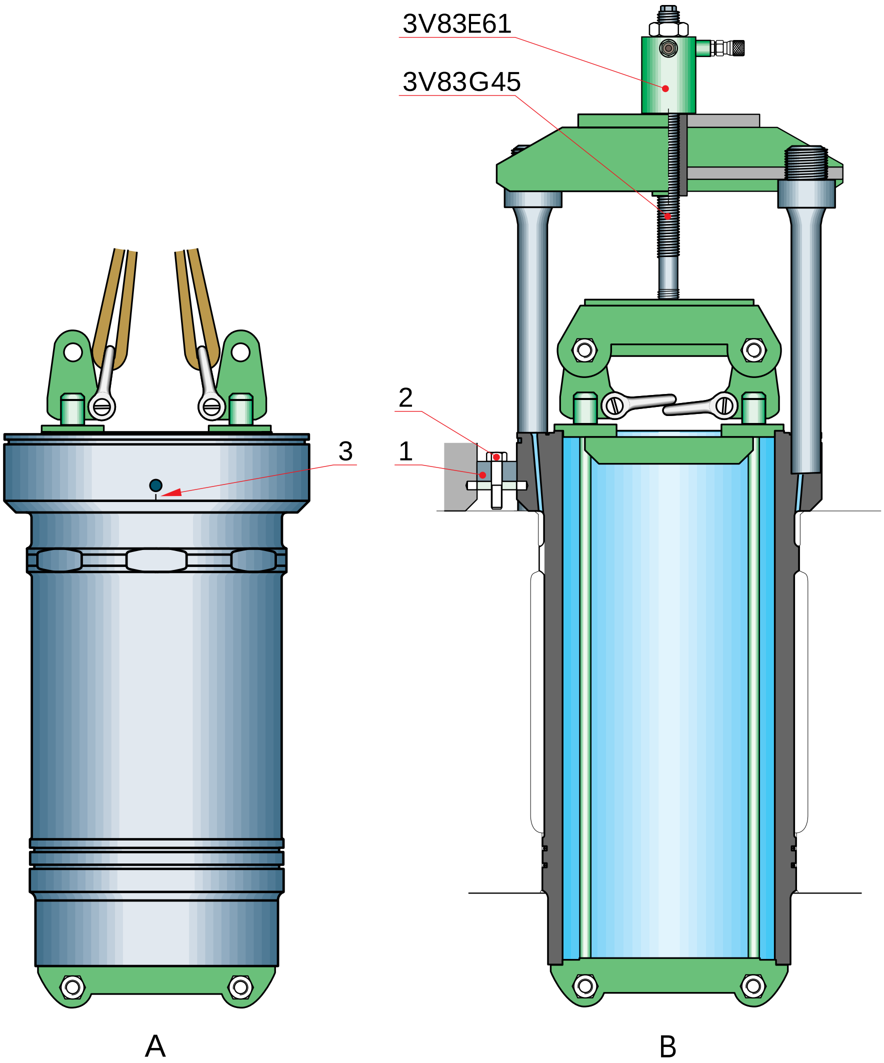


Fig 10-13

V1

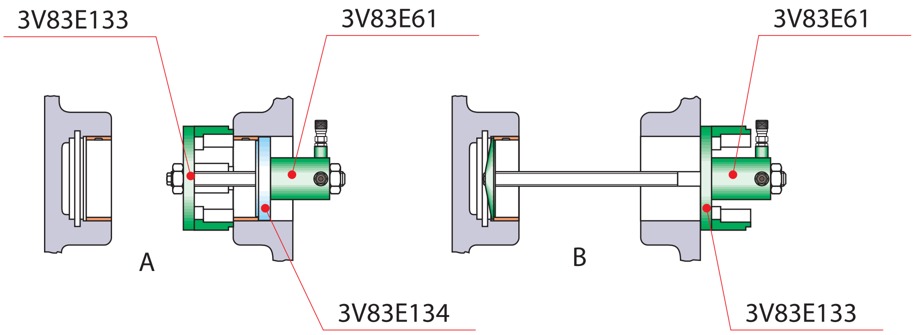
10.5. Camshaft driving gear bearings

10.5.1. Removing of camshaft driving gear bearing bush

V2

1. Remove the camshaft gearing according to section 13.1.1.
2. Assemble the removing device 32.13T01 (834053) according to Fig 10-14.
3. Proceed according to section 10.3.2.

Removing of camshaft driving gear bearing bush



A. *Outer* B. *Inner*

Fig 10-14

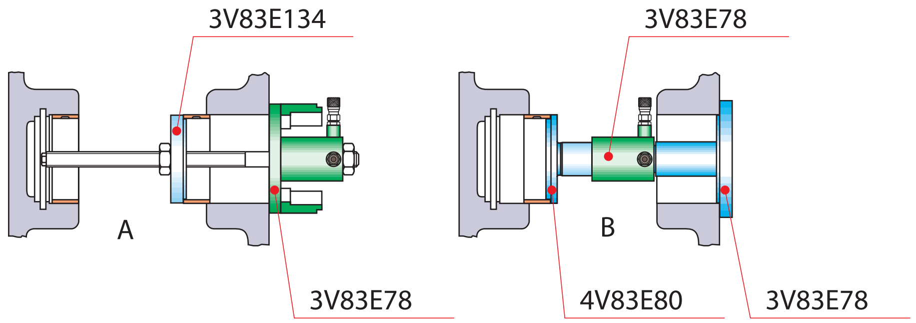
V1

10.5.2. Mounting of camshaft driving gear bearing bush

V1

1. **Lightly lubricate the new bearing bush** with clean engine oil on the outer surface and put it on the guide sleeve 834056 or 834058 . Note the bearing bush position. Mount the oil groove according to section 13.1.2.
2. **Assemble the removing device** 32.13T01 (834053) according to Fig 10-15.
3. **Proceed according to** section 10.3.3.

Mounting of camshaft driving gear bearing bush



A. *Outer* B. *Inner*

Fig 10-15

V1

10A. Lubricating Oil Level Monitoring

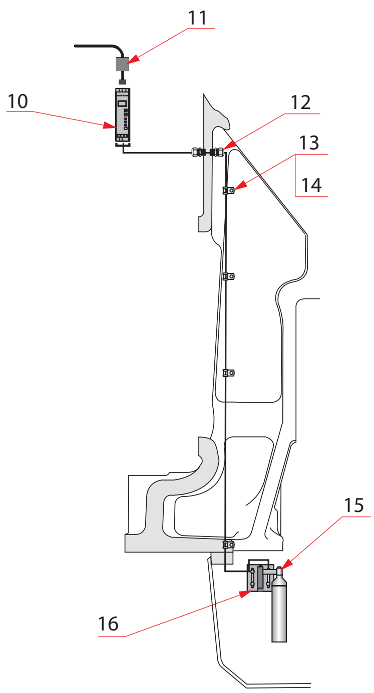
V2

Wärtsilä has developed a real time lubrication oil level monitoring system. The online system, compared to the traditional dipstick watch, is a beneficial system for monitoring the lubrication oil level for all engines with wet sump, especially for installations with several engines.

The system is connected to the engine monitoring system for real-time monitoring with alarm functions for low and high level. The product can also be integrated into an automatic fill up system for new oil being supplied to the engine lubrication oil system.

The system gives the operators real time information about the oil level in the engine, and the trend picture gives accurate data on oil level changes.

Lubricating oil level monitoring system



10.*Transducer* 11.*Adapter* 12.*Bushing* 13.*Clamp* 14.*Screw* 15.*Body* 16.*Bracket*

Fig 10A-1

3210010105 V3

10A.1. The benefits of the real-time monitoring system

V2

On power plant and marine installations with several engines, a system with real-time monitoring of the lubrication oil level is essential for avoiding costly damage. The system will save time and avoid serious problems by monitoring online the engine oil sump level in case of possible water leakage into the crankcase from different source, such as the lubrication oil purifier.

- High measuring accuracy, 1 mm
- No moving parts
- Ready-calibrated at factory
- Easy and fast installation – can be connected to any existing alarm and monitoring system
- Reliable strain gauge principle
- Standard current and voltage output

10A.2. Description of the system

V2

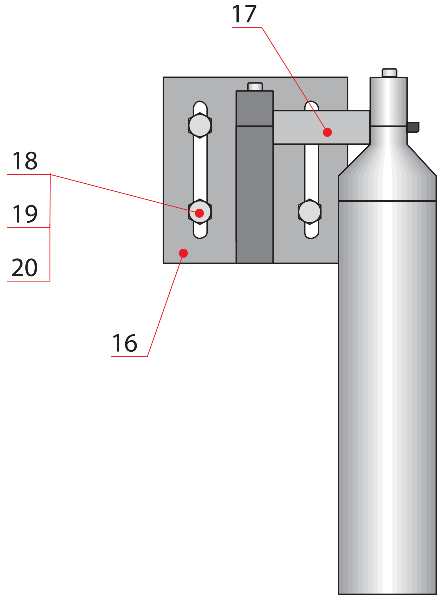
An aluminium cylinder (15), see Fig 10A-1, is bolted to a special load cell made of stainless steel. The whole unit is bolted by a specially made bracket (16) to a partial wall inside the engine oil sump. Four holes need to be drilled in the partial wall when the right position is known.

Final adjustment is possible by moving the bracket (16), see Fig 10A-2, up or down in the slots made for the fastening bolts. The transmitter and sensor are adapted to each other and calibrated so that the transmitter's 4 - 20mA corresponds to 0 - 320 mm on the dipstick.

When the lubrication oil level decreases, the weight of the cylinder will increase. The electronic transmitter converts the strain gauge bridge signal to a current signal. The construction of the load cell will eliminate all lateral forces caused by oil or ships movement.

Note!
Before removing the bracket plate, mark the position of it.

Adjustment of bracket



16. *Bracket* 17. *Sensor* 18. *Washer* 19. *Nut* 20. *Screw*

Fig 10A-2 3210020105 V1

The position for the bracket (16) depends on the lubricating oil maximum level with engine in stop position. This can be seen from the oil level dipstick maximum mark which then need to correspond to the top line marks on the sensor´s aluminium cylinder (15).

Electrical diagram

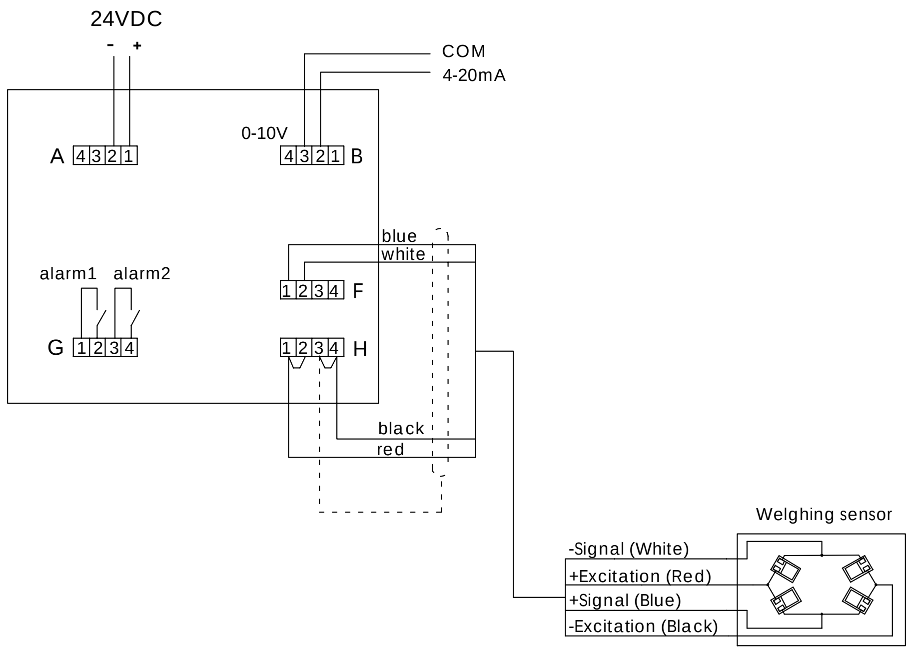


Fig 10A-3 3210030105 V1

10A.3. Specification

V2

Oilstic 320

Measuring range ....320 mm

Maesuring accuracy ....±1 mm

Temperature coefficient ....±0,25 mm/10°C

Working temperature range ....-10...+100°C

Weight ....9,6 kg

NOKEVAL 6841- 24VDC

Load cell input

Excitation voltage ....10 VDC

Output and power supply

Current output ....0-20 mA, 4-20 mA

Maximum load ....550 Ohm

Accuracy ....0.1% of full range

Voltage output ....0-10 V, 0-5 V, 1-5 V

Output impedance ....10 Ohm

Accuracy ....0.1% of full range

Supply voltage ....18-30 VDC

Current consumption ....90 mA

Mechanical

IEC 68-2-32 ....free fall

IEC 68-2-6 ....vibration

Enviromental

IEC 68-2-1 ....cold

IEC 68-2-2 ....dry heat

IEC 68-2-3 ....damp heat

IEC 68-2-14 ....temp. change

EMC susceptibility

EN 50082-2 ....basic

IEC 1000-4-2/EN61 000-4-2/IEC 801-2 ....ESD

IEC 1000-4-2/EN61 000-4-4/IEC 801-4 ....Fast transient

ENV50140/IEC 801-3 ....radiated RF

ENV50141 ....conducted RF

ENV50204 ....radiated tel. RF

EMC emission

EN 50081-1 ....basic

EN 55014 ....emission limits

EN 55022 ....emission limits

Safety

IEC 348/IEC 1010 ....electrical safety

Performance

Linearity ....±0.1%

Range, temp. coef. ....±50 ppm/°C

Zero, tem. coef. ....±0.1 V/°C or

±100 ppm/°C which ever is greater

Common mode rejection ration ....> 100 db input to output/power

Conversion time ....selectable 200, 400, 800 ms

Digital filter ....walking window, settable as: off, normal, maximum

Isolation voltage ....2500 V dc or 1500 V ac rms: input/output/power

Environmental & physical

Warm-up time ....1 min

Operating temperature range ....-10 to +60°C

Relative humidity range ....0 to 90% non-condensing

Case ....Standard DIN rail 35 mm mounting

High-impact moulded plastic case

UL94V-0 rated...

Dimensions ....98x23x117 mm (HxWxD)

Weight ....180 g

Re-calibration ....12 month

2060 VXZ LOAD CELL

Capacity ....10 kg

Tolerance of sensitivity ....±0.1%

Temperature drift on span /10°K ....±0.05%

Zero temperature drift /10°K ....±0.035%

Combined error ....±0.1%

Safe load limit ....±150% FS

Insulation resistance ....> 5000 M Ohm

Compensated temperature range ....- 10 to 100°C

Sensitivity ....1.0 mV/V

Off - centred ....100 x 100 mm

Input impedance ....353 Ohm ±2 Ohm

Output resistance ....353 Ohm ±2 Ohm

11. Crank Mechanism: Crankshaft, Connecting Rod, Piston

11.1. Counterbalancing the crankshaft

V2

The crankshaft is counterbalanced by means of weights on the crank webs. The in-line engines normally have counterweights on one web per cylinder, the V-engines on all webs.

11.1.1. Counterbalancing of 4-cylinder engines

V1

The second-order free forces of 4-cylinder in-line engines are completely counterbalanced by means of an arrangement consisting of two eccentric shafts 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.

The shafts are pivoted in the bearing brackets, which are fastened to the engine block by means of hydraulically tightened screws. The shafts are driven from the crankshaft split gear through a gear drive.

For further information see section 11.4.

11.1.2. Counterbalancing of 9-cylinder engines

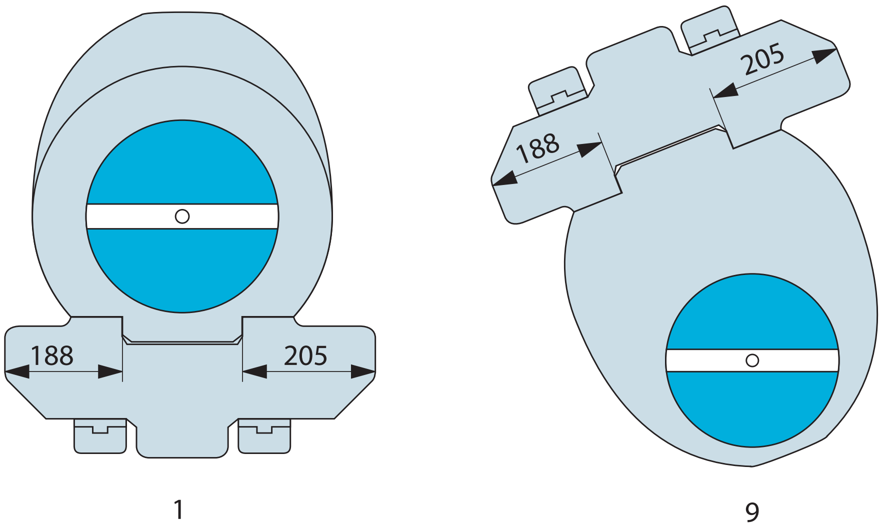
V1

The 9-cylinder in-line engines differ from the other engines in that they have counterweights on all webs. Furthermore, the utmost counterweight at each end of the crankshaft is larger than the other ones and unsymmetrical in order to counterbalance the free moment of the engine. When such a counterweight has been removed from the engine, it is of the greatest importance that it is correctly re-installed, Fig 11-1.

11.1.3. Counterbalancing of 18-cylinder V-engines V1

The counterbalancing of the free moment of the 18-cylinder V-engines is accomplished by means of a supplementary weight at the free end of the engine and a specially balanced flywheel. After a possible removal, it is important that the supplementary weight is correctly re-installed, Fig 11-2.

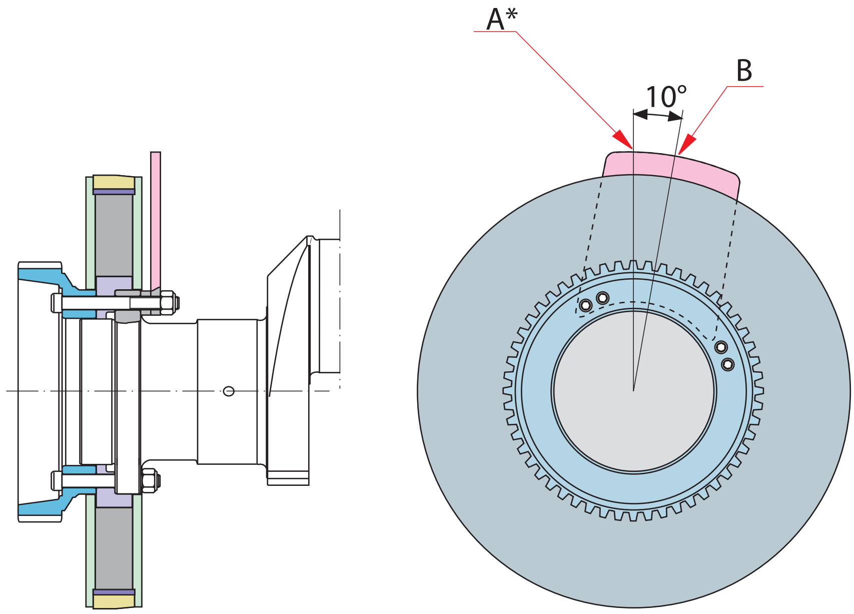
Mounting of counterweights on 9R32



1, 9 *Cylinders (seen from the flywheel end)*

Fig 11-1 V1

Supplementary weight for 18V32



A. *Crank web for cylinder A1 and B1 is straight upwards* B. *Centerline of counter weight seen from the free end*

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

Fig 11-2 V1

11.2. Crankshaft V2

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

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

At the free end, there is a gear for driving pumps and usually a vibration damper. If power is taken off at the free end, sealing of the crankshaft is arranged by a V-ring, as at the driving end.

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

11.2.1. Crankshaft alignment

V5

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

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

By using a dial indicator:

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

2 Set indicator at zero.

3 Read deflections when turning crank to rear side, TDC (top dead centre), operating side and BDC. Record readings in the form "Crankshaft alignment".

See also work steps for both methods.

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

By using an electronic deflection indicator:

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

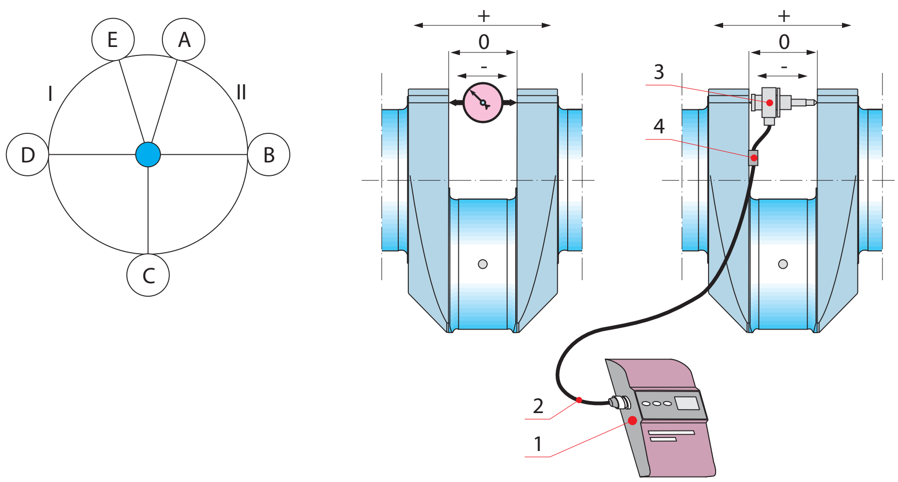
5 Connect cable (2) on the measuring unit (1).

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

7 Reset the measuring unit by pressing the Reset button.

8 **Turn crank of the first cylinder** near BDC (bottom dead centre) and fit the transducer to the centre marks between two crank webs. The distance between the transducer and the connecting rod should be as small as possible. Fix the cable to the crank web by using suitable bandage or magnetic holder (4), see Fig 11-3..

Dial indicator position and reading



I.*Operating side,*II.*Rear side, as seen from the flywheel end.*

Fig 11-3 V1

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

10 **Read deflections while turning the crank** in the marked positions according to Fig 11-3. The starting point for clockwise rotating engine is measuring point "A" and for a counter-clockwise rotating engine measuring point "E". B is the rear side, C is TDC (top dead centre), D is the operating side, A and E are BDC (bottom dead centre). Record readings in the Measurement Record: "Crankshaft alignment".

Note, values in 1/100 mm!

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

For both methods:

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

12 **The following limits of misalignment** are stated for an engine having normal running temperature (within 10 min. after running at 60% load or higher, for 6 h or more) :

a)on the same crank, the difference between two diametrically opposed readings must not exceed 0.04 mm after installing or realigning. Realignment is necessary if this limit is exceeded by more than 0.02 mm.

b)on two adjacent cranks, the difference between two corresponding readings must not exceed 0.04 mm. Realignment is necessary if this limit is exceeded.

c)when the crank pin for cyl. 1 is at TDC, the reading should be negative, max. -0.04 mm (-0.06 mm if flex coupling).

Before realigning the engine and the driven machinery, a control measurement of the main bearings should be made.

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

11.2.2. Measurement of thrust bearing axial clearance

V4

1 **Lubricate the bearings** by running the pre-lubricating pump for a few minutes and turn the crankshaft simultaneous a few revolutions with the turning gear.

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

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

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

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

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

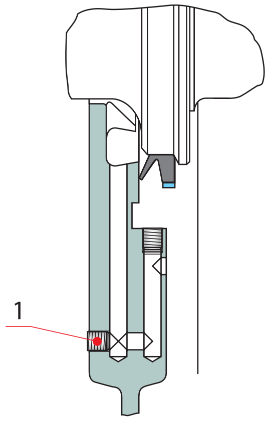
11.2.3. Cleaning of oil lock at crankshaft seal

V5

1 **Remove the outer plug (1),** Fig 11-4.

2 **Blow through the bores of the oil lock** from outside with compressed air. There is no need for refilling the oil lock with oil after cleaning.

Oil lock at crankshaft seal



1.*Plug*

Fig 11-4

V1

11.3. Connecting rod and piston

V5

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

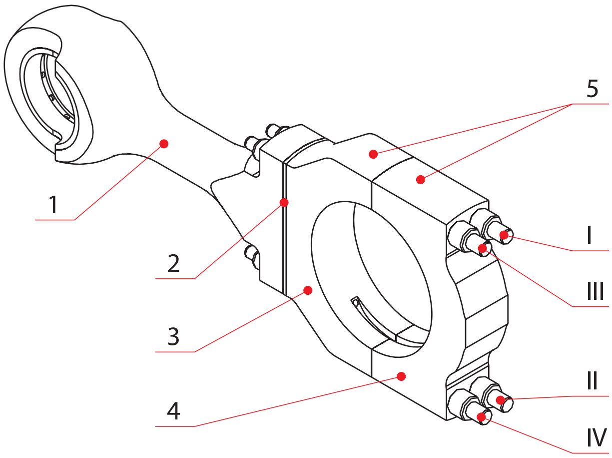
The connecting rod is forged and machined of alloyed steel and split horizontally in three parts to allow removal of piston and connecting rod parts. All connecting rod bolts are hydraulically tightened.

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

Note!
Always handle the pistons with care.

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

Connecting rod parts



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

Fig 11-5 V1

11.3.1. Removing of piston and upper part of connecting rod for overhaul V2

1. **Remove both crankcase covers** adjacent to the connecting rod concerned on both side of engine.
2. **Remove the cylinder head** according to section 12.1.1.
3. **Remove the anti-polishing ring.** Use the tool 836017 if necessary. By cranking the engine, the piston pushes the anti-polishing ring out.
4. **Clean the threaded hole(s)** in the piston crown and fasten the lifting tool 835000 by using the hexagon screws M12x45 (2).
5. **Turn the crankshaft to the BDC** the cylinder concerned.
6. **Lift the distance sleeves** into position.

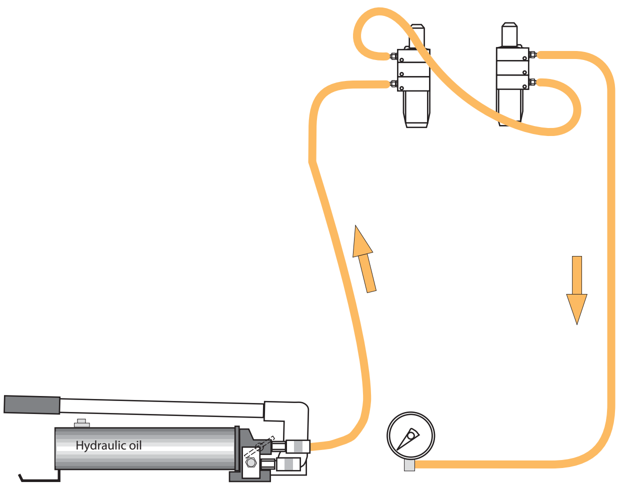
Note!
Before mounting of the tension screws, check that plastic plugs are mounted inside the tension screws.

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

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

9 **Connect the hoses** on the hydraulic pump 860100, see Fig 11-6.

Dismantling with hydraulic tools



1. *Lift the distance sleeve.* 2. *Lift the hydraulic cylinder and screws in a one package in pos.* 3. *Connect hoses, open valve.* 4. *Tighten the tool assembly, until the piston and cylinder is on the same level, open the nuts by 180°.* 5. *Close the valve, pump to required pressure. Open the nuts about half a turn.* 6. *Open the valve slowly and remove the tool.*

Fig 11-6 HYD5A V1

10 **Open the release valve** and tighten the tool assembly to expel possible oil until the piston and cylinder are on the same level, see Fig 11-7.

This is very important as the effective stroke of the pistons is limited and due to that there is a great risk for insufficient tightening of the nuts, which may cause serious engine damage.

Open the nuts about half a revolution (180°).

11 **Strain the screws by raising the pressure** to the value stated in chapter 07.1, and proceed with opening the nuts.

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

12 **Release the pressure slowly and** disconnect the hoses, unscrew the tightening nuts and remove hydraulic tool.

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

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

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

14 **Rotate the crank pin** of the cylinder concerned in the TDC.

15 **V-engines: Mount the protecting rail 3V11T718** on the upper part of the connecting rod, see Fig 11-10.

16 **Separate the upper part (1) from** the big end (5) by lifting the piston. Support the upper part of the connecting rod to avoid damaging the cylinder liner.

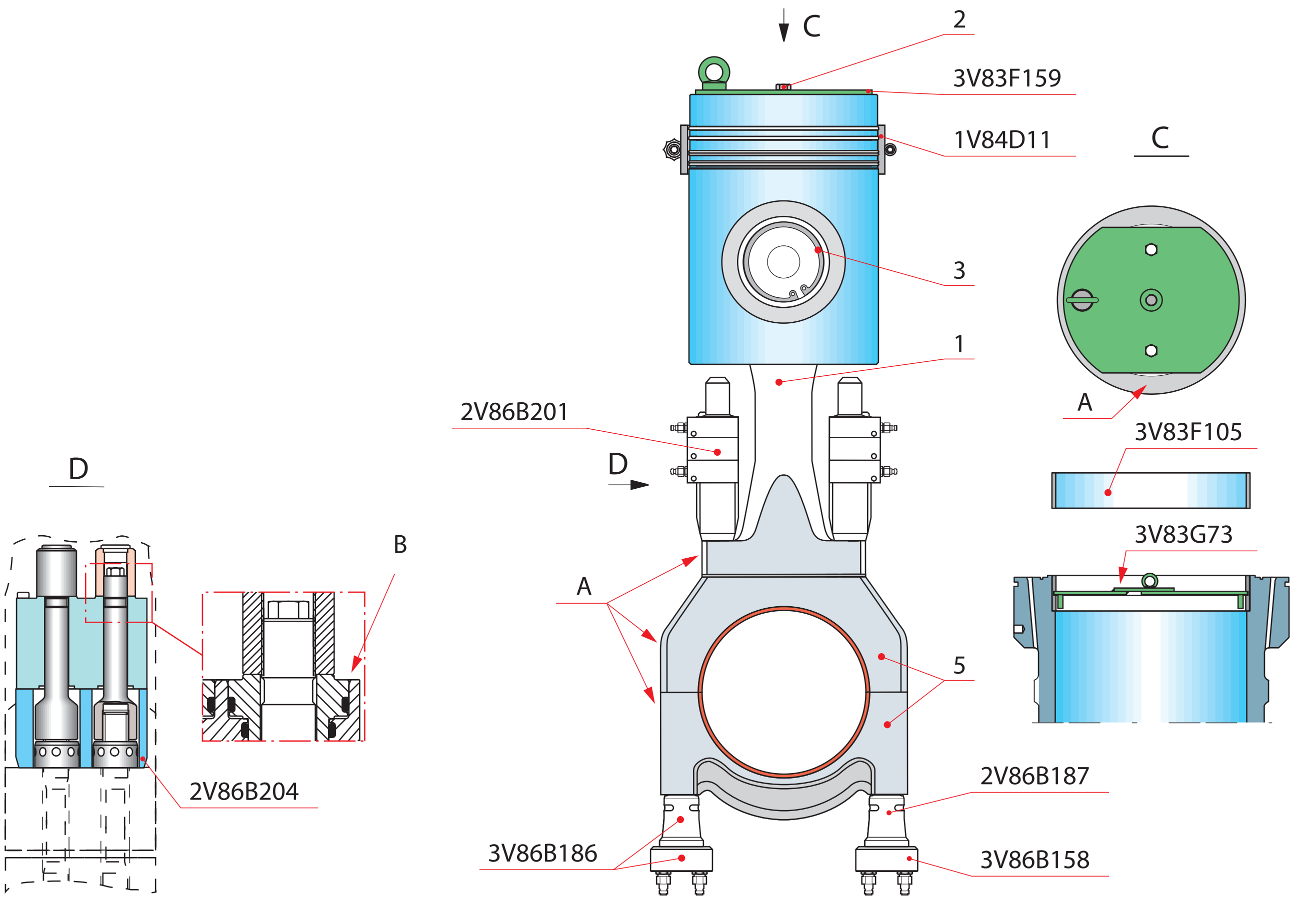
Note! To avoid damaging the guiding pins, the separation of the upper part (1) and the big end (5) should be done aligned.

17 **Remove the shim (2),** see Fig 11-5.

Do not mix the shims with other connecting rod shims.

18 **Repeat the steps above in the other** connecting rod on the same crank pin on a V-engine.

Piston and connecting rod assembly



1.*Upper par,* 2.*Screw* 3.*Securing ring* 5.*Big end* A.*Cyl. nr,* B.*Piston and cylinder on the same level*

3V83F105 *Assembling tool for piston* 3V83F159 *Lifting tool for piston* 1V84D11 *Compression tool for piston rings* 3V86B186 *Hydraulic tightening tool for M30 screws* 3V86B158 *Hydraulic cylinder* 2V86B187 *Distance sleeve* 2V86B201 *Hydraulic tightening tool for M24 screws* 2V86B204 *Distance sleeve*

Fig 11-7 V1

11.3.2. Changing of big end bearings

V4

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

2 **Turn the crankshaft to the BDC** the cylinder concerned.

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

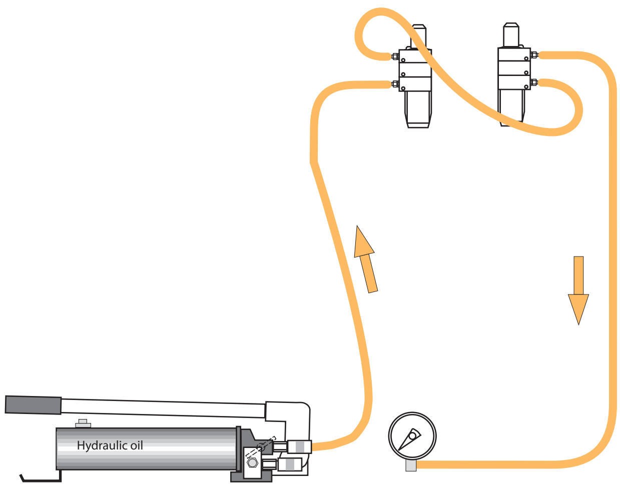
Note!
Before mounting of the tension screws, check that plastic plugs are mounted inside the tension screws.

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

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

6 **Connect the hoses** on the hydraulic pump 860100, see Fig 11-8.

Dismantling



1. *Lift the distance sleeve.* 2. *Lift the hydraulic cylinder and screws in a one package in pos.* 3. *Connect hoses, open valve.* 4. *Tighten the tool assembly, until the piston and cylinder is on the same level, open the nuts by 180°.* 5. *Close the valve, pump to required pressure. Open the nuts about half a turn.* 6. *Open the valve slowly and remove the tool.*

Fig 11-8

HYD5A V1

7 **Open the release valve** and tighten the tool assembly to expel possible oil until the piston and cylinder are on the same level, see Fig 11-7.

This is very important as the effective stroke of the pistons is limited and due to that there is a great risk for insufficient tightening of the nuts, which may cause serious engine damage.

Open the nuts about half a revolution (180°).

8 **Strain the screws by raising the pressure** to the value stated in section 07.1, and proceed with opening the nuts.

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

---

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

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

---

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

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

---

11 **Rotate the crank pin** of the cylinder concerned in the TDC.

12 **Mount the limiter 3V83F178** in the lower part of cylinder liner and tighten the screw, see Fig 11-10 and Fig 11-11.

13 **Separate the upper part (1) from** the big end (5) by turning the crankshaft towards BDC. Support the upper part of the connecting rod to avoid damaging the cylinder liner.

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

14 **Remove the shim (2)**, see Fig 11-5.

Do not mix the shims with other connecting rod shims.

Note!
Observe extremely cautiousness always when assembling tools or/ and the limiter is/are mounted in the crankcase, when cranking the engine.

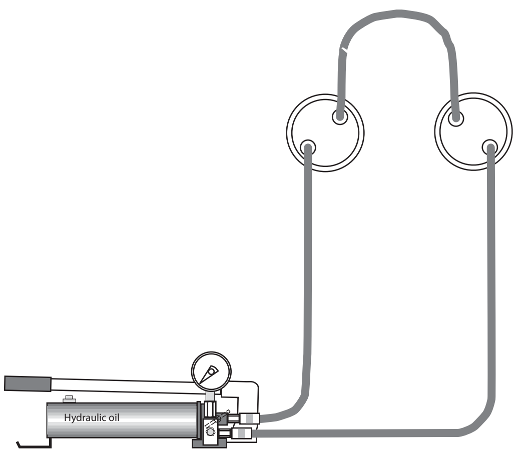
15 **Rotate crankshaft towards rear side** to the position where hydraulic tools can be mounted.

16 **Lift the distance sleeves** and screw on the hydraulic tools 3V86B186 into position on the connecting rod screws, places I and IV, see Fig 11-5. Proceed with opening of the nuts.

Note!
Loosen crosswise.

17 **Lift the distance sleeves** into position II and III, see Fig 11-5. Proceed with opening of the nuts.

Dismantling



1. *Mount the cylinders.* 2. *Connect the hoses and open the pressure release valve.Tighten the cylinders to expel oil out of these.* 3. *Turn the cylinders 180 counter-clockwise.* 4. *Close the valve and pump pressure according to stated value.* 5. *Open the nuts about half a turn.* 6. *Open the release valve and remove the tool.*

Fig 11-9 HYD2A V2

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

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

19 **Mount the mounting screws 3V83F180** in the free thread holes and tighten the protecting nuts 4V86B269 by hand.

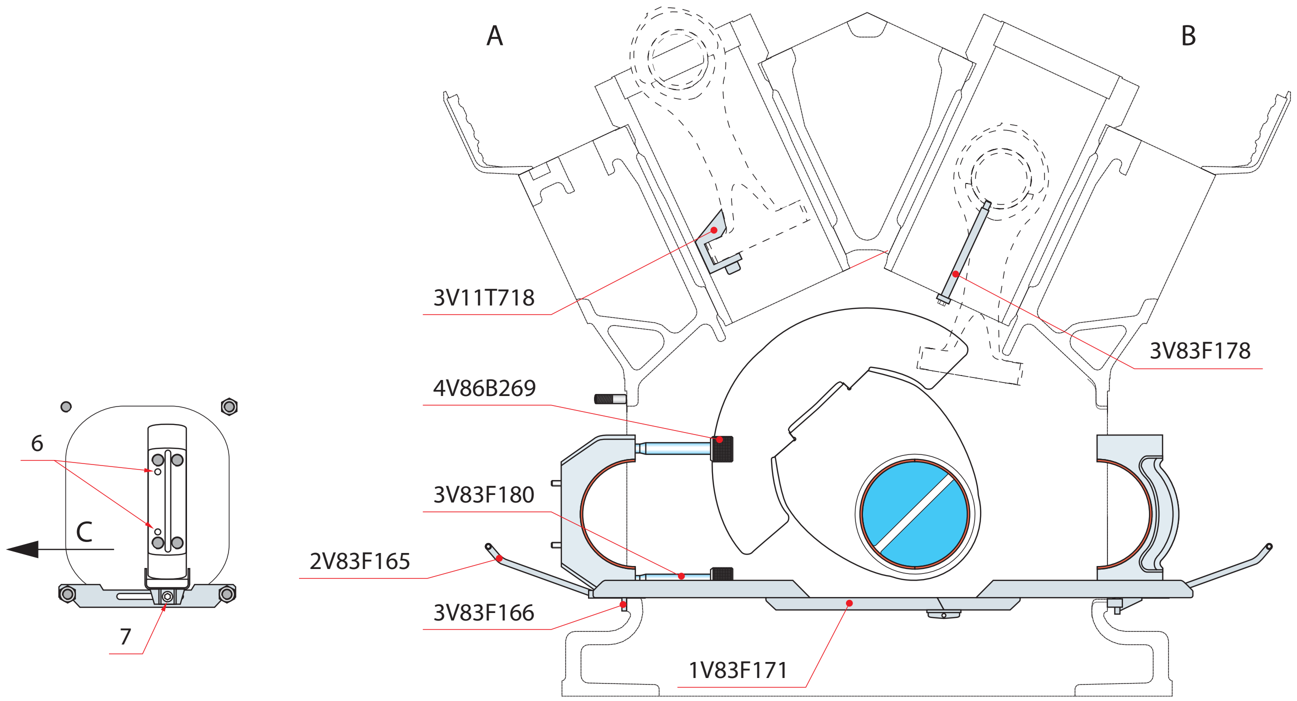
20 **Unscrew the other nuts** and remove the other studs as described above.

21 **Mount the assembly rail** through the crankcase openings on the lower crank case cover studs and tighten the nuts, see Fig 11-10. Lift the sledges on the rail.

22 **V-engine: Loosen the screw (7)** and adjust the side position of the rail correct and tighten the screw.

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

Removing and mounting of V-engine big end lower halves



A. *A-Bank* B. *B-Bank* C. *Free end* 6. *Guiding pins* 7. *Screw*

3V11T718 *Protecting rail*, 2V83F165 *Sledge*, 3V83F166 *Support*, 1V83F171 *Assembly rail*, 3V83F178 *Limiter*, 3V83F180 *Mounting screw*, 4V86B269 *Protecting nut*

Fig 11-10 V1

Note!
Observe extremely cautiousness always when assembling tools or/ and the limiter is/are mounted in the crankcase, when cranking the engine.

24 **Mount the support arm 3V83F163** on the upper threads (M24) of the big end and support arm on the upper crank case stud, see Fig 11-13. Tighten the nut.

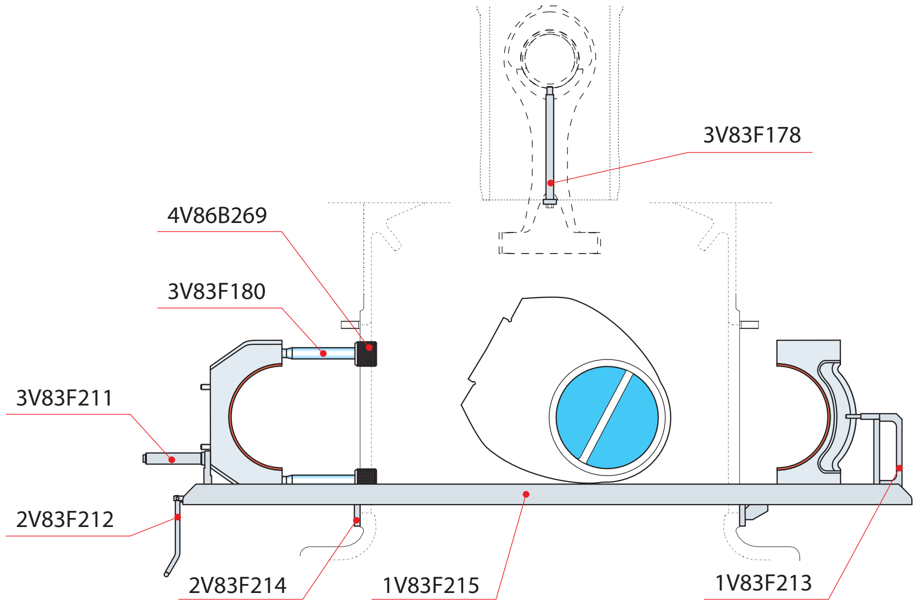
25 **Tighten the hand nut of the tool.**

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

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

28 **Apply the protecting nuts** 4V86B269 on the screws and remove the support arm.

Removing and mounting of In-line engine big end lower halves



3V83F178 *Limiter*, 3V83F180 *Mounting screw*, 3V83F211 *Fastening arm*, 2V83F212 *Sledge*, 1V83F213 *Sledge*, 2V83F214 *Support*, 1V83F215 *Assembly rail*, 4V86B269 *Protecting nut*

Fig 11-11 V1

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

Note!
Take care not to damage the crank pin.

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

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

32 **For mounting, see** section 11.3.4section 1.

11.3.3. Maintenance of piston, rings and connecting rod bearings

V5

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

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

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

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

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

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

5 **Measure the height** of the piston ring grooves e.g. with an inside micrometer and fill in the measuring record.

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

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

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

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

Note!
Mark new bearings with the bearing number.

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

11.3.4. Assembling and mounting of piston and connecting rod

V1

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

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

2 **Mount the securing ring (3).**

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

3 **Mount the assembly rail** through the crank case openings on the crankcase cover lower studs and tighten the nuts, see Fig 11-10 and Fig 11-11. Lift the sledges on the rail.

Note!
Observe extremely cautiousness always when assembling tools or/ and the limiter is/are mounted in the crankcase, when cranking the engine.

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

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

5 **Clean the big end upper half carefully.** Lubricate the bearing surface of the shell with clean engine oil. Mount the shell, so that the lug guides in its groove.

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

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

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

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

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

10 **Mount the support arm** on the upper crankcase stud, see Fig 11-13. Tighten the nut.

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

12 **Clean the big end lower half carefully.** Lubricate the bearing surface of the shell with clean engine oil. Mount the shell, so that the lug guides in its groove.

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

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

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

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

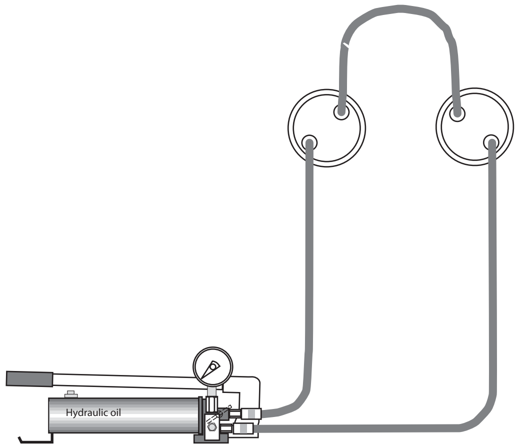
16 **Mount the studs** and tighten to the stated torque by using the tool 4V80D26, see section 07.3.1. Mount the nuts and tighten by hands.

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

18 **Lift the distance sleeves** and screw on the hydraulic tools 3V86B186 into position on the big end studs, places I and IV, see Fig 11-5 and proceed with tightening of the nuts in hydraulic pressure according to section 07.3.1.

Note!
Tighten crosswise in two steps.

Reassembling

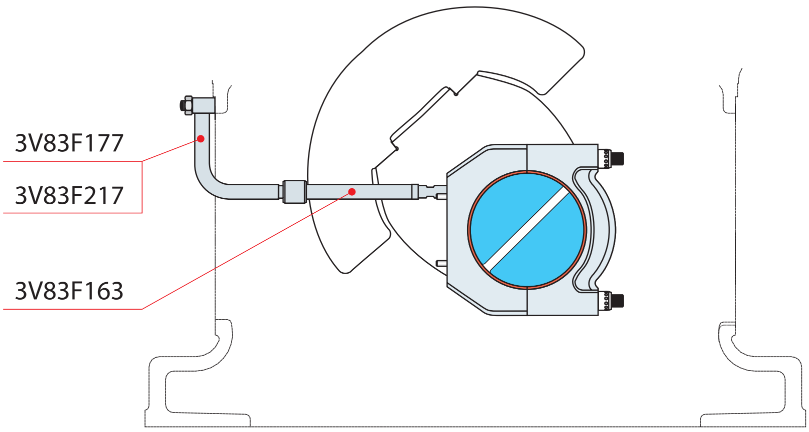


1. *Mount the nuts, the distance sleeves and the cylinders.* 2. *Connect the hoses, open the pressure release valve. Tighten the cylinders to expel oil out of these.* 3. *Close the valve and pump pressure to stated value for step 1.* 4. *Turn the nuts until close contact is reached.* 5. *Release the pressure by opening the valve.* 6. *Close the valve and pump pressure to the full stated value.*7. *Turn the nuts until close contact is reached.* 8. *Open the valve and remove the tool set.*

Fig 11-12 HYD2A V2

19 **Lift the distance sleeves** into position II and III, see Fig 11-5 and proceed with tightening of the nuts in hydraulic pressure according to section 07.3.1.

Mounting of the support arm



3V83F163 *Support arm*, 3V83F177 *Support arm for V-engine*, 3V83F217 *Support arm for In-line engine*

Fig 11-13 V1

20 **Release the pressure slowly by opening the valve.** Close the valve and rise the pressure to the fully stated pressure, according to section 07.3.1.

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

22 **Lift the distance sleeves** and screw on the hydraulic tools into position on the big end studs, places I and IV. Proceed with tightening of the nuts in fully stated pressure according to section 07.3.1.

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

Note!
Check that the connecting rod is movable axially after tightening.

24 **Fasten the lifting tool to the piston crown** by using hexagon screws (2), see Fig 11-7.

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

26 **Mount the piston rings** by using the pliers 320D12/6-S7/8. If rings are reused, take care not to turn them upside down. The rings should be placed with gaps located 120° in relation to each other. The marking "TOP" to be upwards.

Piston ring locations shown in the table below.

Groove #	Marking near the ring gap
I	"TOP C101 GROOVE I"
II	"TOP C67"
III	"TOP C79"

27 **Lubricate the piston** and place the clamp device for piston rings, 843000, around the piston, checking that the piston rings slide into their grooves.

28 **V-engines: Mount the protecting rail** 3V11T718 on the upper part of the connecting rod, see Fig 11-10.

29 **Mount the limiter** 3V83F178 for piston inside the cylinder liner.

30 **Place the mounting tool 3V83F105** into the cylinder liner.

31 **Lower the piston/connecting rod upper part** carefully into the cylinder liner.

32 **V-engines: Remove the protecting rail.**

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

34 **Rotate the crank pin** of the cylinder concerned in the position ~ 28° after TDC.

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

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

36 **Turn the crankshaft counterclockwise** until the studs (M24) and nuts can be mounted. Tighten studs to correct torque by using the tool 4V80D30, see section 07.3.1.

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

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

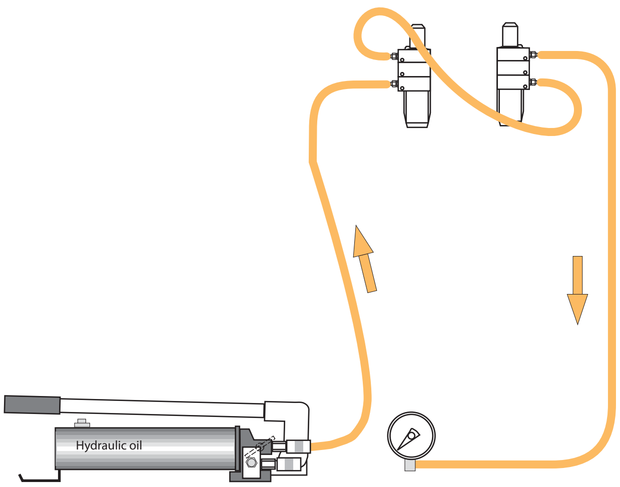
Note!
Before mounting of the tension screws, check that plastic plugs are mounted inside the tension screws.

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

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

41 **Connect the hoses** on the hydraulic pump 860100, see Fig 11-12.

Reassembling



1. *Lift the distance sleeve.*2.*Lift the hydraulic cylinder and screws in a one package in pos.* 3.*Connect hoses, open valve.*4.*Tighten the tool assembly, until the piston and cylinder is on the same level.* 5.*Close the valve, tighten the tool, pump to required pressure. Tighten the nuts. Release the pressure slowly.* 6. *Repeat steps 4, and 5.* 7.*Open the valve slowly and remove the tool.*

Fig 11-14 HYD5A V1

42 **Open the release valve** and tighten the tool assembly to expel possible oil until the piston and cylinder are on the same level, see Fig 11-7.

This is very important as the effective stroke of the pistons is limited and due to that there is a great risk for insufficient tightening of the nuts, which may cause serious engine damage.

43 **Strain the screws by raising the pressure** to the value stated in the chapter 07, section 07.3.1 and tighten the nuts by the pin. Release the pressure slowly.

44 **Repeat the steps 42 and 43.** See Fig 11-12.

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

Note!
Check that all tools are removed from crankcase.

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

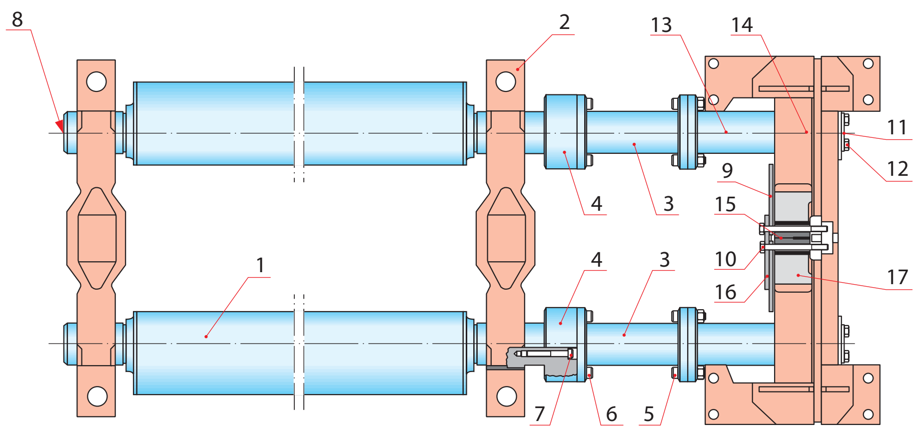
11.4. Balancing shaft mechanism for 4-cylinder engines

V5

The second-order free forces of the 4-cylinder in-line engines are completely counterbalanced by means of an arrangement, according to Fig 11-15, consisting of two eccentric shafts 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.

The shafts are pivoted in the bearing brackets (2), which are fastened to the engine block by means of hydraulically tightened screws. The shafts are driven from the crankshaft split gear through a gear drive.

Balancing shaft for 4R32



1. *Balancing shaft* 2. *Bearing bracket* 3. *Shaft piece* 4. *Shaft flange* 5. *Nut* 6. *Nut* 7. *Screw* 8. *Plug* 9. *Bearing shield* 10. *Screw* 11. *Washer* 12. *Screw* 13 .*Driving shaft* 14. *Drive gear* 15. *Journal* 16. *Washer* 17. *Intermediate gear*

Fig 11-15

V1

11.4.1. Removal of balancing shaft bearing bush

V3

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

2 **Loosen the nuts (5) and (6) and remove the shaft piece (3) from the shaft,** the bearing of which is to be removed.

3 **Loosen the screws (7) and remove the shaft flange (4).**

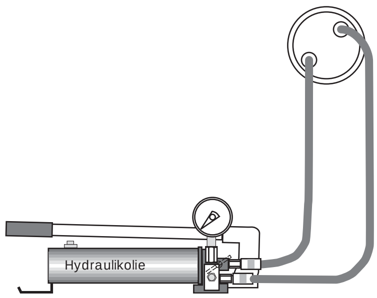
4 **Screw on the pulling screw,** 834040 see Fig 11-17A, to the end of the shaft from which the bearing is to be removed. When removing the bearing at the free end of the shaft, remove the centre plug (8) at first.

5 **Fit the split ring** 834040 between the bearing and the shaft inner shoulder. In order to keep the ring halves together, use e.g. a suitable thread and place it in the groove, on the ring.

6 **Apply the support** 834040 and the hydraulic tool 834050 and tighten the nut of the pulling screw 834040.

7 **Connect the hoses** of the hydraulic pump 860100 to the hydraulic tool.

Dismantling



1.*Mount the cylinder.* 2.*Connect the hoses and open the pressure release valve. Tighten the cylinder to expel oil.*3.*Turn the cylinder 180° counter-clockwise.* 4. *Close the valve and pump pressure according to stated value.* 5. *Open the nut about half a turn.* 6. *Open the release valve and remove the hydraulic tool.*

Fig 11-16 HYD V1

8 **Pump pressure** into the hydraulic tool to remove the bearing bush. Pressure must not exceed the value stated in the section 07.3.1. 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.

9 **Open the pump valve,** disconnect the hoses of the hydraulic tool and lift out the removing tool and bearing bush. Now the shaft end rests in the split ring which must not be removed until the bearing bush is reinstalled.

Balancing shaft bearing bush

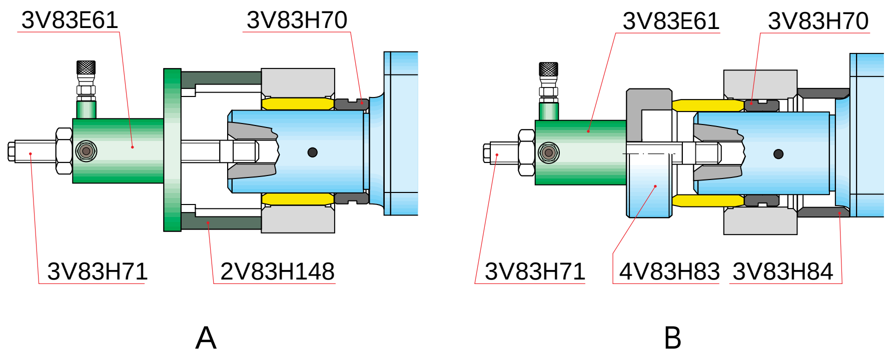


Fig 11-17 V1

11.4.2. Installing balancing shaft bearing bush V5

1 **Screw in the pulling screw** 834040 into the end of the shaft to which the bearing is to be mounted.

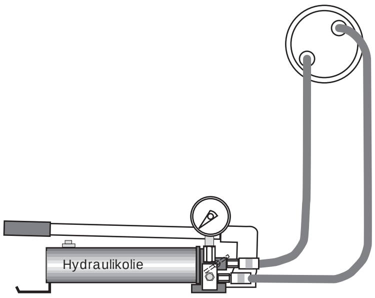
2 **Place the split ring 834040between the bearing housing and the outer shaft shoulder.** Keep the ring halves together by e.g. a suitable thread.

3 **Oil the bearing bush surfaces** lightly with clean engine oil and place the bush on the shaft end.

4 **Apply the pressure plate** 4V83H83 and the hydraulic tool 834050, and tighten the nut of the pulling screw.

5 **Connect the hoses** of the hydraulic pump 860100 to the hydraulic tool.

Reassembling



1. *Mount the nut, the distance sleeve and the cylinder.* 2.*Connect the hoses, open the pressure release valve. Tighten the cylinder to expel oil.* 3.*Close the valve and pump pressure to stated value.* 4.*Turn the nut until close contact is reached.* 5. *Release the pressure by opening the valve.* 6. *Close the valve and pump pressure to the full stated value.* 7.*Turn the nut until close contact is reached.* 8. *Open the valve and remove the tool set.*

Fig 11-18 HYD V1

6 **Pump pressure into the hydraulic tool** to press in the bearing bush. Pressure must not exceed the value stated in section 07.3.1. The bearing is in position when the pressure plate 4V83H83 rests against the bearing housing.

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

8 **Lock the centre plug** (8),Fig 11-15, in the free end of the shaft with Loctite 270 and tighten to the bottom position in case it was removed.

9 **Reinstall the shaft flange** (4), clean threads of fastening screws (7) thoroughly and apply Loctite 242 to them.

10 **Tighten the screws** (7) to the stated value.

11 **Reinstall the shaft piece** (3), clean the threads of the fastening screws (6) thoroughly and apply Loctite 242 to them.

12 **Tighten the screws** (5) and (6) to the stated torque.

11.4.3. Removal of balancing shaft gear

V1

1. **Turn the engine** into a position where the balancing shaft eccentrics point downwards.
2. **Loosen the fastening screws** (12) of the axial washers (11) at the free end of the shafts.
3. **Loosen the screws** (5) and (6) and remove the shaft pieces (3).
4. **Pull out the driving shafts** (13) and the drive gears (14).
5. **Loosen the fastening screws** (10) of the bearing shield (9) at all intermediate gears. The main bearing cap No. 1 must be lowered before undoing the fastening screws of the topmost intermediate gear. See chapter 10, section 10.1.1.
6. **Remove the bearing shield** (9) from the bearing journals by tightening the M8 screws in the extractor holes of the bearing shield. Tighten the screws in turn and as evenly as possible.
7. **Remove the topmost intermediate gear.** To do this, the main bearing cap No. 1 must be lowered. To remove the rest of the intermediate gear, lift the main bearing cap No. 1. See chapter 10, section 10.1.3.

11.4.4. Installing balancing shaft gear

V5

1. **Oil the sliding surfaces** of the bearing bushes with clean engine oil.
2. **Fit the intermediate gears** (17) on their respective journals (15). For fitting of the topmost intermediate gear, lower the main bearing cap No. 1.
3. **Reinstall the bearing shield** (9) and washers (16), and tighten the fastening screws (10) by hand.
4. **Tighten the fastening screws** (10) in turn at the intermediate gears and as evenly as possible.
5. **Tighten the fastening screws** (10) to the stated torque and secure with locking wire.
6. **Turn the engine** so that cylinder 1 is in TDC or BDC. In these positions, the balancing shaft eccentrics should point downwards. Now all the guiding pins between the shaft pieces are also in the bottom position.
7. **Reinstall the driving shafts** (13) and drive gears (14) in their respective bearing sites. The gears will mesh when the guiding pin hole in the shaft flange is right downwards.

8 **Reinstall the shaft pieces** (3), clean the threads of the fastening screws (6) thoroughly and apply Loctite 242 to them.

9 **Tighten the screws** (5) and (6) to the stated torque.

10 **Fit the axial washers** (11) and the fastening screws (12). Tighten to torque stated in chapter 07.1 and secure with locking wire.

Note!

Alternative design with a locking washer.

11.4.5. Removal and re-installation of balancing bearing bracket

V5

Normally, these connections should not be opened. The bearing brackets can, however, be removed by opening the screw connections by means of the hydraulic tool 861120, which is used for, among others, the connecting rod screws, see chapter 11, 11.3.1.

When re-installing, the screws are tightened to the value stated in the chapter 07.1 by using the same tool.

11B. Piston Overhaul

V2

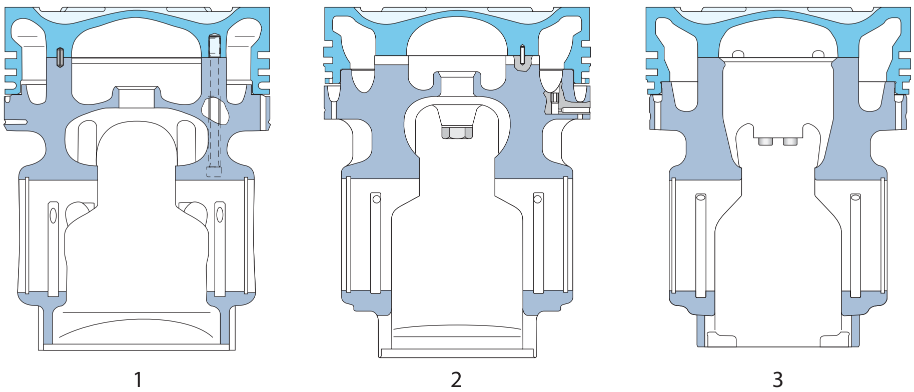
All the engines mentioned in the table below are fitted with composite type pistons.

Manufacturer/ type marked in Instruction Manual	Fastening screws for the crown	W32	32LN	W32 DF	W34 SG
KS / (type 1)	Four (4) M16 screws	X(1)	X		X
Mahle / (type 2)	Two (2) M22 screws	X	X	X	
Wecometal / (type 3)	Four (4) M14 screws	X	X		

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

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

Pistons



1. *Type 1 piston* 2. *Type 2 piston* 3. *Type 3 piston*

Fig 11B-1 321180 V1

11B.1. Pistons

V1

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

11B.2. Piston crown

11B.2.1. Visual inspection

V1

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

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

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

11B.2.2. Crack detection test

V1

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

- No cracks are allowed.

11B.2.3. Measurements

V1

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

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

11B.2.4. Reconditioning

V1

Please contact Wärtsilä for reconditioning of piston crowns.

Note!

No repair welding is allowed.

11B.3. Piston skirt

11B.3.1. Visual inspection V1

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

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

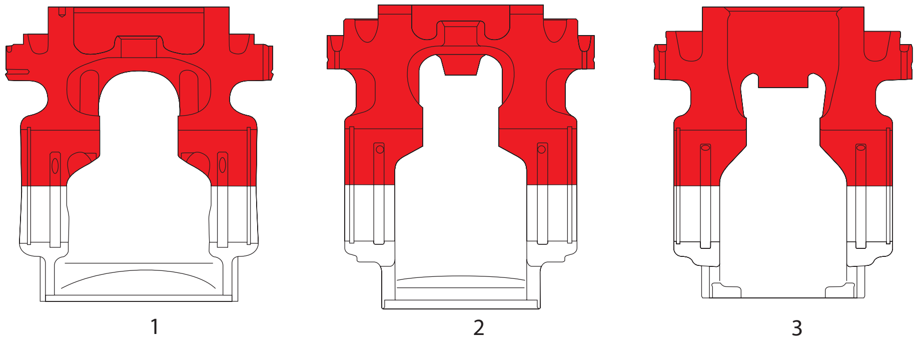
11B.3.2. Support surfaces V1

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

11B.3.3. Crack detection test V2

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

Piston skirt



1. *Type 1 piston* 2. *Type 2 piston* 3. *Type 3 piston*

Fig 11B-2 321181 V1

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

11B.3.4. Measuring of piston crown and piston skirt V1

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

11B.3.5. Assembling of pistons (All types) V4

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

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

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

12. Cylinder Head with Valves

V2

The cylinder heads are cast of special quality grey iron. Each head includes two inlet valves, two exhaust valves, a centrally located injection valve, a starting valve , a safety valve and an indicator valve.

Note!
In V-engines without a starter on B-bank, the starting valve is a dummy.

12.1. Removing and mounting of the cylinder head

12.1.1. Removing of the cylinder head

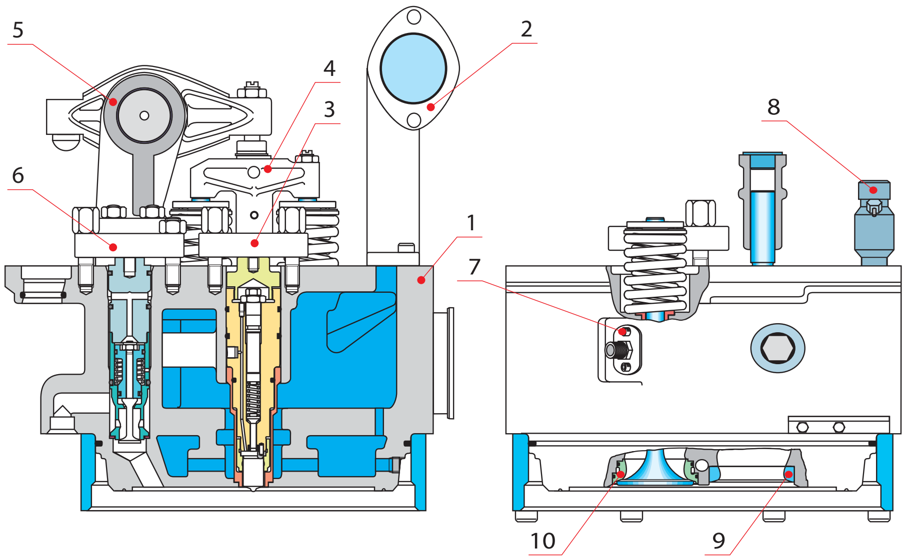
V1

1 **Drain the cooling water.** Remove the cooling water discharge pipe (2).

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

3 **Remove the fastening screws of the exhaust pipe clamp** and air pipe. Loosen the oil pipe and pilot starting air pipe.

Cylinder head



1. Cylinder head, 2. Discharge pipe, 3. Yoke for injection valve, 4. Yoke for valves, 5. Bearing bracket for rocker arms, 6. Yoke for starting valve, 7. Screw, 8. Indicator valve, 9. Inlet valve seat, 10. Exhaust valve seat.

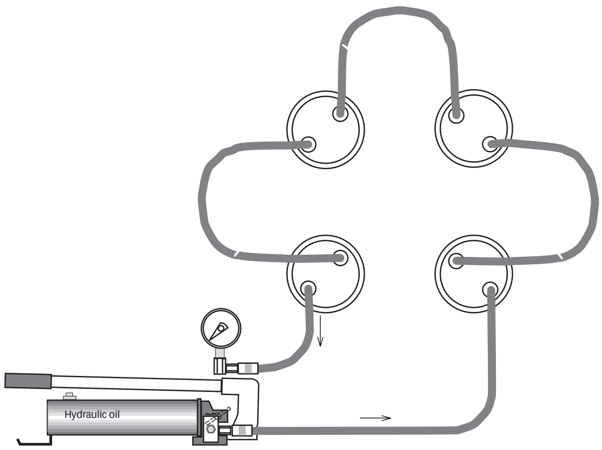
Fig 12-1

V1

4 **Remove the injection pipe.** Protect the connections of the injection pipe, oil pipe and exhaust pipes.

5 **Remove the covers of the cylinder head screws.** Put on the distance sleeves and hydraulic cylinders and proceed with opening of cylinder head nuts.

DISMANTLING



1. Screw on cylinders by hand, 2. Connect hoses, open valve. Tighten cylinders by hand, 3. Screw cylinders 180° counter-clockwise, 4. Close valve, rise pressure, 5. Open the nut about half a turn, 6. Open release valve, remove tool.

Fig 12-2 HYD V1

6 **Remove the cylinder head nuts.**

7 **Apply the lifting tool 832000.**

8 **Lift off the cylinder head.**

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

12.1.2. Mounting of the cylinder head

V2

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

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

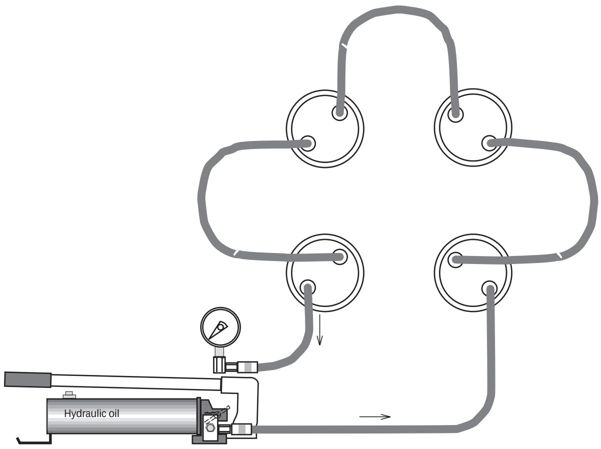
3 **Apply the lifting tool** to the cylinder head.

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

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

6 **Put on the distance sleeves, 832000** screw on the hydraulic cylinders and proceed with tightening of cylinder head nuts. See section 07.3.1

REASSEMBLING



*1. Screw on nuts, attach distance sleeve. Screw on cylinders by hand, **2.** Connect hoses, open valve, **3.** Tighten cylinders by hand, **4.** Close the valve and pump pressure to the stated value, **5.** Screw the nuts until close contact to face, **6.** Open the valve, 7. Repeat steps 4, 5 and 6, **8.** Remove tool set.*

Fig 12-3 HYD V1

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

8 **Connect the exhaust pipe,** charge air pipe, oil pipe and pilot starting air pipe. Fit the discharge pipe. Put on the exhaust pipe insulating piece.

9 **Adjust the valve clearance.**

10 **Put on the cylinder head cover** and injection pump cover.

11 **Before starting, fill the engine circulating water system.** Turn the crankshaft two revolutions, when the indicator cocks are open.

12.1.3. General maintenance of the cylinder head V2

The starting valves are dealt with in chapter 21.

When refitting the starting valves, the outer cylindrical surfaces should be lubricated with engine oil or a special lubricant.

The injection valves are dealt with in 16.

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

The safety valves should be lubricated with high temperature lubricant before refitting. A leaky valve should be replaced by a new one.

Indicator valve. The inside construction of the 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 12-4

Instructions for operation in some cases:

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.

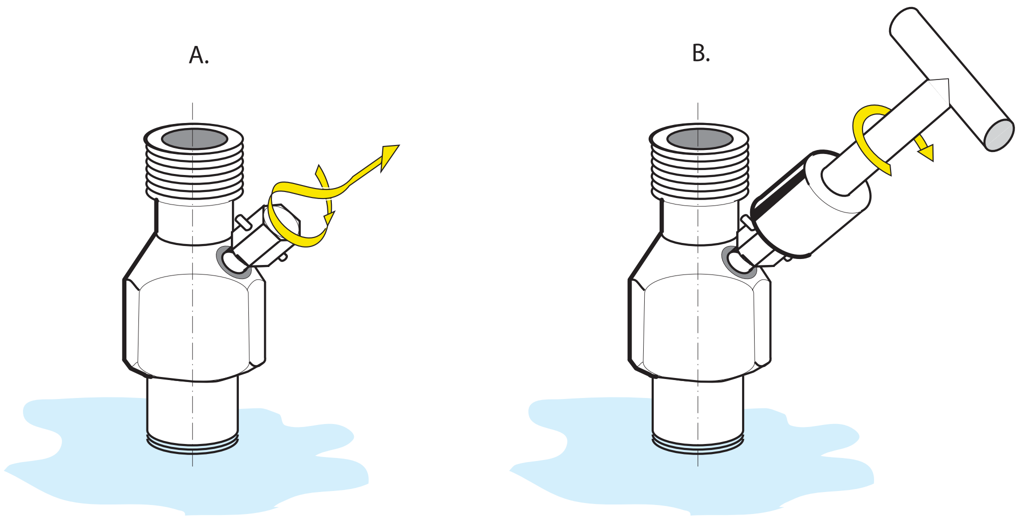
3 **When opening the indicator valve** for measuring the cylinder pressure, tightening to open position by force must be avoided.

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.

Note!
Use always a right T-handle wrench to open and close the indicator valve.

Open and close indicator valve



A. The cock moves upward when closing clockwise,

B. Always use the special handle when closing!

Fig 12-4 V1

12.1.4. Adjusting valve clearance and yoke

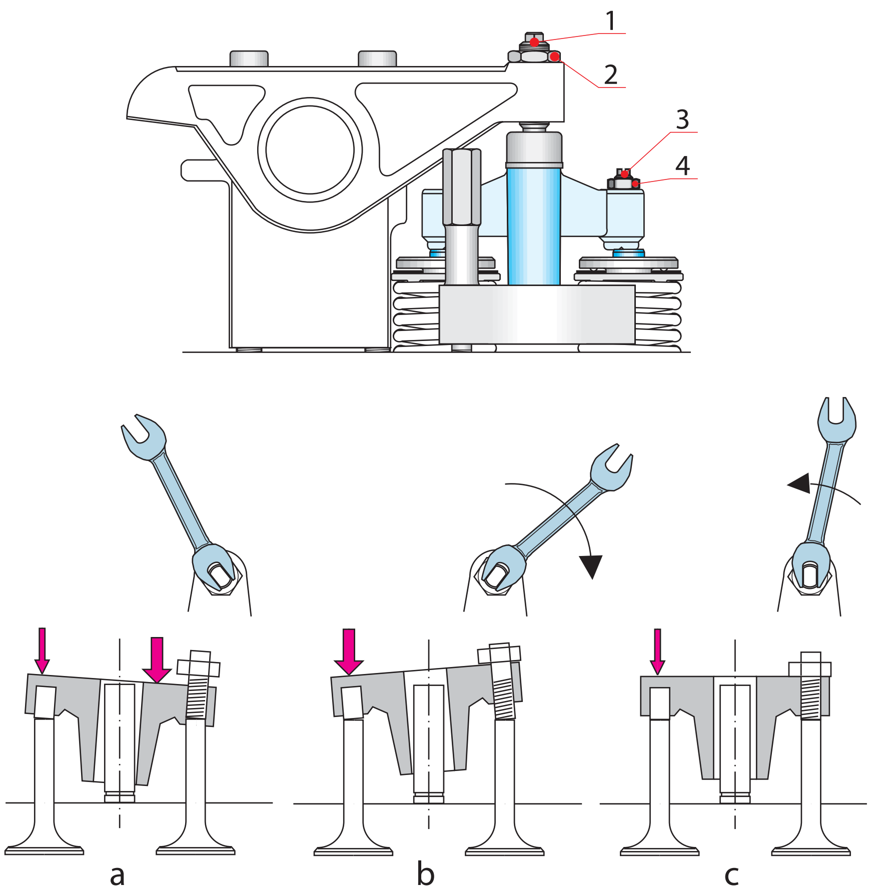
V2

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

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

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

Adjusting valve clearance



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

Fig 12-5

401203 V1

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

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

12.2. Maintenance of exhaust and inlet valves

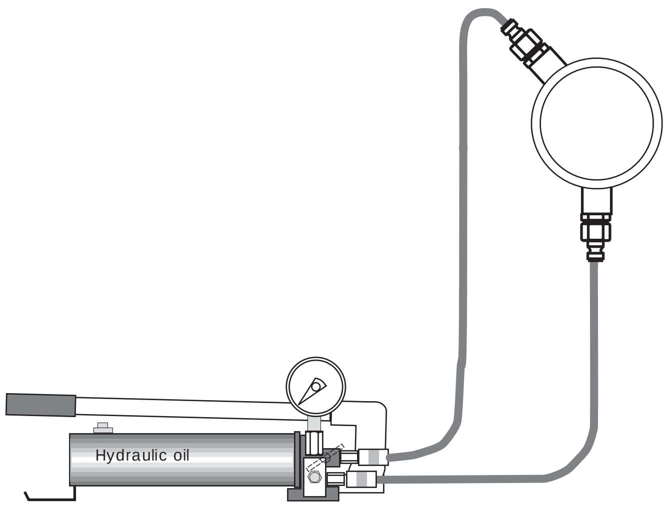
12.2.1. Dismantling valves

V1

1 **Fit the tool assembly 834000** according to Fig 12-7

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

DISMANTLING



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

Fig 12-6

HYD V1

2 **Connect the hydraulic pump 860100** and compress the valve springs 15 - 20 mm.

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

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

5 **Spring holders and springs can now be removed.**

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

Tool assembly for dismantling valves

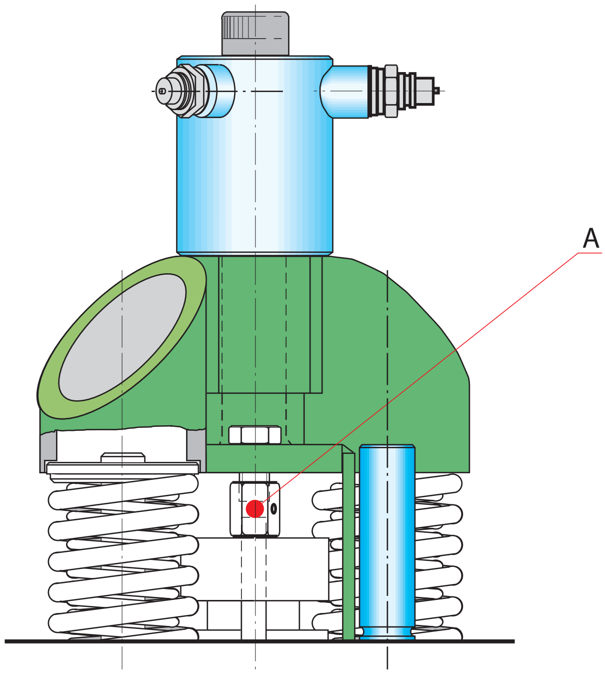


Fig 12-7

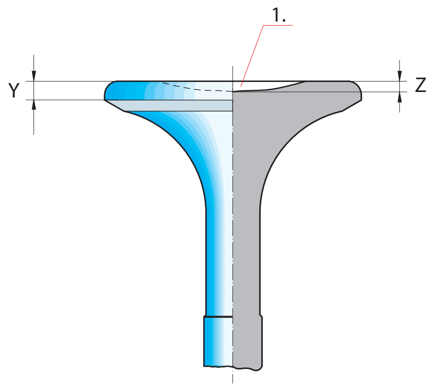
V1

12.2.2. Checking and reconditioning valves and seats V1

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

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

Control of burning-off on valve



1. Burn-off area.

Fig 12-8 V1

3 **Reconditioning of inlet valve and valve seat ring** is recommended to be done by grinding or by machining. If there is only slight pitting, lapping is adequate. Valve and seat ring grinding, see section 12.2.4

4 **Reconditioning of exhaust valve and valve seat ring** has to be done by grinding or by machining. If the sealing faces are bright or if there is a coherent sealing face, grinding is not necessary. Valve and seat ring grinding, see section 12.2.4

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

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

12.2.3. Lapping of inlet valves V1

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

1 **Fit the turning tool 841000** to the valve.

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

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

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

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

Note!
Lapping is not allowed for exhaust valves.

12.2.4. Machine grinding of exhaust and inlet valves V1

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

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

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

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

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

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

12.3. Change of seat ring

12.3.1. Removal of the old ring V1

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

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

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

12.3.2. Fitting a new inlet valve seat ring V1

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

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

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

12.3.3. Fitting a new exhaust valve seat ring V1

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

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

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

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

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

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

6 **Mount the sealing rings** on the cooled valve seat.

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

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

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

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

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

12.3.4. Reassembling of the engine valves

V1

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

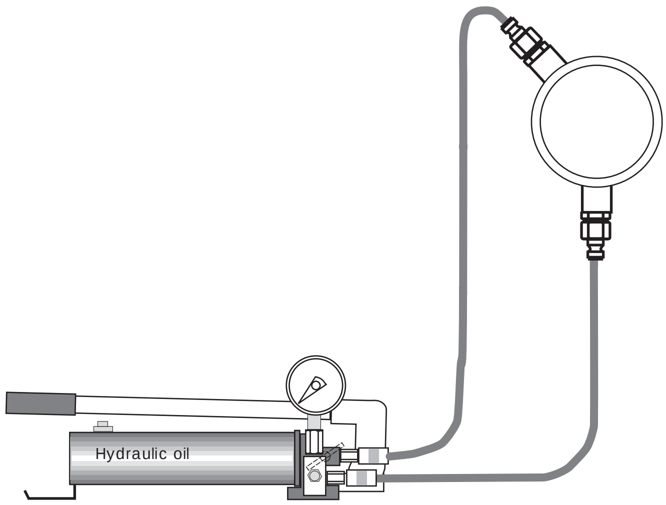
2 **Put new seal rings** in the valve guides.

3 **Lubricate the valve stems** with engine oil.

4 **Put in the valves** and check for free movement.

5 **Put on the springs** and spring discs or rotators. Compress the springs with the tool set 834000. Put in the valve cotters and unload the springs. Check that the valve cotters fit properly.

REASSEMBLING



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

Fig 12-9 HYD V1

12.3.5. Pf "Maximum firing pressure", measured at the indicator valve

V1

It is recommended to measure the Pf by using an electronic tester.The Pf "Maximum firing pressure" has to be measured as an average of at least 32 cycles. Operation and adjustments of the amplifier, see the tester manual.

12A. Testing the cylinder tightness

V5

Note!
Test the cylinder tightness immediately after the engine has stopped.

A tool can be used to control the cylinder and valve tightness.

1 Turn the appropriate piston to ignition TDC (all valves closed) for the cylinder concerned.

12A.1. Connecting the tool for Vasa 32

V7

1 Connect the tool to the open indicator valve. .

Testing the cylinder tightness

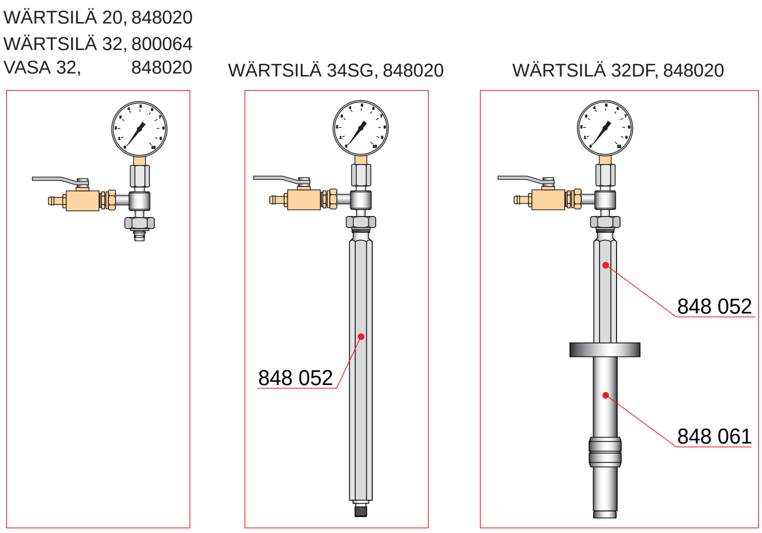


Fig 12A-1 321260 V1

2 Measure the cylinder tightness. See section 12A.2

12A.2. Measurement

V3

1. Connect air to the tool with a pressure of 6-7 bar (= normal working air pressure).
2. Open the valve on the tool and record the pressure.
3. Close the valve.
4. Measure the time (in seconds) it takes for the pressure to drop to 0.5 bar .

- If the pressure from the beginning was 6 bar and it takes more than 10 sec. for the pressure to drop to 0.5 bar, the result is acceptable.
- If the pressure drops directly to 0 bar, it is possible that one or more valves are sticking or the valve(s) are burnt.

  A sticking valve will be indicated by the immobility of the valve when the engine is turned.

  A burnt valve can normally be seen from the exhaust temperature. If the valve clearance is zero, it will also cause a direct pressure drop.
- Carbon particles that were trapped between the valve and the seat when the engine was stopped, could also prevent the valve from closing properly thus causing a direct pressure drop. If this is suspected, the engine should be run for a few minutes and the test repeated.
- If a blow-by between the cylinder liner and piston is suspected e.g. due to the fast fouling of filters or high crankcase pressure, it is best to test all the cylinders and compare the readings.

  For example: From a six cylinder engine you get a serial: 12, 17, 15, 4, 19 and 18 seconds.

  This shows that cylinder No. 4 is the one where blow-by is to be suspected.

  This conclusion can be verified by listening for leaking sounds inside crankcase during testing.
- If time restrictions only allow the overhaul of one piston, the piston of the cylinder with the worst blow-by should be dismantled and inspected. The result of the inspection will give some indication of the general engine condition.
- When testing the cylinder after an overhaul, a rapid pressure drop can be observed. This is because the pistons have not been run-in.

Note!
Keep pre-lubricating pump running during test.

Note!
The turning gear should be engaged during test.

- In general, the location of leakage can be found by listening when the air valve is open.

Note!
The general condition of an engine is indicated with the test device, but the operation data records are more important. Overhaul the engine at the recommended intervals; do not wait until a test such as this indicates a fault.

13. Camshaft Driving Gear

V2

The camshaft is driven by the crankshaft through a gearing. The gear wheel (1) is split and fixed to a flange on the crankshaft by the axial screws (2). These screws as well as the fastening screws (25) are locked with Loctite 262.

The bearing shafts (26) and the intermediate wheels (3), (10) and (11) are journalled in the engine block.

The camshaft driving wheel (12) is fixed to the camshaft end (24) by a guiding pin (20) and fastened by means of a flange connection between the end and the camshaft extension (14). The camshaft driving wheel supports a helical gear wheel (22) for the speed governor drive, and the camshaft extension is equipped with an overspeed trip (15). Lube oil nozzles provide for lubrication and cooling of the gearing.

13.1. Intermediate gears

13.1.1. Removing of camshaft gearing

V1

1 **Remove the gearing covers, the adjacent camshaft covers and half of the camshaft bolts (13),** see Fig 13-2. Turn the crankshaft to TDC at firing for cylinder No.1.

2 **Remove concerned oil distributing pipes, oil sprays and the governor drive.**

3 **Unscrew the fastening screws (18)** for the housing of the overspeed tripping device (15) and remove the cover (17).

4 **Unscrew the fastening screws (16),** and remove the overspeed tripping device (15) and the housing (19).

5 **Remove the cover (6),** Fig 14-2, from the starting air distributor at the free end of the camshaft (in-line engine and V-engine, A-bank).

6 **Unscrew the remaining flange connection screws (13) and remove the camshaft extension (14).**

7 **Unscrew the fastening nuts (1),** of all rocker arm brackets Fig 14-1, only on the A-bank for a V-engine. Move the camshaft in the direction of the free end (max. 25 mm) by using a suitable lever or the hydraulic jack, and lift the camshaft driving wheel out.

8 **Unscrew the cover fastening screws (7).** Remove the cover (32). Unscrew the shaft plate fastening screws (8) and remove the shaft plate (31).

9 **Remove the outer thrust bearing ring (30).**

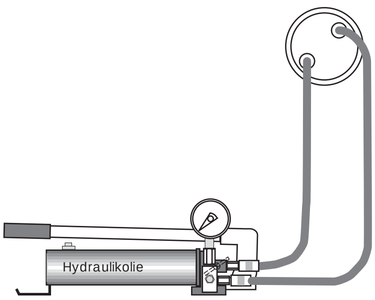
10 **Unscrew the housing fastening screws (9) and remove the housing (5).**

11 **Remove the inner thrust bearing ring (29).**

12 **Unscrew the extension shaft fastening screws (27) and remove the extension shaft (28).** Secure the intermediate wheels (10) and (11) in a nylon strap.

13 **Apply distance sleeve 3V86B135** and hydraulic cylinder 3V86B150 to the fastening bolt (6) and remove the nut (33).

Dismantling



1.*Mount the cylinder.* 2.*Connect the hoses and open the pressure release valve. Tighten the cylinder to expel oil.*3.*Turn the cylinder 180° counter-clockwise.* 4. *Close the valve and pump pressure according to stated value.* 5. *Open the nut about half a turn.* 6. *Open the release valve and remove the hydraulic tool.*

Fig 13-1 HYD V1

14 **Remove the shaft (35).** The shaft can be pulled out by using suitable screws, i.e. M8 screws.

15 **Unscrew the bolt (6)** by using the tool 3V84G189 803005.

16 **Remove the intermediate gear wheel (11).**

17 **Remove the intermediate wheel (10).** Using lifting tools will make the gear wheel handling easier.

18 **Remove the intermediate wheel (3)** by proceeding as with the intermediate wheels (10) and (11).

Note!
Even though the design of both intermediate gear shafts is similar, the parts must not be mixed with each other.

13.1.2. Mounting of the camshaft gearing

V2

1 **Turn the crankshaft as follows:**

a) In-line engine: Turn crankshaft to TDC for cylinder No.1.

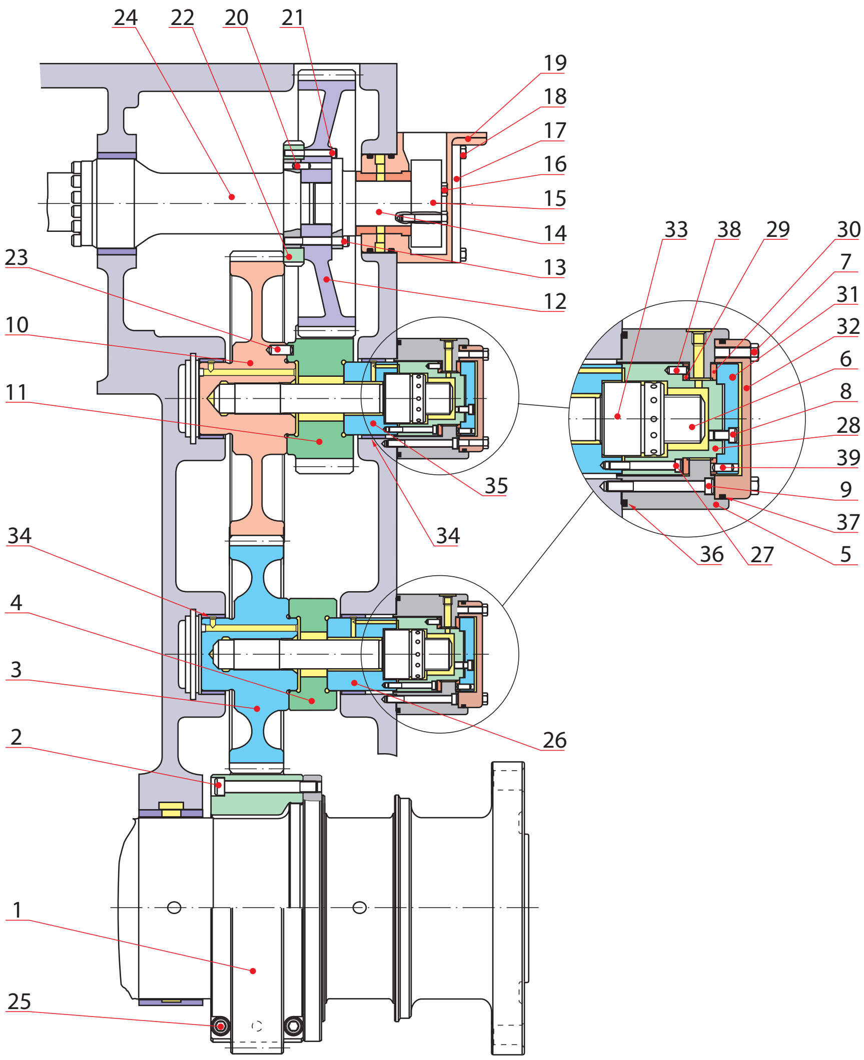
b) V-engine; camshaft gearing of both cylinder banks removed: Turn crankshaft to TDC for cylinder No.A1.

c) V-engine; gearing of A-bank mounted, gearing of B-bank removed: Turn crankshaft to TDC at ignition for cylinder No.A1. Then turn 50° in direction of TDC for cylinder No.B1.

d) V-engine; gearing of B-bank mounted, gearing of A-bank removed: Turn crankshaft to TDC at ignition for cylinder No.B1. Then turn 50° in direction of TDC for cylinder No.A1.

Note!
Make sure that the crankshaft is in TDC at ignition for cylinder No.1 in an in-line engine and for respective bank in a V-engine before proceeding with the job.

Camshaft driving gear



1. *Gear wheel* 2. *Screw* 3. *Intermediate gear wheel* 4. *Distance sleeve* 5. *Housing* 6. *Cover* 7. *Screw* 8. *Screw* 9. *Screw* 10. *Intermediate wheel* 11. *Intermediate wheel* 12. *Driving wheel* 13. *Camshaft screw* 14. *Camshaft extension* 15. *Overspeed trip* 16. *Screw* 17. *Cover* 18. *Screw* 19. *Housing* 20. *Guiding pin* 21. *Screw* 22. *Gear wheel* 23. *Pin* 24. *Camshaft end* 25. *Screw* 26. *Bearing shaft* 27. *Screw* 28. *Extension shaft* 29. *Bearing ring* 30. *Bearing ring* 31. *Shaft plate* 32. *Cover* 33. *Nut* 34. *Bearing* 35. *Shaft* 36. *O-ring* 37. *O-ring* 38. *Guiding pin* 39. *Pin*

Fig 13-2 V2

2 **Lift the intermediate wheel (3)** into position. The wheel must be tilted, when inserted, to get free from the rib in the engine block.

Note!
Insert the intermediate gear wheels and bearing bushes according to the marking of the wheels, see Fig 13-4 and Fig 13-5.

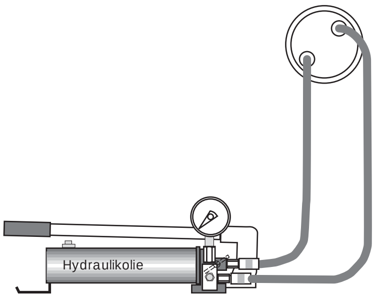
3 **Insert the distance sleeve (4).**

4 **Screw in the bolt (6)** and tighten to the torque stated in section 07.1.

5 **Insert the shaft (26).**

6 **Tighten the nut (33)** by hydraulic cylinder 861144 to stated pressure. Release the pressure and pump to stated pressure again. Tighten the nut finally and release the pressure.

Reassembling



1. *Mount the nut, the distance sleeve and the cylinder.* 2.*Connect the hoses, open the pressure release valve. Tighten the cylinder to expel oil.* 3.*Close the valve and pump pressure to stated value.* 4.*Turn the nut until close contact is reached.* 5. *Release the pressure by opening the valve.* 6. *Close the valve and pump pressure to the full stated value.* 7.*Turn the nut until close contact is reached.* 8. *Open the valve and remove the tool set.*

Fig 13-3 HYD V1

7 **Mount the guiding pin (38)** and insert the extension shaft (28). Tighten the screws (27) to the stated torque.

8 **Insert the inner thrust bearing ring (29)**

9 **Mount the O-ring (36)** in the housing (5) and insert the housing. Tighten the screws (9) to the stated torque.

10 **Insert the outer thrust bearing ring (30).** The gear wheels should be in the outer most position to achieve the correct axial bearing clearance.

11 **Mount the pin (39) to the shaft plate (31),** and insert it. Apply Loctite 242 to the screws (8) and tighten crosswise to the stated torque. Insert the cover (32) and the O-ring (37) and tighten the screws (7) crosswise to the stated torque.

12 **Check the axial bearing clearance** for the gear wheel (3) and the backlash between the wheels (1) and (3).

13 **To get the intermediate wheels (10) and (3) into the correct position,** mark the meshing teeth of both wheels (10) and (3) with a pencil according to Fig 13-4 and Fig 13-5. (The wheel (10) can be marked before mounting by marking the third tooth downwards from a line drawn from the centre point of gear wheel (10), through the dowel pin in the wheel (10)).

Note!
V-engines: Do not install the intermediate wheel (10) before camshaft end (24) is installed. Place the intermediate wheel (10) as low as possible in gear train.

14 **Mount the gear wheel (10)** to the engine block according to meshing marks.

15 **Mount the gear wheel (11) to the wheel (10)** The dowel pin of the wheel (10) should be in the middle of the groove in the wheel (11) to get enough timing adjustment allowance.

16 **Screw in the bolt (6).**

17 **Insert the shaft (35).**

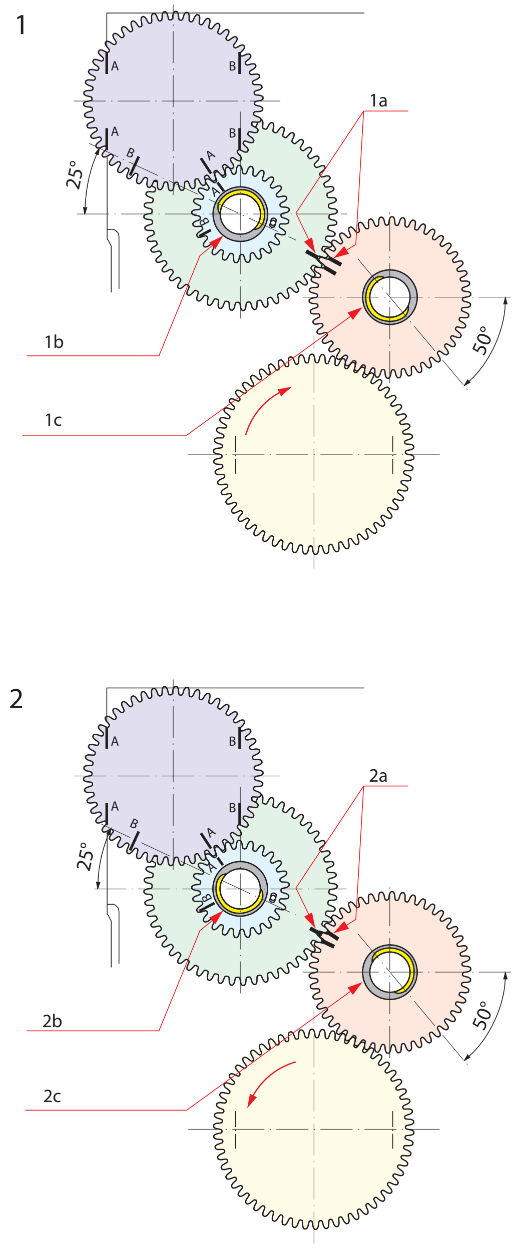
18 **Tighten the nut (33)** by hand.

19 **Check the backlash** between the wheels (10) and (3).

20 **Lift the camshaft driving wheel (12) into position.** The marks on the wheels should be aligned with the edge of the engine block according to Fig 13-4 and Fig 13-5.

21 **Fit the camshaft extension (14),** push the camshaft into position, guided by the pin (20), and tighten the flange connection screws (13).

Marking of the intermediate gear wheels, in-line engines



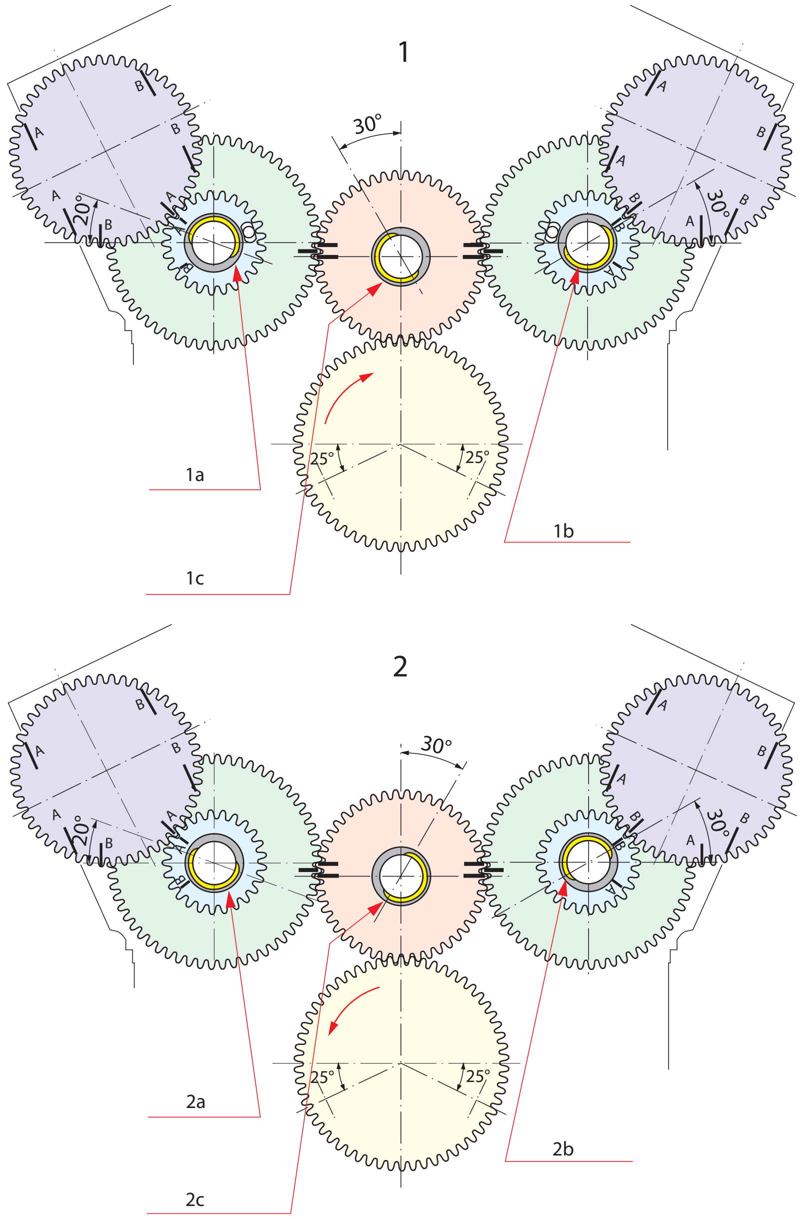
1. *Clockwise rotating engines (seen from the flywheel end)* 1a. *Mark with a pencil.* 1b. *Note the bearing bush position! Groove upwards, 25° clockwise.* 1c. *Note the bearing bush position! Groove downwards, 50° clockwise.*

2. *Counter clockwise rotating engines* 2a. *Mark with a pencil.* 2b. *Note the bearing bush position! Groove downwards, 25° clockwise.* 2c. *Note the bearing bush position! Groove upwards, 50° clockwise.*

Fig 13-4 V2

22 **Mount the overspeed trip housing (19)** and the overspeed trip device (15) and tighten the screws (16). On the V-engine B-bank, the overspeed trip housing and overspeed trip device are substituted by a bearing housing and an end flange.

Marking of the intermediate gear wheels, V-engines



1. *Clockwise rotating engines (seen from the flywheel end)* 1a. *A-bank. Note the bearing bush position! Groove upwards, 20º clockwise.* 1b. *B-bank. Note the bearing bush position! Groove downwards, 30º counter clockwise* 1c. *Note the bearing bush position! Groove towards A-bank, 30º counter clockwise.*

2. *Counter clockwise rotating engines* 2a. *A-bank. Note the bearing bush position! Groove downwards, 20º clockwise.* 2b. *B-bank. Note the bearing bush position! Groove upwards, 30º counter clockwise* 2c. *Note the bearing bush position! Groove towards B-bank, 30º clockwise.*

Fig 13-5 V2

23 Lock the screws (16) with locking wire or alternative design with Loctite and mount the cover (17).

24 **Check the axial bearing clearance** for the camshaft and the backlash between the wheels (11) and (12).

25 **Mount the oil sprays.**

26 **Check the valve timing** of one cylinder and the fuel timing. On the V-engine, check the firing sequence of the cylinder banks. If necessary, the timing can be adjusted by loosening nut (33) slightly so that the gears (10) and (11) can be moved in relation to each other. Tighten the nut (33) according to step 6 above after adjustment and recheck timing.

27 **Proceed with tightening** of screws and nuts according to step 7 - 11 above.

28 **Mount the oil distributing pipes and the covers** for the gearing, cam-shaft and starting air distributor.

29 **Check the axial bearing clearance** and the tooth clearance between the wheels (10) and (3).

Axial positions of bearings

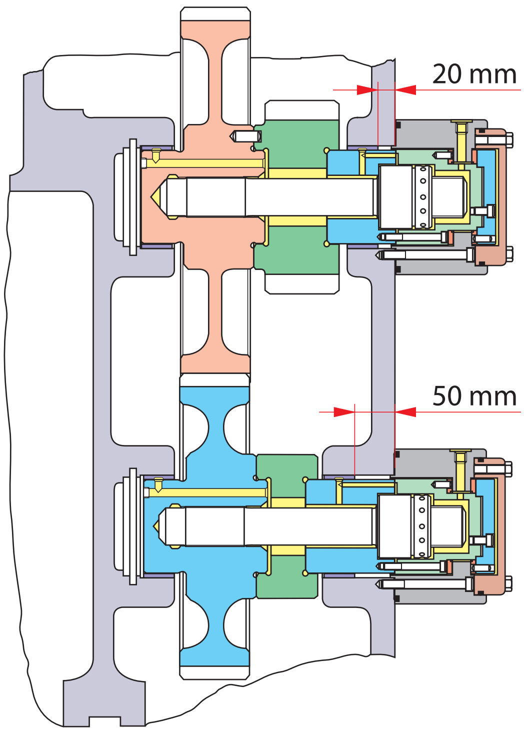


Fig 13-6 V2

13.2. Split gear

V1

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.

13.2.1. Removing of the split gear wheel

V2

After the gearing is removed according to section 13.1.1, the split gear wheel (1) can be removed from the crankshaft.

1 **Lower the bearing cap** for main bearing No. 1, see chapter 10, section 10.1.1.

2 **Loosen the fastening screws (25).**

3 **Unscrew the axial screws (2).**

4 **Unscrew the fastening screws (25)** and remove the gear wheel halves.

13.2.2. Mounting of the split gear wheel

V2

1 **Clean the parting surfaces of the wheel halves** and the contact faces of the gear wheel and the crankshaft.

2 **Lower the bearing cap for main bearing No.1,** see chapter 10, section 10.1.1.

3 **Apply Loctite 262 on the threads of the screws (2) and (25).**

4 **Mount the gear wheel halves on the crankshaft** with the parting face at right angles with the crank of cylinder No.1 and fasten the screws (2) and (25) by hand.

5 **Tighten the axial screws (2)** to a torque of 10 Nm and check that contact is established between the gear wheel and the crankshaft flange.

6 **Tighten the fastening screws (25)** to a torque of 40 Nm. The screws closer to the crankshaft flange are to be tightened at first.

7 **Tighten the fastening screws (25)** to stated torque. The tightening order is the same as in the previous point.

8 **Tighten the axial screws (2)** to the stated torque.

9 **Check the gear wheel roundness.** Place a cylindrical pin (ø16 mm) in the tooth gap as shown in Fig 13-7. Turn the engine and use a dial indicator to get an indication for the diameters. The maximum permissible difference between the measured values is 0.05 mm .

10 **Lift the bearing cap for main bearing No.1,** see chapter 10 section 10.1.1.

Measuring split gear wheel

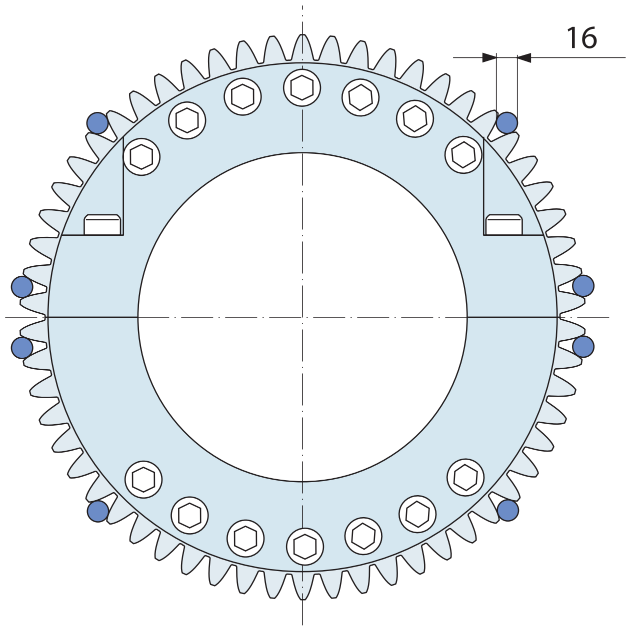


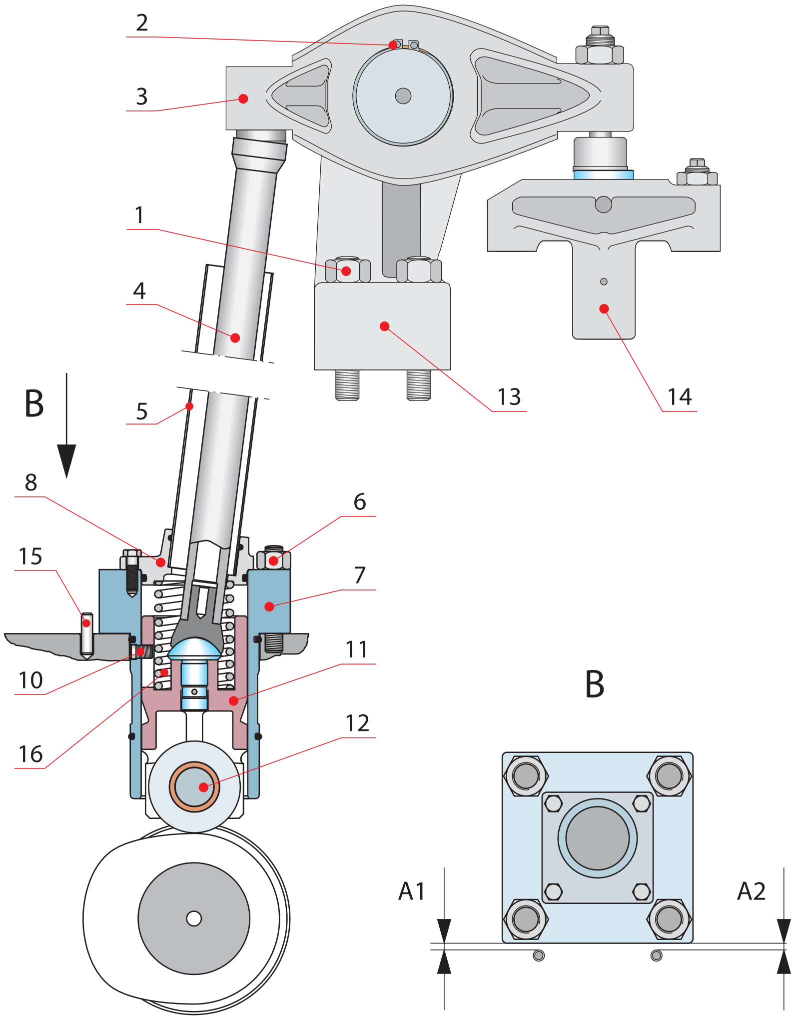
Fig 13-7 V2

14. Valve Mechanism and Camshaft

14.1. Valve mechanism V1

The valve mechanism consists of valve tappets (11) of the piston type moving in separate guide blocks (7) of cast iron, tubular push rods (4) with ball joints, nodular cast iron rocker arms (3) journalled on a rocker arm bearing bracket (13), and a yoke (14) guided by a yoke pin.

Valve mechanism



1.*Nut,* 2.*Retainer ring,* 3.*Rocker arm,* 4.*Push rod,* 5.*Protecting sleeve,* 6.*Nut,* 7.*Guide block,* 8.*Cover,* 10.*Guiding pin,* 11.*Valve tappet,* 12.*Bearing journal,* 13.*Bearing bracket,* 14.*Yoke,* 15.*Cylindrical pin,* 16.*Spring.*

Fig 14-1 V1

14.1.1. Dismantling of valve mechanism V1

1 **Remove the covers** of the valve mechanism and camshaft from the cylinder concerned.

2 **Turn the crankshaft** to a position where the valve tappet rollers of the valves are on the base circle of the cam.

3 **Unscrew the nuts (1)** and remove the rocker arm bearing bracket (13) from the cylinder head.

4 **Remove the retainer rings (2)** and rocker arms (3) for inspection. To remove the retainer rings, use pliers A40 DIN 5254.

5 **Remove necessary pipes.**

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

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

8 **Remove the cover (8)** and the guiding pin (10). An M6 screw can be used to remove the pin.

Caution!
When removing the cover (8), note that it is spring loaded.

9 **Remove the valve tappet (11)** and dismantle by removing the bearing journal (12). Before dismantling, mark the parts for mounting into the original positions.

14.1.2. Inspection of valve mechanism parts V1

1 **Clean the rocker arm bearing bush** and the journal and measure for wear. When cleaning, pay special attention to the oil holes.

2 **Clean and inspect all parts of the valve tappet and guide block.** When cleaning, pay special attention to the angled oil holes.

3 **Measure the valve tappet bearing bush** and the journal as well as the cam roller for wear.

4 **Change all O-rings.**

14.1.3. Assembling of valve mechanism V2

1 **Mount the cover (8).**

2 **Lubricate the parts of the valve tappet** with clean engine oil and assemble. Observe the marks for correct positions.

3 **Insert the spring (16) and the valve tappet (11)** into the guide block (7) and apply the guiding pin (10).

4 **Mount the guide block** to the engine block and tighten the nuts (6).

5 **Check the parallelism** of the roller axis to the camshaft by measuring the distance to the cylindrical pins on both sides of the guide blocks with a feeler gauge, i.e. measures $A_1 = A_2$ according to Fig 14-1.
Tighten the nuts (6) to the right torque, acc. to section 07.1.

6 **Grease the O-rings,** insert the push rods (4) and protecting sleeves (5) into the guide block.

7 **Mount the yoke.** For adjusting the yokes, see section 12.1.4.

8 **Lubricate the rocker arm bearing bushes** and mount the rocker arms (3) on the bracket.

9 **Apply the retainer rings** (2) by using pliers A40 DIN 5254 and check the axial bearing clearance and free rotation of rocker arms.

10 **Mount the rocker arm bracket** on the cylinder head and tighten the nuts (1) to the torque, see section 07.1.

11 **Check the valve clearance** according to section 06.1.1 and mount the covers.

14.2. Camshaft

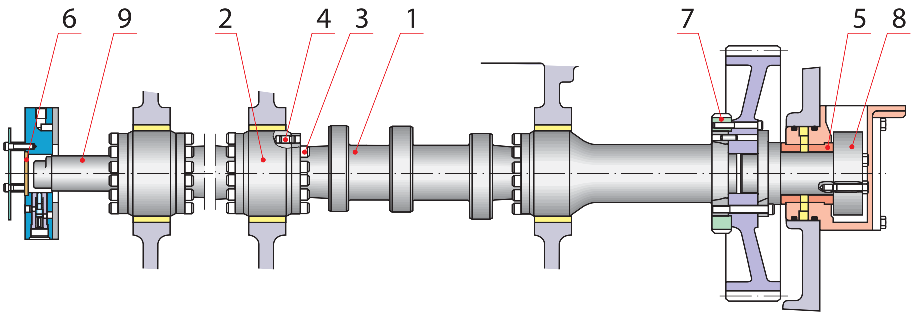
V2

The camshaft is built up of one-cylinder camshaft pieces (1) and separate bearing journals (2). The drop forged camshaft pieces have integrated cams, the sliding surfaces of which are case hardened. The bearing surfaces of the journals are induction hardened. The camshaft is driven by the crankshaft through a gearing at the driving end of the engine.

At this end (on A-bank in V-engine) the camshaft is equipped with an overspeed trip (8), an axial bearing (5) and a helical gear (7) for driving of the speed governor. At the free end, the camshaft has an extension (9) with a cam for operating the starting air distributor.

On a V-engine, B-bank, the camshaft has an axial bearing situated at the driving end, similar to A-bank.

Camshaft



1.*Camshaft piece,* 2.*Bearing journal,* 3.*Screw,* 4.*Fixing pin,* 5.*Axial bearing.* 6.*Cover,* 7.*Gear,* 8.*Overspeed trip device,* 9.*Extension piece,*

Fig 14-2

V1

14.2.1. Removing of camshaft piece V2

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

2 **Unscrew the flange connection screws (3)** from both ends of the camshaft piece by using the tool 806040. The flange connection screws are treated with a locking compound and can be used only once.

3 **Remove the cover** (6) from the starting air distributor and unscrew the rocker arm bracket fastening nuts and remove the rocker arm brackets of the cylinders in which the camshaft is to be axially displaced. Move the part of the camshaft locating towards the free end of the engine 15 - 20 mm in direction of the free end by using a suitable lever.

4 **Disengage the camshaft piece** from the centerings and fixing pins (4) and remove it sideways.

Note!
The rocker arm bearing brackets towards the free end side has to be removed if the crankshaft is turned, otherwise there will be contact between the valve and piston.

14.2.2. Mounting of camshaft piece V2

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

2 **Insert the fixing pins** (4) with retainer rings, the longer part of the pin in the bearing journal.

3 **Mount the camshaft piece** (1) on the fixing pin and centering at either end, then press the camshaft together. Use two or three mounting screws, not the fastening screws, because they are applied with locking glue.

4 **Insert the flange connection screws,** dry and tighten by using the tool 806040. The flange connection screws are treated with a locking compound and can be used only once.

Note!
Tighten the screws immediately to correct torque since the screws are treated with a locking compound.

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

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

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

15. Turbocharging and Air Cooling

V5

The turbochargers are of the axial turbine type. The insert type charge air cooler is mounted in a housing, which also serves as a bracket for the turbocharger. The housing is normally fitted to the free end of the engine. V-engines have two identical cooler inserts in a common housing.

The gas inlet and outlet housings of the turbocharger are cooled with water and connected to the engine cooling system. The turbocharger has its own lubricating oil system.

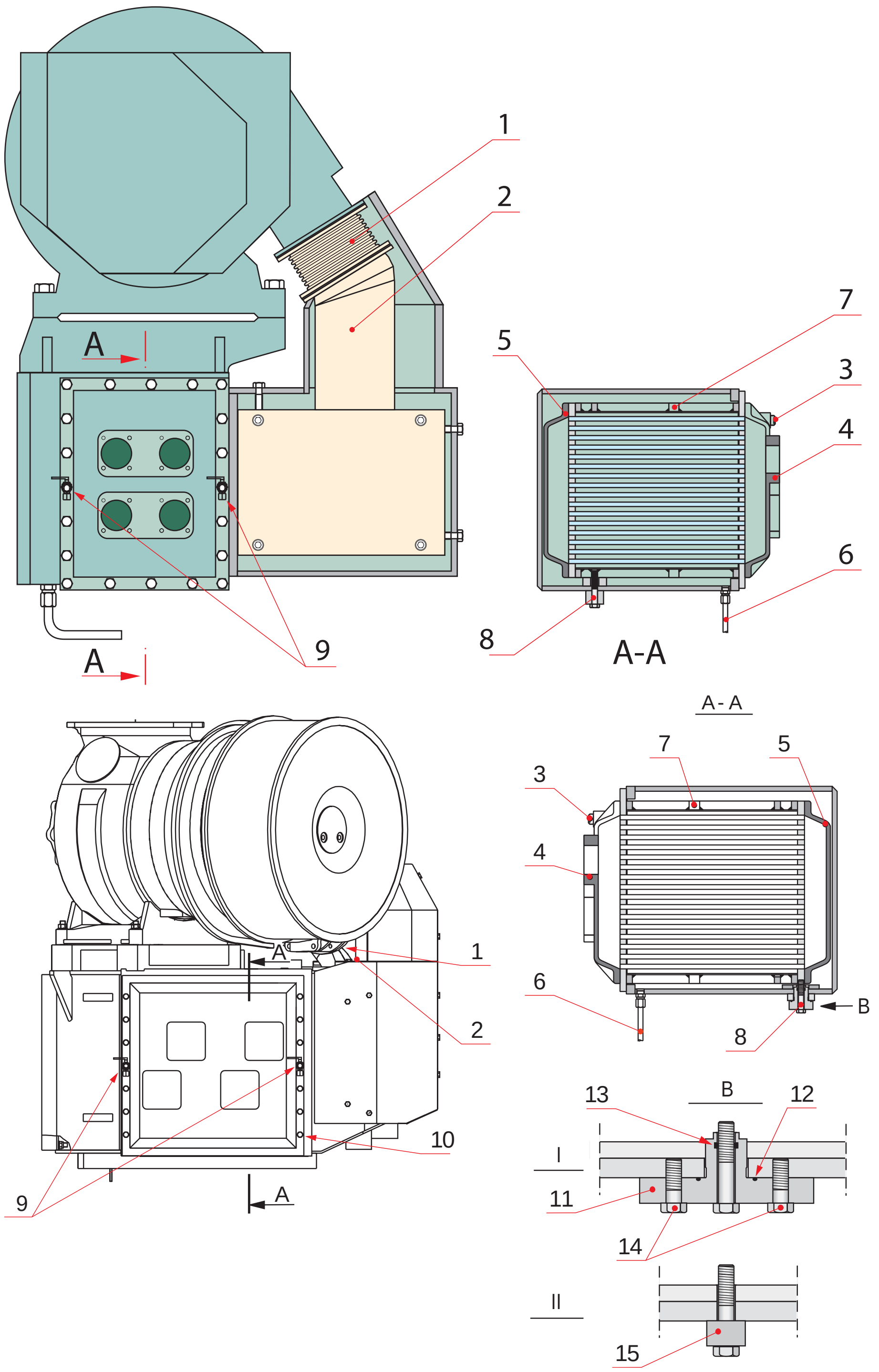
The turbocharger is connected to the engine lubricating oil system.

The charge air outlet is connected to the air duct (2) with metal bellows (1). The exhaust pipes from the engine are also connected to the charger with metal bellows.

The turbocharger is equipped with cleaning devices for cleaning both the compressor and the turbine by water injection.

Materials of the tubes and water boxes of the air cooler depend on the cooling medium used.

Turbocharger and air cooler



I*Alternative 1.*, II*Alternative 2.*

1. Bellows, 2. Air duct, 3. Air vent screw, 4. Header, 5. Header, 6. Drain pipe, 7. Thread hole for lifting tool, 8. Screw.9. Connections for diff. press. measuring, 8. Screw, 9. Connections for diff. press. measuring, 10. Screw, 11. Support pin, 12. O-ring, 13. O-ring, 14. Screw, 15. Sleeve.

Fig 15-1 V1

15.1. Turbocharger maintenance

V5

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 change the seals. High temperature resistant lubricants are used for exhaust pipe screws.

Maintenance of the turbocharger is carried out according to section 15.2.1 and to the instructions of the turbocharger manufacturer. It is recommended to use the service organisation of the engine manufacturer or the turbocharger manufacturer.

15.2. Water cleaning of turbocharger during operation

15.2.1. Water cleaning of turbine

V7

Water cleaning instructions for the turbine do not concern 34SG engines.

As practical experiences show, the dirt deposits on the turbine side can be reduced by periodic cleaning (washing) during operation. Dirty turbines cause higher temperatures of the exhaust gas and higher stresses of the bearings due to imbalances. Washing of the turbine side is necessary when running on heavy or light fuel. The wash interval when running on light fuel can be extended to ≥500 hour.

During long periods of operation, periodic water cleaning prevents the build-up of 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 have significant effect on the exhaust gas temperature level, hard deposits have probably built up on the nozzle ring and the turbine blades in the turbocharger, and they have to be cleaned mechanically. For that purpose, the rotor and the nozzle ring have to be removed from the turbocharger.

The water must be injected into the exhaust system with the engine running at reduced output, see Cleaning procedure. 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 according to the table. Additives or solvents must not be used in the cleaning water. The use of salt water is prohibited.

Turbocharger gas inlets are provided with an inlet valve for each exhaust pipe. The valves are connected to a quick-coupling.

Housings with several gas inlets are provided with an inlet valve for each exhaust pipe. The engine 4R32 is provided with two valves on the same pipe in case it has only one gas inlet (generating sets). The valves are connected to a quick-coupling .

The water washing of the turbine should be done as described in Cleaning procedure. The water flow is adjusted by flow meter to a recommended value.

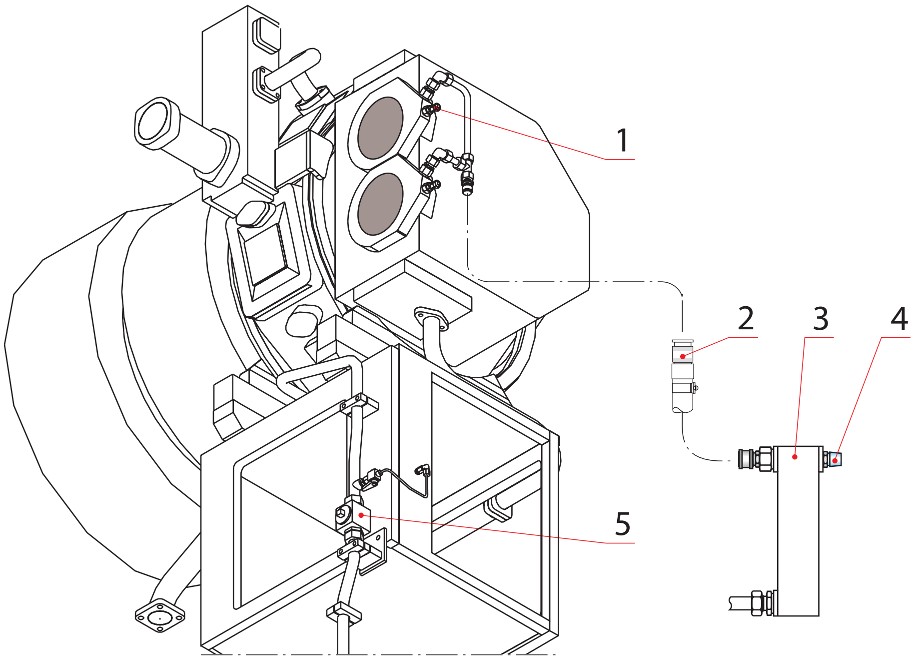
Water cleaning of turbine	
Water pressure	3.0...5.0 bar
Turbocharger size	Water flow (l/min)
VTR 254	13
VTR 304	16
VTR 354	28

Water cleaning of turbine	
Turbocharger size	Water flow (l/min)
TPL 65	13

During cleaning, the exhaust housing is drained through the valve.

Cleaning should take place regularly, see Maintenance Schedule . Depending on the results obtained, the interval between two washings can be increased or reduced.

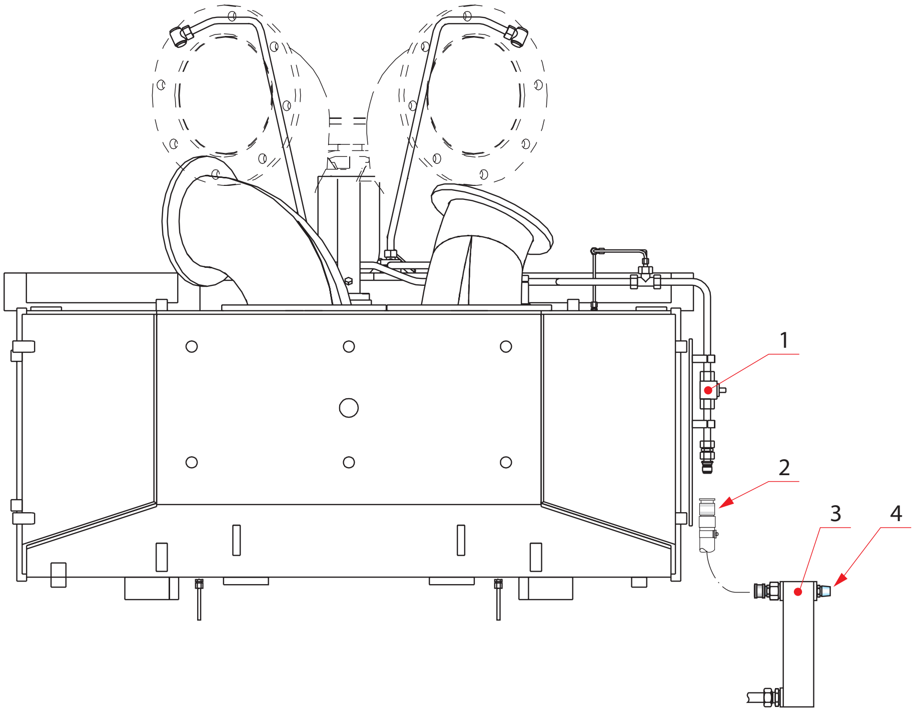
Water cleaning of turbine



1. *Inlet valve* 2. *Quick-coupling* 3. *Flow meter* 4. *Flow adjustment valve* 5. *Drain valve*

Fig 15-2 V2

Water cleaning of turbine



1. *Inlet valve* 2. *Quick-coupling* 3. *Flow meter* 4. *Flow adjustment valve*

Fig 15-3 V2

15.2.2. Cleaning procedure V2

1 **Record charge air pressure, cylinder exhaust gas temperatures, turbocharger speed, at nominal load for later use to evaluate the efficiency of the cleaning.**

2 **Only for diesel engine.** Reduce engine load corresponding to an exhaust gas temperature after cylinder 340°C at nominal speed or in marine main engine installations with a fixed propeller, reduce the speed to between 400 and 600 RPM. Run the engine for ten minutes on this load before the washing is started.

Note!
If the washing is started earlier than after ten minutes on stable load as above, it may damage the turbocharger.

Note!
Clean the turbine (exhaust side) of the turbocharger at low engine loads (20 - 40% of full rated load).

3 **Only for DF engine.** Reduce engine load to 10-15% in diesel mode. Run the engine in diesel mode for 10 minutes on this load before the washing is started. Maximum allowed exhaust gas temperature after cylinder during the stabilizing time is 340°C!

Note!
If the washing is started earlier than after ten minutes on stable load as above, it may damage the turbocharger.

4 **Open inlet valves and check that they are not clogged.**

5 **Connect the water hose.**

6 **Open flow adjustment valve slowly and increase the water flow until the correct flow is reached.**

7 **Close the inlet valve after 10 minutes.**

8 **After termination of water injection the engine must run for at least 10 minutes before the load is increased.**

9 **Shut all valves and disconnect the hose to ensure that no water can enter exhaust pipes after washing.**

10 **Resume normal engine operation at higher output and after at least one hour at normal output.** Repeat the readings taken in step1 above at same load for comparative purposes.

11 **In case the engine shall be stopped after the cleaning.** Run the engine for 10 to 20 minutes more after the turbocharger has been cleaned by water. Doing so will ensure that all parts are completely dry.

15.2.3. Cleaning procedure

V2

1 **Record charge air pressure, cylinder exhaust gas temperatures, turbocharger speed, at nominal load for later use to evaluate the efficiency of the cleaning.**

2 **Only for diesel engine.** Reduce engine load corresponding to a receiver pressure of 0.5...0.6 bar at nominal speed or in marine main engine installations with a fixed propeller, reduce the speed to between 400 and 600 RPM. Run the engine for 10 minutes on this load before the washing is started. Maximum exhaust gas temperature after cylinder is 380°C!

Note!
If the washing is started earlier than after ten minutes on stable load as above, it may damage the turbocharger.

Note!
Clean the turbine (exhaust side) of the turbocharger at low engine loads (30 - 50% of full rated load).

3 **Only for DF engine.** Reduce engine load to 10-15% in diesel mode. Run the engine in diesel mode for 10 minutes on this load before the washing is started. Maximum allowed exhaust gas temperature after cylinder during the stabilization time is 380°C!

Note!
If the washing is started earlier than after ten minutes on stable load as above, it may damage the turbocharger.

4 **Open inlet valves and check that they are not clogged.**

5 **Connect the water hose.**

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

7 **Open flow adjustment valve slowly and increase the water flow until the correct flow is reached.**

8 **The washing time is 10 min.** The cleaning procedure can be repeated if necessary after one to two hours of normal operating.

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

10 **Shut all valves and disconnect the hose to ensure that no water can enter exhaust pipes after washing.**

11 **Resume normal engine operation at higher output and after at least one hour at normal output.** Repeat the readings taken in step1 above at same load for comparative purposes.

12 **In case the engine shall be stopped after the cleaning.** Run the engine for 10 to 20 minutes more after the turbocharger has been cleaned by water. Doing so will ensure that all parts are completely dry.

15.2.4. Water cleaning of compressor

V5

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 deposits.

Regular cleaning of the compressor prevents or delays the formation of deposit, but it does not eliminate the need of normal overhauls, for which the turbocharger has to be dismantled.

The water must be injected while the engine is running and at the highest possible load, i.e. at a high compressor speed. See also turbocharger instruction manual.

Note!
Clean the compressor air side of the turbocharger at as high a load as possible (at least 75% load).

Cleaning should take place regularly according to Maintenance Schedule. Depending on the results obtained, the interval between two washings can be increased or reduced.

15.2.5. Compressor cleaning procedure

V6

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

2 **Fill the water container with clean water and close the water container.**

3 **Open the valve and press the button.** The button opens a valve which admits compressed air from the compressor through the pipe. This forces the water through a passage and through the pipe. In V-engines, choose turbocharger for cleaning with the valve.

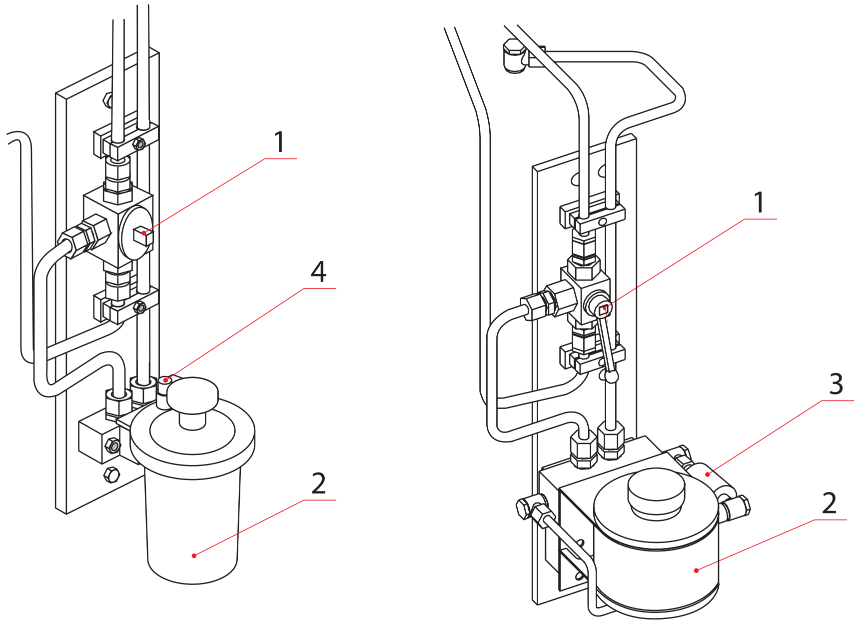
4 **Push the valve lever towards the spring or alternatively push the button.** Hold it for about 10 seconds until all the water has been injected.

5 **After at least one hour at normal output repeat the readings taken in step1 for comparative purposes.** The success of injection can be recognized by the change in charge air pressure and in the exhaust gas temperature.

6 **In case the engine shall be stopped after the cleaning.** Run the engine for 5 minutes more after the compressor has been cleaned with water. Doing so will ensure that all parts are completely dry.

Note!
If washing is not successful, wait for 10 minutes before repeating.

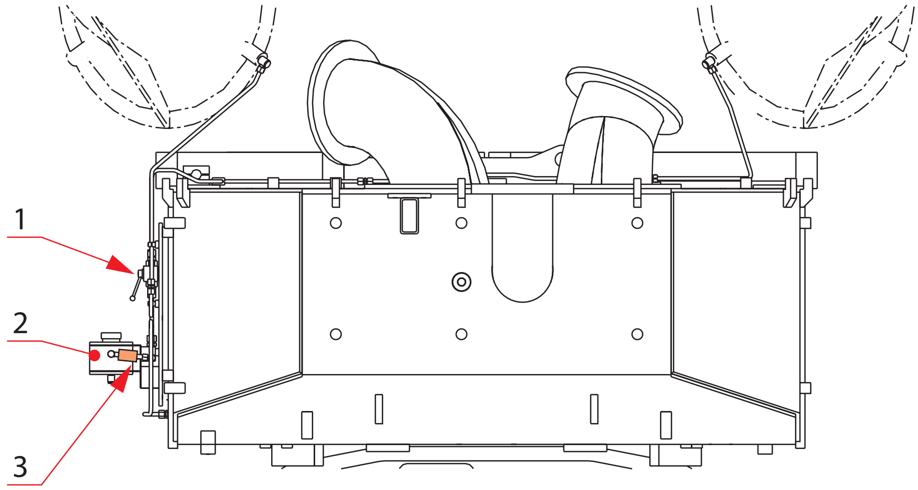
Water cleaning of compressor



1. *Valve* 2. *Water container* 3. *Valve lever* 4. *Push button*

Fig 15-4 V3

Water cleaning of compressor



1. *Valve* 2. *Water container* 3. *Valve lever*

Fig 15-5 V1

15.3. Allowable operation with damaged turbocharger V3

In case of a serious breakdown of the turbocharger, a blanking device or a rotor locking device can be fitted according to the instructions in the turbocharger manual.

When the engine is in an emergency situation like this, it can be operated temporarily at 20% output (DF engines, only in diesel mode). The thermal overload is a limiting factor on the diesel engine. Therefore, the exhaust gas temperatures must be carefully watched during operation with a locked rotor.

The exhaust gas temperature after the cylinders must not exceed 500°C.

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

15.4. Maintenance of charge air cooler

15.4.1. General maintenance

V4

1 **Condensation from the air is drained through the drain pipe at the bottom of the cooler housing after the cooler.** Examine regularly that the draining pipe is open by checking the air flow with running engine.

Note!
If water keeps 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 leaking and must be dismantled and pressure tested.

2 **At longer stops, the cooler should be either completely filled or completely empty, as a half-filled cooler increases the risk of corrosion.** If there is a risk of that the water level in the system goes down when the engine is stopped, drain the cooler completely. Open the air vent screw to avoid vacuum when draining.

3 **Clean and pressure test the cooler at intervals, see Maintenance Schedule.** If the pressure difference over the air side of the cooler is too high or if the receiver temperature cannot be held within stipulated values at full load.

4 **Always when cleaning, check for corrosion.**

15.4.2. Cleaning of air cooler

V3

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

Generally an increase of pressure drop (Δp) over the air side of the cooler with 100 mmH_2O compared to a new/clean cooler means that the cooler needs cleaning. The pressure drop should be measured at 100 % load or at least always at the same high load level. See Fig 15-1 for connections.

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.

15.4.3. Dismantling the air cooler

V6

1 **Remove the support screws (9) and (10), seeFig 15-7**

2 **Remove the cooling water pipes.**

a) **Loosen the cooler flange screws (10), see Fig 15-1.**

b) **Unscrew the support screws (8).**

c) **Loosen the flange screws (14) and the support pin (11).**

Note!
The previous design of Wärtsilä Vasa 16V32LN & 18V32LN with TPL65 turbochargers, have only lower support screws (8) and sleeve (15), see Fig 15-1, alternative 2.

3 **Loosen the cooler flange screws.**

a) **On In-Line engine, withdraw the cooler until the thread or the hole (7) for the lifting tool is visible.**

b) **On V-engine, withdraw the cooler about 300 mm and fit the tool 846025.** Fit the tool by using four of the air cooler fastening screws. Withdraw the cooler completely towards the tool stop. Use screws in the two threaded extractor holes in the flange to loosen the cooler.

4 **Apply the lifting tool (shackle) and lift off the cooler.**

15.4.4. Chemical cleaning

V5

1 **Clean the air side of the cooler by immersing it in a chemical cleaning bath for at least 24 hours.** Recommend cleaning detergents, see section 15.4.6. We recommend that cleaning tank should be equipped with perforated pipes on the bottom for the best cleaning effect, see Fig 15-6. During cleaning, steam or pressurised air should be connected to the pipes to get a good circulation. When cleaning is completed, the cooler should be flushed thoroughly with water.

Note!
The use of a high pressure water jet for flushing, should be avoided because:

- it will push the dirt into the middle of the cooler.

- the risk of damaging the cooler fins.

Both of above will result in an increased pressure drop over the cooler.

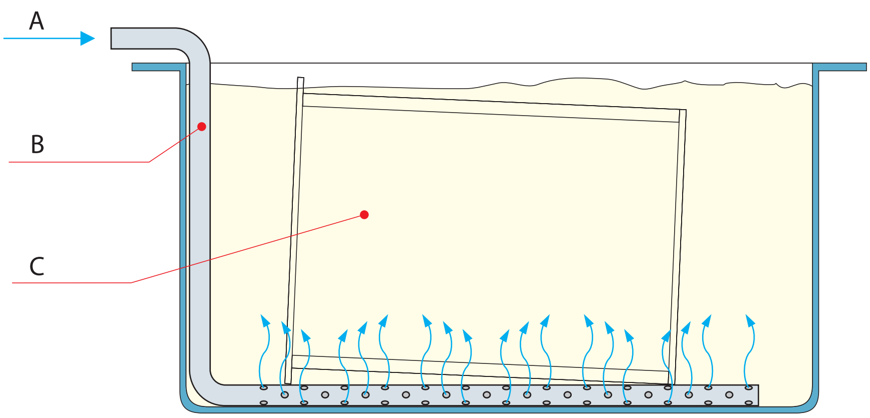
2 **Clean the water side by detaching the headers (4) and (5) from the cooler and immersing the tube bundle into a chemical cleaning bath for at least 24 hours.** Upon completion, follow the instruction given for the air side.

3 **Change the gaskets before reassembling the headers.**

Note!
No gasket is used neither between cooler and air cooler housing nor at the bellows (1) (turbo - air cooler housing). Loctite 5900 to be used as sealing compound.

4 **It is also recommended to pressure test the cooler before mounting it on the engine.**

Air cooler cleaning tank



A. *Steam or air,* B. *Perforated pipes,* C. *Cooler insert.*

Fig 15-6 V1

15.4.5. Assembly of charge air cooler V4

1 **Mount the cooler on the engine** and tighten the screws (8) by hand.

2 **Change O-rings (12) and (13).**

3 **Assemble parts (8,11-14)** and tighten the flange (14) and support screws (8) by hand. (Loctite 242 or 243 can be put on the screws to prevent loosening).

Note!
The previous design of Wärtsilä Vasa 16V32LN & 18V32LN with TPL65 turbochargers, have only lower support screws (8) and sleeve (15). See Fig 15-1, alternative 2.

4 **Tighten the cooler flange screws (10)** to specified torque, see section 07.13.1.

5 **Tighten the screws (8) and (14)** to specified torque, see section 07.13.1.

6 **Mount the cooling water pipes.**

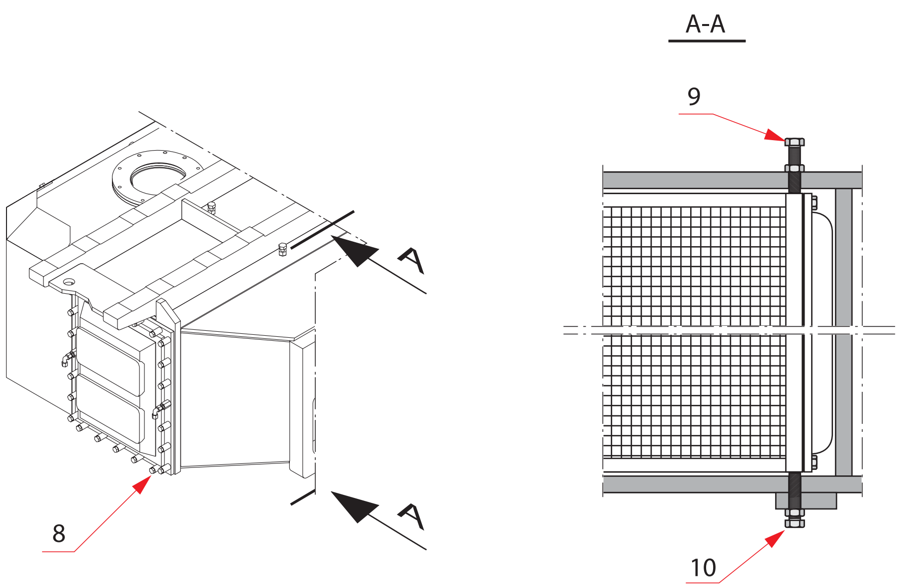
7 **Apply water resistant grease** onto the upper (9) and lower (10) support screws.

8 **Tighten the upper support screws** (9) by hand until the contact to the cooler is reached. Tighten the counter nuts.

9 **Tighten the lower support screws** (10) to a torque of 40 Nm. Tighten the counter nuts.

10 **Vent the cooler** and check the tightness when starting up.

Supporting of air cooler



8.*Screw,* 9.*Screw,* 10.*Screw.*

Fig 15-7 V1

15.4.6. Recommended detergents

V1

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

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

15.4.7. Combi Degreaser Cleaning

V1

When an air cooler is due for cleaning Wärtsilä recommend using the new cleaning method together with the latest type of Wärtsilä Biodegradable cleaning concentrate, Wärtsilä Combi Degreaser, product number C51003.

This Wärtsilä Combi Degreaser concentrate is environmentally friendly and not harmful for health, not fire hazardous, does not affect O-rings or gaskets and is not corrosive.

For inquiries and price quotation for the product, contact your nearest Wärtsilä office or Wärtsilä Finland, Service department.

15.4.7.1. Description of the cleaning process

V2

The cleaning effect is based on the cleaning liquid, Wärtsilä Combi Degreaser, in combination with the flow of the liquid, transporting the dirt out of the cooler.

The work procedure for cleaning the air cooler, airside according to the new procedure is as follows:

1. **Dismantle the air cooler from the engine,** see section 15.4.3, step 1 and 2.
2. **Put the air cooler in a suitable stainless steel or plastic tank** with a filterscreen in the bottom (replaceable filter pad).
3. **Install the funnel-shaped cover** on the coolers air outlet side.
4. **Fill up the tank with the cleaning liquid,** Wärtsilä Combi Degreaser, mixing ratio 1:4 (WCD/water).
5. **The liquid needs to be heated to about 60°C** for best cleaning effect.
6. **Connect a rubber hose from the circulation pump unit** to the cover and a suction hose from the tank.
7. **Circulate the liquid for 4 to 8 hours** depending on degree of fouling.
8. **Check the pH value** (it should not exceed 3 for best cleaning result).

9 **Flush the cooler with fresh clean water after cleaning.**

Note!
The use of a high pressure water jet for flushing, should be avoided because:

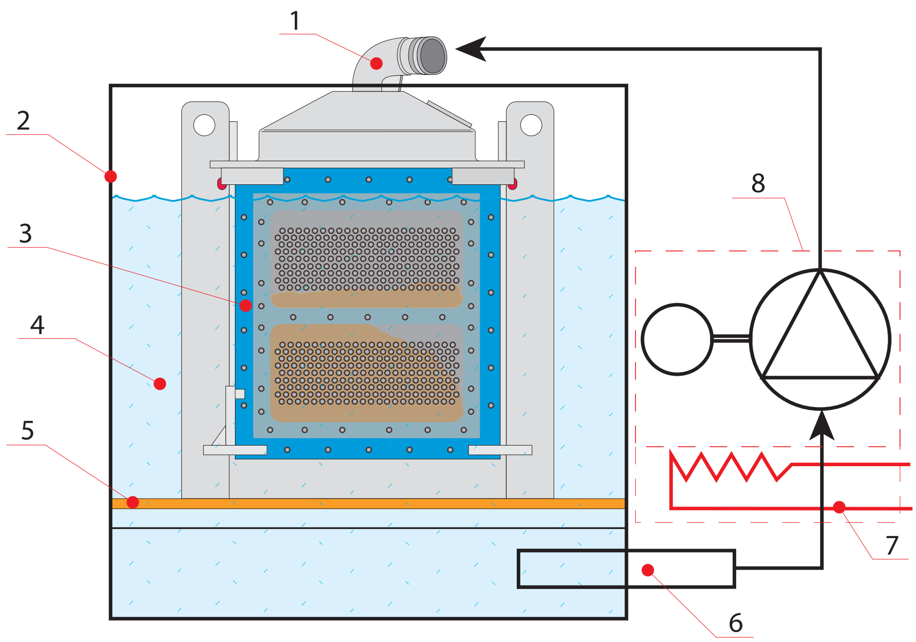
- it will push the dirt into the middle of the cooler.

- the risk of damaging the cooler fins.

Both of above will result in an increased pressure drop over the cooler.

This procedure can be combined with ultrasonic equipment if available.

Combi Degreaser cleaning system



1. *Funnel* 2. *Tank* 3. *Cooler* 4. *Cleaning liquid* 5. *Filter* 6. *Suction* 7. *Heater* 8. *Pump unit*

Fig 15-8 V1

15.4.8. Ultrasonic cleaning V1

Cleaning with ultrasonic equipment will loosen the deposits but it has to be combined with an efficient flushing to remove the deposits from the cooler. It is also important that the correct settings, temperature and detergent is used, according to manufacturer's instruction, when cleaning with ultrasonic cleaning.

16. Injection System

V2

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, of mono element type, is pressure lubricated and the drain fuel is led to a pipe system with atmospheric pressure outside the pump, or back to the low pressure cycle of the injection pump.

Each injection pump is equipped with an emergency stop cylinder coupled to an electro-pneumatic overspeed protecting system.

The injection line consists of an injection pipe and a connection piece, screwed sideways into the nozzle holder. The injection valve consists of a nozzle holder and a multi-orifice nozzle.

16.1. Injection pump

16.1.1. Removal of injection pump

V2

It is recommended that the engine runs 5 min. with light fuel before it is stopped for overhaul of the injection pump.

1 **Shut off fuel supply** to the engine and stop the prelubricating pump.

2 **Unscrew and remove** the fuel feed pipes and the pneumatic air pipe. Loosen the oil pipes to the pump.

3 **Remove the pneumatic shut-down cylinder.**

4 **Remove the injection line.** Immediately cover all openings with tape or plugs to prevent dirt from entering the system.

5 **Turn the crankshaft** so that the injection pump tappet is in the bottom position, the roller resting on the base circle of the cam.

6 **Loosen the flange nuts and** lift off the pump.

7 **Cover the bore** in the engine block.

16.1.2. Mounting of injection pump

V2

1 **Clean the contact surfaces of the pump.** Also clean the plane and the bore of the engine block.

2 **Check the O-ring** of the insert part and lubricate with grease or engine oil. Check that the fuel cam is not in the lifting position.

3 **Fit the pump.** Slide the fuel rack connection into place during this operation.

4 **Check with a feeler gauge** that the pump housing is aligned with the camshaft, i.e. measures $B_1 = B_2$ according to Fig 16-1.

5 **Tighten the flange nuts** to torque, remove protecting tapes and/or plugs and connect the oil pipes.

6 **Rotate the control shaft** and check that all pumps follow the shaft movement. Check the fuel rack positions of all pumps, see section 22.1.

7 **Remove the protecting tapes** or plugs and connect the fuel feed pipes and the injection line. Tighten the nuts to torque.

8 **Open fuel supply** to the engine and vent the fuel system according to the instructions in chapter 17. The injection pump is provided with a venting plug (42).

9 **Mount the de-aeration plug** with a new steel sealing ring and tighten to the torque stated in section 07.1.

Note!
Never use copper seal rings on the injection pumps. A deformed seal ring may cause hazardous fuel spray and/or fire.

16.1.3. Control of fuel delivery commencement

V2

The beginning of the effective pump stroke is determined by an indirect method, i. e. by watching when the passage between the low pressure side and the high pressure side of the injection pump is shut by the edge of the element plunger, A in Fig 16-1, the so-called "flowing position".

One method is described below but it is recommended to use the pneumatic test equipment (848 044) for more accurate control and when calibrating an injection pump.

Control of fuel delivery commencement is necessary only if major components have been changed, e. g. injection pump, injection pump element or camshaft piece.

1 **Shut off fuel supply** to the engine.

2 **Remove the injection pipe.**

3 **Open the screws (39)** crosswise in steps of 30°, remove the head piece (35) and the fuel delivery valve cone and spring (33).

4 **Replace the head piece (35)** and tighten the screws (39) to torque.

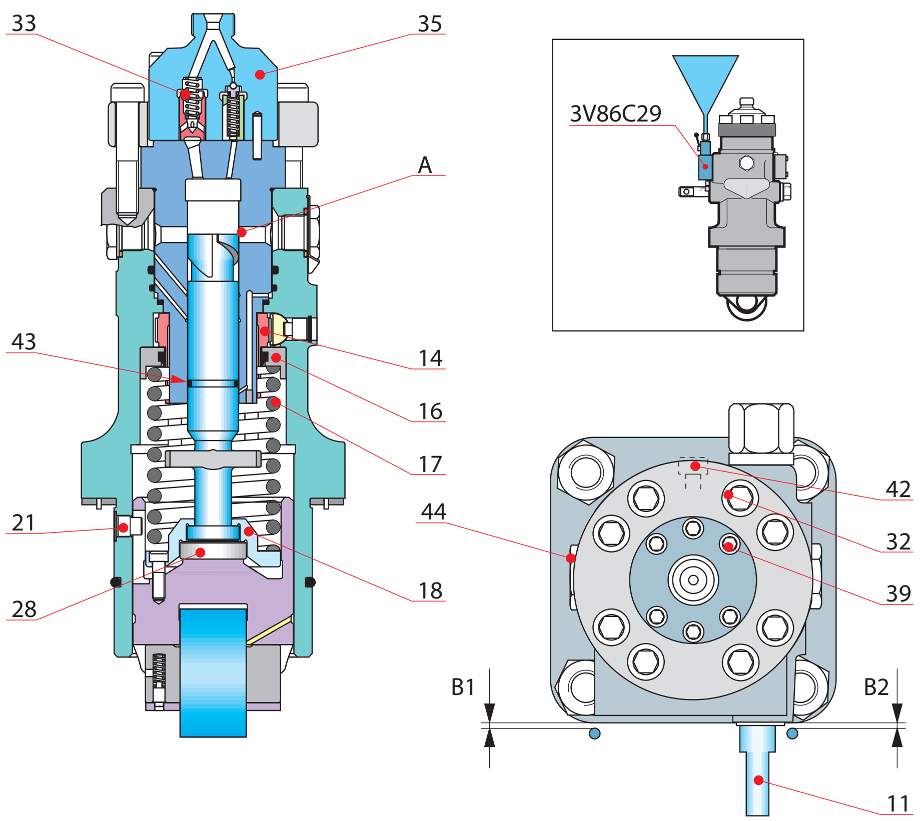
5 **Connect the funnel 3V86C29** to the injection pump to obtain fuel supply.

6 **Set the injection pump rack** at its maximum end position.

7 **Turn the crankshaft** to a position 22° before TDC at ignition.

8 **Fill the funnel** with distillate fuel. Fuel is now flowing out from the head piece (35).

Injection pump



11. *Fuel rack* 14. *Control sleeve* 16. *Spring disc* 17. *Spring* 18. *Spring disc* 21. *Fixing screw* 28. *Calibrating disc* 32. *Screw* 33. *Spring* 35. *Head piece* 39. *Screw* 42. *Vent screw* 43. *Seal ring* 44. *Erosion plug*

Fig 16-1 V1

9 **Keep the level in the funnel constant** by refilling and turn the crankshaft slowly in the engine rotating direction. Watch when fuel stops emerging. Read the position of the crankshaft.

10 **Repeat steps 7, 8 and 9** for all the cylinders to be checked.

11 **Compare the crankshaft positions** with the correct values, see test records. The deviation between the different cylinders in one engine should not exceed 0.5° crank angle. If larger deviations are noted, the injection pumps must be changed and/or overhauled and checked. It is recommended to check/re-calibrate whenever the pump element or tappet is changed on an injection pump. The tolerance for the calibrating disc (28) when calibrating a pump is +0.00 ... +0.05 mm which corresponds to 1/5° crank angle.

Note! For accurate calibrating, the pneumatic test equipment (848 044) for injection pump should be used.

12 **Reassemble the fuel delivery valve,** pressure relief valve and the head piece. Tighten the screws (39) to torque given in section 07.1.

16.1.4. Injection pump overhaul

V2

It is presupposed that the injection pump is removed from the engine and the outside of the pump carefully cleaned.

Note!
The element cylinder, plunger and delivery valve are matched and they must be kept together during the overhaul.

1 **It is recommendable** to put the pump in a screw vice, in positions convenient for the different operations.

2 **Support the roller tappet** and open the fixing screw (21).

3 **The roller tappet** and the element plunger can now be taken out. Take care when handling the plunger because it may come loose from the tappet.

4 **Remove the spring** and the control sleeve.

5 **Turn the pump** into vertical position.

6 **Open the screws (39)** crosswise in steps of 30°, remove the head piece and remove the fuel discharge valve with spring and pressure relief valve with spring.

7 **Open the screws (32)** of the element in steps of 30°.

8 **Take out the element cylinder** by using a soft tool. Always use clean latex gloves when handling injection equipment.

9 **Wash the element plunger** and the cylinder in clean fuel or special oil and always keep them together, the plunger being inserted in the cylinder. Pay special attention to the grooves and bores for leak fuel and lubrication oil.

10 **Normally, further dismantling** is not necessary. It is recommendable to keep the components of different pumps apart from each other, or to mark the details so they can be fitted into the same pump. The details must be protected against rust and especially the running surface of the element plunger should not be unnecessarily handled with bare fingers.

11 **Wash the parts** in absolutely clean diesel oil and lubricate with engine oil.

12 **Renew the seal rings and supporting rings** in the pump house and on the element cylinder and lubricate the rings with vaseline or lubricating oil.

13 **Re-install the element cylinder** into the position where the fixing groove corresponds to the guiding pin.

14 **Tighten the screws (32)** crosswise in steps according to section 07.13.1 to ensure equal tightening of every screw.

15 **Reinstall the main delivery valve** with spring and the pressure relief valve with its spring.

16 **Mount the head piece (35)** and tighten the screws (39) crosswise in steps, according to section 07.13.1, to ensure equal tightening of every screw.

Caution!
Incorrect mounting may cause the engine to overspeed!

17 **Turn the pump** and fit the control sleeve (14). Move the fuel rack (11) to a position where two marks can be seen. **One of the control sleeve teeth is chamfered, and this tooth must slide into the tooth space between the marks of the rack.**

18 **Re-install the spring disc (16)** and spring (17).

19 **Remove the seal ring (43)** and mount a new one using the tool 846195.

20 **Assemble the element plunger** and tappet with the spring disc (18) and calibrating disc (28).

21 **Note the mark on one of the plunger vanes.** The marked plunger vane must slide into the fuel rack side of the control sleeve, i.e. correspond to the marks on the fuel rack and the chamfered tooth of the control sleeve. The guiding groove of the tappet must correspond to the fixing screw, i.e. be turned to the slide opposite the marked plunger vane.

22 **Re-install the plunger tappet assembly.**

23 **Screw in and tighten the fixing screw (21).**

24 **Check that the fuel rack (11)** can be easily moved.

25 **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.

16.1.5. Changing of erosion plugs

V1

1 **Remove the locking wire or plate** and the erosion plugs (44), see Fig 16-1.

2 **Mount new erosion plugs** and tighten to correct torque, see section 07.1.

3 **Lock the erosion plugs** with the locking plates or with wires to the fastening screws.

Note!
To prevent the risk of a high pressure fuel leakage, the erosion plugs must be locked.

16.2. Injection line

V2

The injection line consists of two parts, the connection piece, which is screwed into the nozzle holder, and the injection pipe.

The 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 tighten the connection piece when 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.

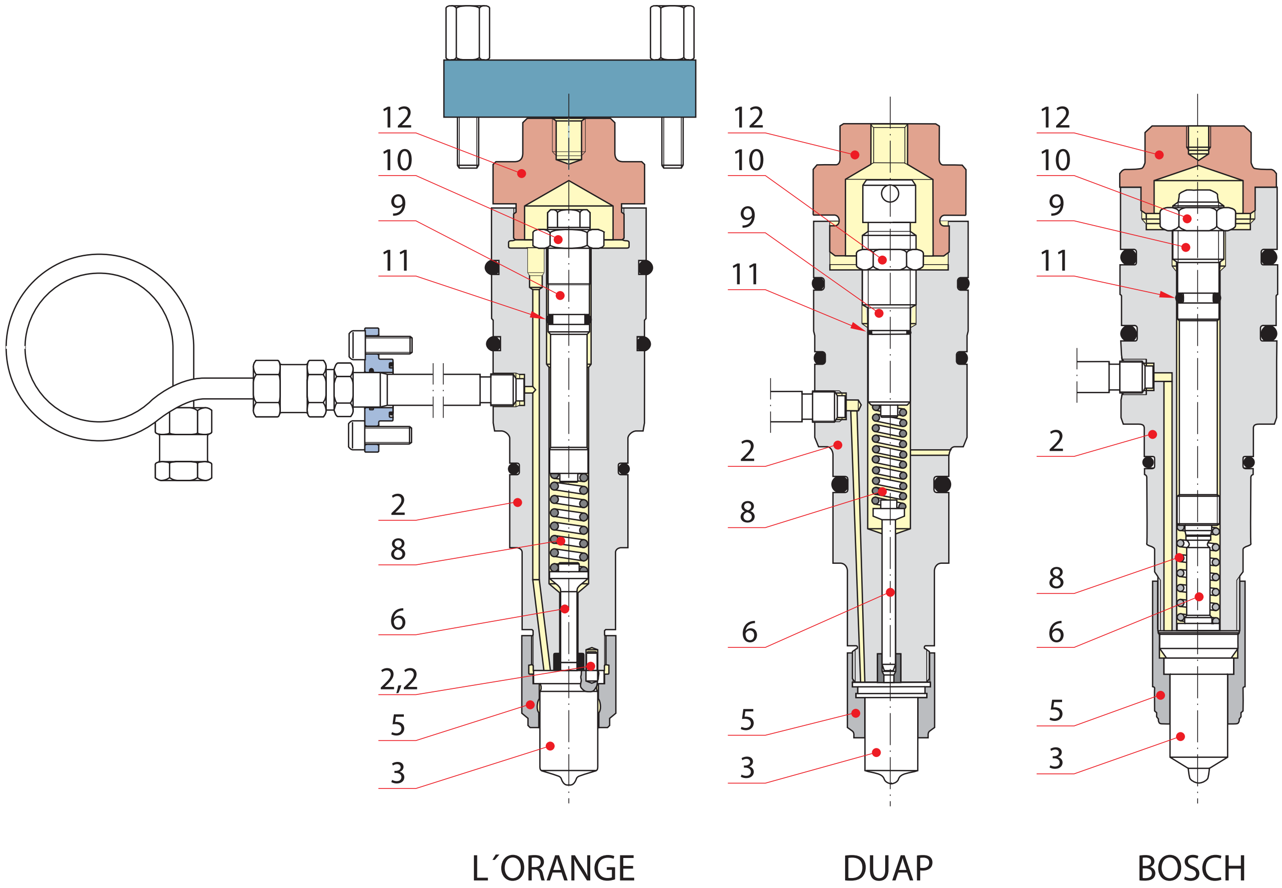
When removed, the injection line details have to be protected against dirt and rust.

16.3. Injection valve

V2

The injection valve is centrally located in the cylinder head and includes the nozzle holder and nozzle. The fuel enters the nozzle holder sideways through a connection piece screwed into the nozzle holder.

Injection valve



2. *Injection valve body* 2.2 *Fixing pin* 3. *Nozzle* 5. *Nozzle nut* 6. *Push rod* 8. *Spring* 9. *Adjusting screw* 10. *Nut* 11. *Seal ring* 12. *End cup*

Fig 16-2

V1

16.3.1. Removing nozzle holder

V2

1 **Remove the cylinder head cover** and the hot box cover.

2 **Remove the injection pipe.**

3 **Loosen the sealing flange** of the connection piece and unscrew the connection piece.

4 **Remove the fastening nuts** of the injection valve.

5 **Lift out the injection valve.** If necessary, use the extractor 837000. If too 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.

6 **Protect the fuel inlet hole** of the injection valve and bore in the cylinder head.

16.3.2. Mounting injection valve

V2

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 set 3284B01. 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 seals directly to the bottom of the stainless sleeve.

2 **Put new O-rings on the injection valves.** Lubricate the injection valve with engine oil or vaseline/grease.

3 **Fit the injection valve** into the cylinder head bore.

4 **Put new O-rings in the sealing flange** of the connection piece. Mount the flange on the connection piece and screw in the connection piece by hand. Tighten to correct torque.

5 **Tighten the fastening nuts** of the injection valve to correct torque in steps of 10 - 20 Nm.

6 **Fasten the sealing flange of the connection piece.**

7 **Mount the injection pipe** and tighten the cap nuts to torque.

8 **Mount the covers.**

16.3.3. Overhauling injection valve

V2

1 **Inspect the nozzle** immediately after removing the injection valve from the engine. Carbon deposits (trumpets) may indicate that the nozzle is in poor condition, or the spring is broken. Clean outside of the nozzle with a brass wire brush. **Don't use steel wire brush.**

2 **Release nozzle spring tension** by opening the counter nut (10) and screwing up the adjusting screw (9).

3 **Remove the nozzle from the holder** by opening the cap nut (5). Keep the nozzle together with the holder body, don't let it follow up with the nut. If there is coke between the nozzle and the nut, the dowel pins may break and damage the nozzle. To avoid this, knock on the nozzle, using a piece of pipe according to Fig 16-3, to keep it towards the holder. **Never knock directly on the nozzle tip.** Be careful not to drop the nozzle.

4 **Check the nozzle needle movement** which may vary as follows:

- needle completely free
- needle free to move within normal the 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 oil to 150 - 200°C. Normally, the needle can be removed from a hot nozzle.

Max lift of nozzle, removing of nozzle from holder

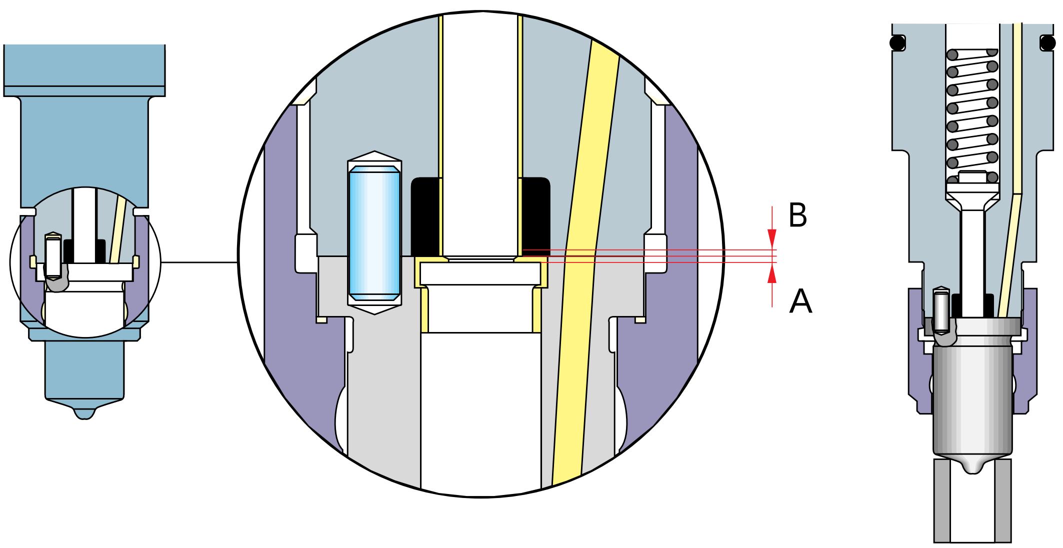


Fig 16-3

V1

5 **Clean the details.** If possible, use a chemical carbon dissolving solution. If there is no such available, immerse the details in clean fuel oil, white spirit or similar to soak carbon. Then clean the details carefully by tools included in the tool set. **Do not use steel wire brushes or hard tools.** Clean the nozzle orifices with needles provided for this purpose. After cleaning, rinse the details to remove carbon residues and dirt particles.

Before inserting the 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 the cap nut carefully; if necessary, dismantle the nozzle holder to clean all details.

Check the nozzle spring.

7 **Check the high pressure sealing faces** of the nozzle holder, i.e. the contact face to nozzle and the bottom of the fuel inlet hole.

8 **Check maximum nozzle needle lift,** i.e. sum of measures A and B in Fig 16-3. If the wear B exceeds 0.05 mm, the nozzle holder can be sent to the engine manufacturer for reconditioning. If total lift is out of the value stated insection 06.2, the nozzle should be replaced by a new one.

9 **Reassemble the injection valve.** Tighten the cap nut to the torque given in section 07.1.

10 **Connect the injection valve** to the test pump. 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 manometer valve
- pump slowly and watch manometer to note the opening pressure. If the opening pressure is more than 20 bar below the stated value, with damped movement of indicator, it indicates a broken spring or badly worn parts.

12 **If the spray is uniform,** adjust the opening pressure to the stated value and check the spray uniformity once more.

13 **Check the needle seat tightness:**

- increase pressure to a value 20 bar below the stated opening pressure
- keep pressure constant for 10 s. 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 the stated opening pressure
- measure the time for a pressure drop of 50 bar. If the time is below 3s., it indicates a worn nozzle, and it must be replaced by a new one. A time longer than 20 s. indicates a fouled needle, and the nozzle must be cleaned.

15 **If the tests according to step 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.

17. Fuel System

V1

The Wärtsilä Vasa 32 engine is designed for continuous Light, Heavy or Crude Oil duty. The fuel feed system pressure adjustment recommendations varies depending on fuel quality and installation and the values mentioned in this chapter should be used as guidelines only.

As the fuel treatment system plan usually varies from one installation to another, the system described in this manual may not exactly correspond to the actual installation. See installation specific documentation for further information.

The engine can be started and stopped on heavy fuel or crude oil provided that the fuel is heated to operating temperature, see recommended operating data in chapter 01.1.

In multi-engine installations the engine is equipped with an electrically driven fuel feed pump and a duplex filter to provide correct flow, pressure and filtration irrespective of the number of engines connected to a common external treatment system.

17.1. Functional description

V1

The fuel feed system is pressurized by the pump (7) and filtered in the duplex filter (6), see Fig 17-1. The pressure control valve (3) maintains correct pressure in the system. The filter (6) is provided with a pressure difference indicator, which indicates a possible high pressure drop over the filter. The filter cartridges must then be changed. This is described in section 17.6.1.

A pressure gauge (1) on the instrument panel indicates the fuel inlet pressure and a local thermometer (2) indicates the inlet temperature. A pressure switch (5) for low fuel pressure is connected to the automatic alarm system.

Fuel leaking from injection pumps and injection valves is collected (103) in a separate enclosed system. Thus this fuel can be reused. A special module for automatic handling of this fuel back to the system can be delivered on request.

A separate pipe system leading from the top level of the engine block collects waste oil, fuel and water arising, for example, when overhauling cylinder heads.

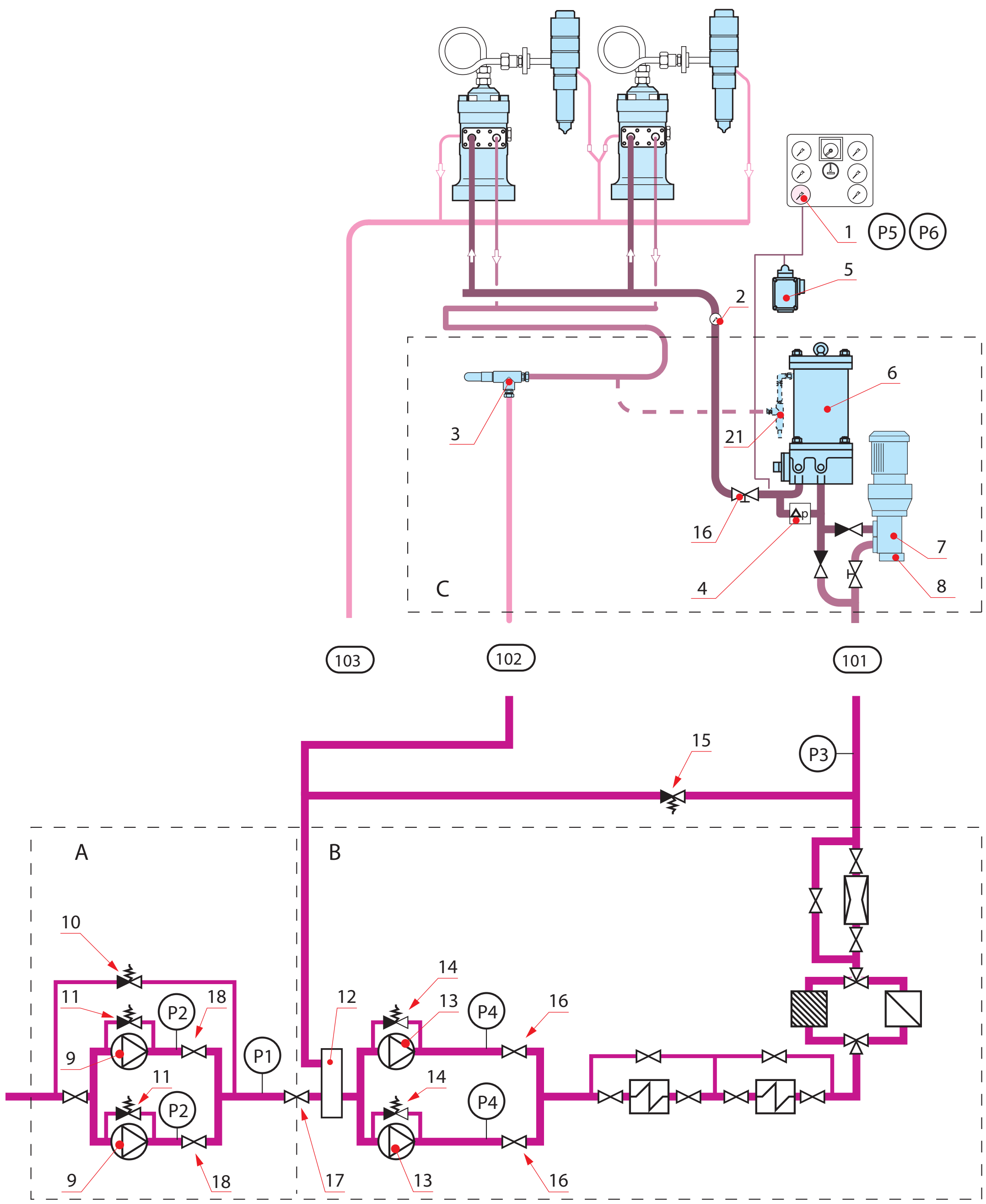
The high pressure system, with injection pump and injection valve, is described in chapter 16.

Fuel feed and circulating unit

In the fuel feed unit (A), see Fig 17-1, the fuel is pressurized in order to avoid disturbances due to vaporising of water and fuel.

The fuel-circulating unit (B) maintains de-aerated fuel of correct viscosity (correct temperature) and pressure to the engines and circulates the fuel in the main system.

Fuel system



1. *Pressure gauge* 2. *Thermometer* 3. *Pressure control valve* 4. *Pressure difference indicator* 5. *Pressure switch* 6. *Fuel filter* 7. *Fuel feed pump* 8. *Safety valve* 9. *Fuel transfer pump* 10. *Pressure regulating valve* 11. *Safety valve* 12. *Deaeration tank* 13. *Circulating pump* 14. *Safety valve* 15. *Pressure regulating valve* 16. *Valve* 17. *Valve* 18. *Valve* 19. *Pilot fuel filter* 20. *Pilot fuel pump* 21. *Filter safety valve (older versions)* 101. *Fuel oil inlet* 102. *Fuel oil outlet* 103. *Clean fuel oil leakage* P1. *Fuel feed pressure* P2. *Safety valve adjustment* P3. *Circulation pressure* P4. *Safety valve adjustment* P5. *Fuel feed pressure* P6. *Safety valve adjustment*

Fig 17-1 V1

17.2. Maintenance

V1

When fuel system maintenance work is carried out, always observe utmost cleanliness. Pipes, tanks and the fuel treatment equipment, such as pumps, filters, heaters and viscosimeters, included in the engine delivery or not, should be carefully cleaned before taken into use.

Change the filter cartridges regularly. The fuel filter is provided with a combined visual indicator/electrical switch, connected to the automatic alarm system, which indicates too high pressure drop over the filter.

Note!
The paper cartridges should be changed as soon as possible when too high a pressure drop is indicated.

The intervals between changes of cartridges depend largely on the quality and dirt content of the fuel as well as on fuel treatment before the engine. Guidance values are stated in chapter 04.

The fuel should always be 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

V1

Open the air vent screws on the injection pumps (see chapter 16, Fig 16-1 pos. 42.). Start the fuel feed pump if the static pressure from the day tank is not sufficient. **Note!** Always vent the filter after changing cartridges in the filter.

If the engine has been stopped and the feed pump is not running, the three-way valve can be changed directly over to the position where both sides are in operation. The air can be vented through the respective air vent screw. If the engine is running, the change-over of the three-way valve should be carried out very carefully to give only a small flow of fuel to the filter side to be vented. The best way is to use the slow filling valve on the three-way valve. Set the valve in "slow filling" position (see Fig 17-2) 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 will give a signal for too low a fuel pressure. This may also involve the risk of air escaping from the filter to the injection pumps, which may also cause the engine to stop.

Note!
To avoid air escaping to the injection pump, fill up the filter with clean fuel before changing over.

Three-way valve positions

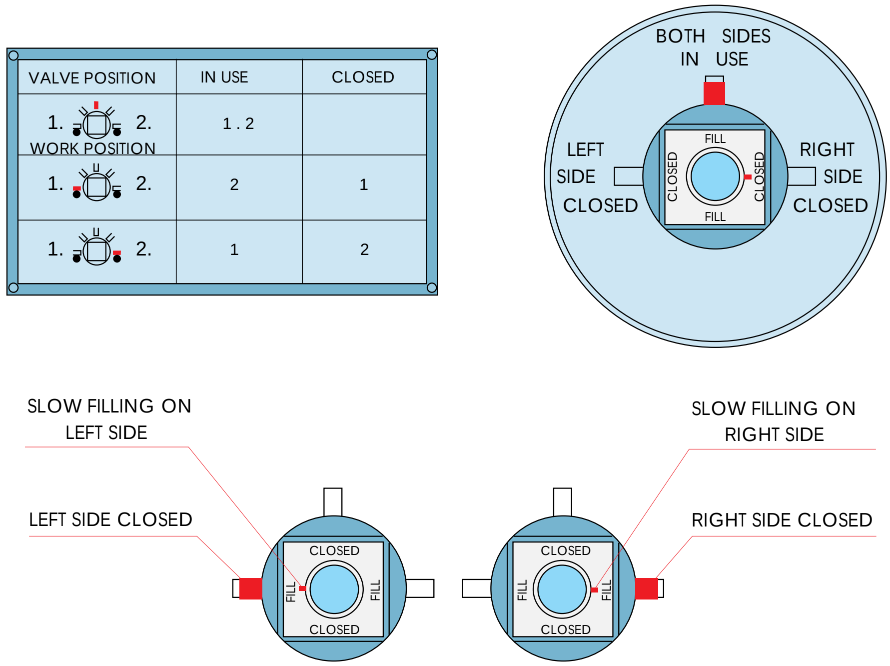


Fig 17-2 V1

17.4. Adjustments of fuel feed system V1

A long lasting and safe functionality of the diesel engine demands an appropriate adjusted fuel feed system. This will ensure a correct fuel feed pressure and a sufficient fuel flow to all injection pumps on all engines in the installation. Check the adjustment at intervals recommended in chapter 04. Adjust the valves at normal temperatures and at engine idling.

17.4.1. Fuel feed pumps in unit (A) V1

The fuel feed pumps (9) maintains the system pressure P1, see Fig 17-1 and section 17.4.4.

1 **Close the valve (17) and adjust the pressure (P1)** on the regulating valve (10). Open the valve (17).

2 **Close the valves (18) and adjust the pressure (P2)** on the safety valve (11) located on the pump.**Note! The purpose of this safety valve is only to protect the pump.** Open the valve (18).

Warning!
The pump safety valve should be adjusted rapidly as the pump may run hot if the system is closed for a lengthy time.

17.4.2. The fuel circulating pumps in unit (B) V1

The fuel circulating pumps (13) keep the fuel in the system in constant circulation and maintain a system pressure (P3) between the circulating pumps and the pressure regulating valve (15), see Fig 17-1 and section 17.4.4.

1 **Adjust the system pressure (P3)** at the pressure regulating valve (15).

2 **Close the valves (16) and adjust the pressure (P4)** on the safety valve (14) located on the pump.**Note! The purpose of this safety valve is only to protect the pump.** Open the valve (16).

17.4.3. Fuel feed pump at each engine (C) V1

In multi-engine installations every engine is equipped with a fuel feed pump (7). This pump ensures the providing of a sufficient engine low pressure system fuel flow. The pump ensures also that a sufficient fuel pressure is maintained for each engine irrespective of the numbers of engines connected to the system.

Note!
The fuel feed pumps should always be running when the engines are in operation and when they are stopped on HFO or Crude Oil.

The fuel feed pumps (7) maintains the engine fuel feed low pressure system P5, see Fig 17-1 and section 17.4.4.

1 **Adjust the system pressure (P5)** at the pressure regulating valve (3).

2 **Close the valve (16) and adjust the pressure (P6)** on the safety valve (8) located on the pump. **Note! The purpose of this safety valve is only to protect the pump.** Adjust the filter safety valve (21) opening pressure (old installation only). Open the valve (16).

17.4.4. System operating values

V1

Fuel feed system pressures*), LFO or HFO	
Specification / Location	**(bar)**
Fuel feed pressure / P1	3-4
Safety valve adjustment /P2	12
Circulation pressure / P3	4-5
Safety valve adjustment / P4	12
Fuel feed pressure / P5	5-8
Safety valve adjustment / P6	12

*) See installation specific documentation concerning system pressure adjustments for Crude Oil engines.

17.4.5. Start and stop

V1

The engine can be started and stopped on HFO and Crude Oil. The preheating systems for the engine and the fuel feed system should always be switched on, also during engine stop.

However, if the engine for some reason is started and stopped on diesel oil (LFO), the engines should be operated at high load and on diesel oil for at least 30 minutes before they are stopped. This will secure that there is only diesel oil in the system.

Note!
The hot box covers should always be mounted on the engine for safety reasons and to keep the fuel feed piping sufficiently preheated also during engine stop.

17.5. Fuel feed pump

V1

The electrically driven fuel feed pump is of the same type as the pre-lubricating pump. For description and maintenance, see chapter 18, section 18.8.

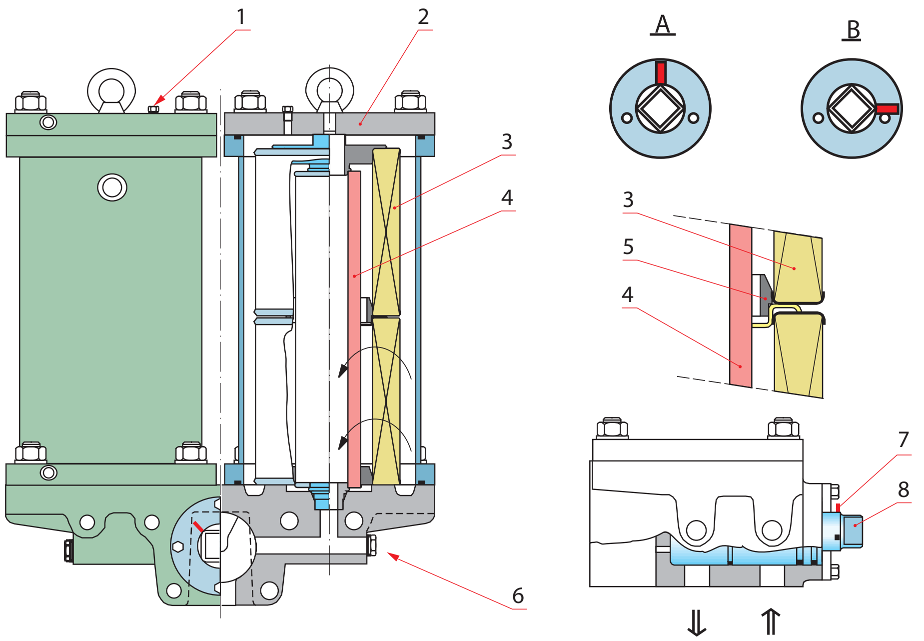
Set the pressure according to section 17.4.

17.6. Fuel filter

V1

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 17-3A shows the valve in this position. When changing cartridges during operation one side can be closed.

Fuel filter



1. *Vent screw* 2. *Cover* 3. *Cartridge* 4. *Insert* 5. *Guide ring* 6. *Drain plug* 7. *Mark* 8. *Three-way valve*

Fig 17-3

V1

Fig 17-3B 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.

17.6.1. Changing of filter cartridges and cleaning of filter

V1

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:

Note!
Take care not to open the side of the filter in operation.

1. **Shut off the filter side to be serviced.**
2. **Open the air vent screw (1)** and, afterwards, the drain plug (6). Drain the fuel.
3. **Open the filter cover (2).**
4. **Remove the wire gauze insert (4).** Wash in gas oil. Check that it is intact.
5. **Remove the paper cartridge(s) and throw away.** Paper cartridges cannot be cleaned. Always keep a sufficient quantity of cartridges in stock.
6. **Clean and rinse filter housing** carefully with gas oil.
7. **Fit new paper cartridges** and the cleaned wire gauze insert. Check that all seals are intact and in position.
8. **When the filter has two or three inserts per side,** check that the guide ring (5) is mounted.
9. **Mount the drain plug and cover.**
10. **If possible, fill the filter with clean fuel** before changing over to the working position (both sides of filter in operation). If the filter cannot be filled, change over very slowly, see section 17.3.
11. **Vent the filter** if not completely filled according to pos. 10. See section 17.3.

18. Lubricating Oil System

V4

Normally, a wet sump system is used, but dry sump systems can also be used.

The engine is provided with a lubricating oil pump (10) directly driven by the pump gear at the free end of the crankshaft. In some installations there is a separately driven stand-by pump in parallel. The pump sucks oil from the engine oil sump and forces it through the lubricating oil cooler (1) equipped with a thermostat valve (3) regulating the oil temperature, through the lubricating oil main filters (4) to the main distributing pipe (5) in the oil sump, through the hydraulic jacks (in this respect acting as ordinary pipes) to the main bearings and through the bores in the connecting rods to the gudgeon pins (6) and piston cooling spaces. Oil is led through separate pipes to other lubricating points, like camshaft bearings (7), injection pump tappets and valves, rocker arm bearings (8) and valve mechanism gear wheel bearings, and to oil nozzles for lubricating and cooling. Part of the oil flows through a centrifugal filter back to the oil sump. The oil sump is provided with a level switch connected to the automatic alarm system.

The V-engine is not equipped with a built-on oil cooler nor a filter.

The dry sump system differs from the wet sump system only in that the oil flows freely from the oil sump to a separate tank, and the pump sucks the oil from this tank. (There is also the possibility to mount a second oil pump directly driven by the engine for draining the oil sump to a separate oil tank.)

The electrically driven prelubricating pump is a screw type pump equipped with an overflow valve. The pump is used for:

- filling of the engine lubricating oil system before starting, e.g. when the engine has been out of operation for a long time,
- continuous prelubrication of stopped engine(s) in a multi-engine installation always when one of the engines is running,
- continuous prelubrication of a stopped diesel engine through which heavy fuel is circulating,
- providing additional capacity to the direct driven lubricating oil pump in certain installations where the diesel engine speed drops below a certain value (the pump should start and stop automatically on signals from the speed measuring system).

Note!
In V-engines which have no built-on lubricating oil pump, the prelubrication should be arranged by means of an external pump.

The pressure in the distributing pipe (5) is regulated by a pressure control valve (11) on the pump. The pressure can be adjusted by means of a set screw (Fig 18-2, pos. 17) on the control valve. It is very important to keep the correct pressure in order to provide efficient lubrication of bearings and cooling of pistons. Normally, the pressure stays constant after having been adjusted to the correct value.

The pressure can rise above the nominal value when starting with cold oil but will return to the normal value when the oil is heated.

A pressure gauge (9) on the instrument panel indicates the lubricating oil pressure before the engine (in the engine distributing pipe). The system includes three pressure switches for low lubricating oil pressure (2), two connected to the automatic alarm system and one for lower pressure to the automatic stop system (see section 23.1.1). The temperature can be checked from thermometers (14) before and after the oil cooler (section 01.2). A temperature switch for high lubricating oil temperature is connected to the automatic alarm system (see section 23.1.1).

The speed governor (if equipped) has its own oil system. Depending on the turbocharger type, it can be lubricated by an own oil system or by the engine oil system. See separate instruction books.

The oil filling opening (12) is located at the free end and an oil dipstick (13) is located in the middle of the engine.

Connections for a separator are provided on the oil sump at the free end of the engine.

For taking oil sample a valve (15) is available after oil filter.

18.1. Maintenance of lubricating oil system V2

Use only high quality oils approved by the engine manufacturer according to section 1.

Always keep a sufficient quantity of oil in the system. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level near the max. mark and never allow the level to go below the min. mark. The limits apply to the oil level in a running engine. Add max. 10 % new oil at a time (see section 1). One side of the dipstick is graduated in centimeters. This scale can be used when checking the lubricating oil consumption.

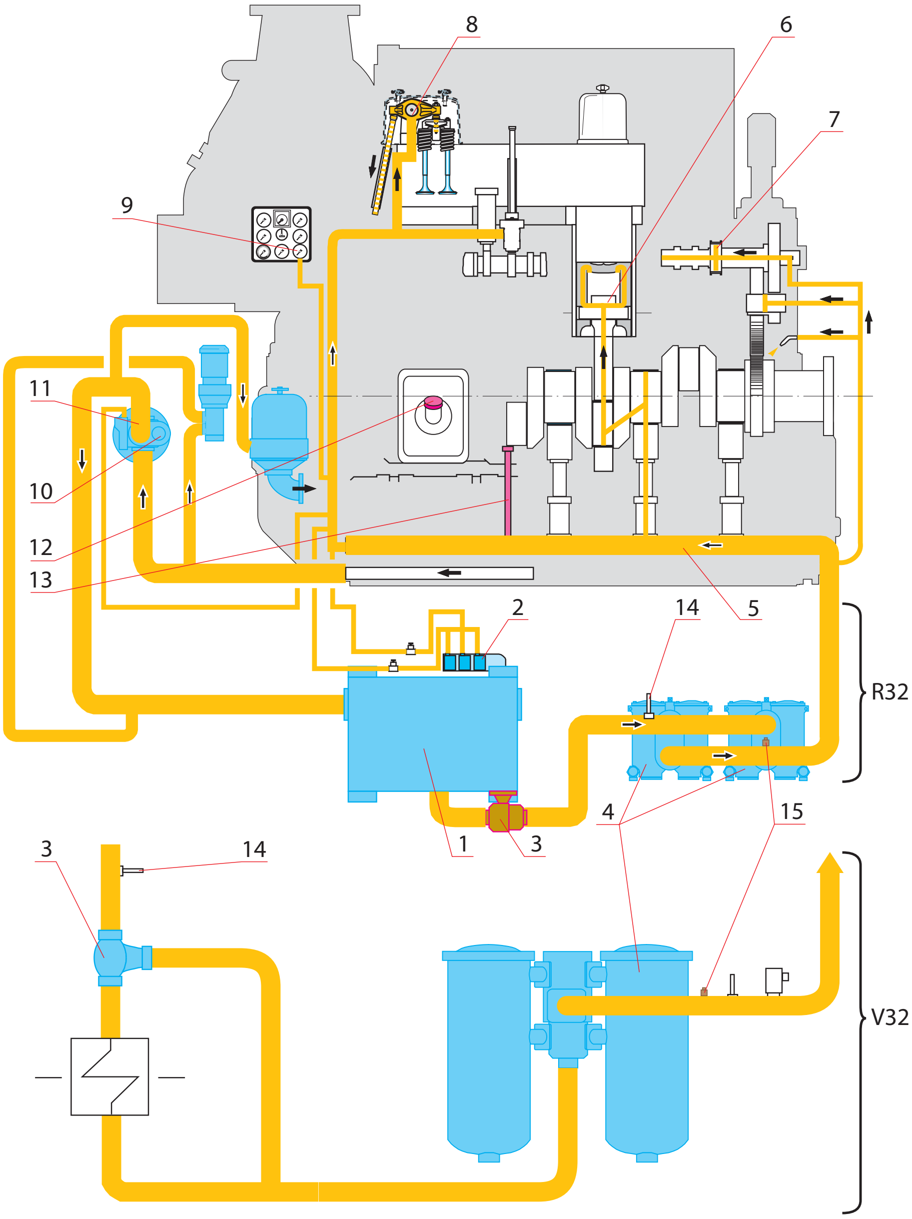
Change oil regularly at intervals determined by experience from the installation concerned, see chapter 04 and section 02.2.2. While the oil is still warm, drain the oil system, as well as the oil cooler and filter.

Clean the crankcase and the oil sump with proper rags (not cotton waste). Clean the main filter and the centrifugal filter. Change cartridges in the main filter unless they have been changed recently.

Centrifuging of the oil is recommended, especially when using heavy fuels, see section 02.2.2.

Note!
Utmost cleanliness should be observed when treating the lubricating oil system. Dirt, metal particles and similar may cause serious bearing damage. When dismantling pipes or details from the system, cover all openings with blank gaskets, tape or clean rags. When storing and transporting oil, take care to prevent dirt and foreign matters from entering the oil. When refilling oil, use a screen.

Lube oil system



1.Lubricating oil cooler, 2.Pressure switch, 3.Thermostat valve,4.Lubricating oil filter, 5.Main distributing pipe, 6. Gudgeon pin, 7.Camshaft bearing, 8. Rocker arm bearing,9.Pressure gauge, 10.Lubricating oil pump,11. Pressure control valve, 12. Filling opening, 13.Dipstick, 14.Thermometer, 15.Oil sample valve.

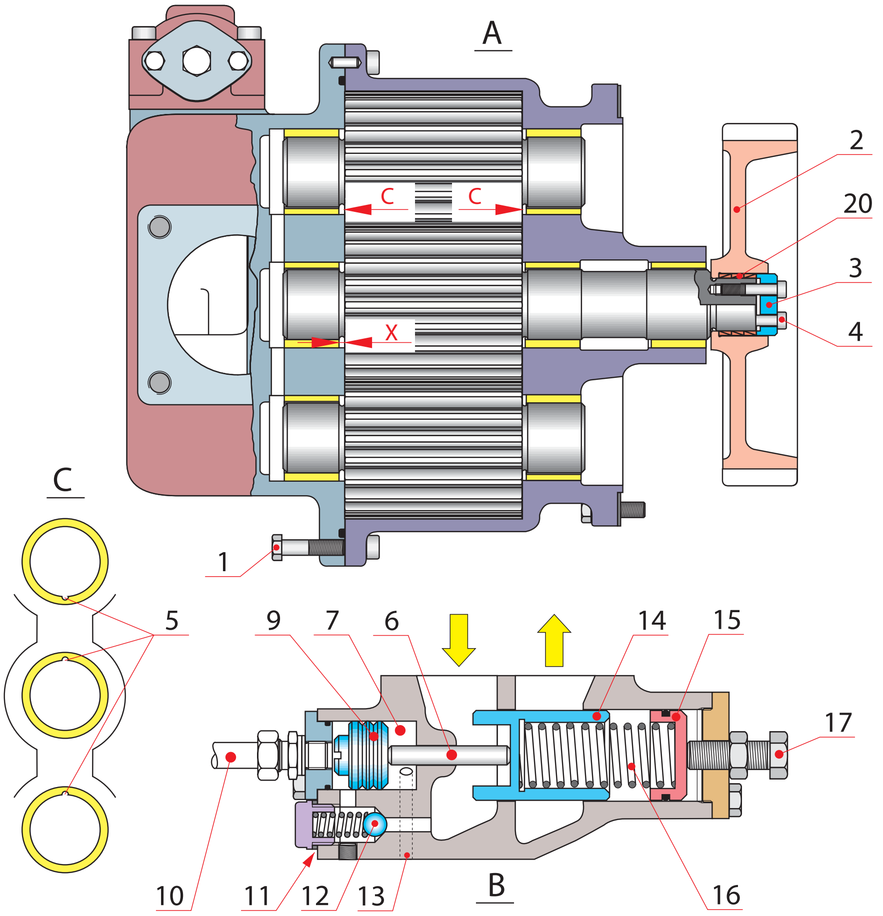
Fig 18-1 V1

18.2. Lubricating oil pump

V2

The pump is of the gear type, equipped with a built-on, combined pressure regulating/safety valve. Four and six cylinder engines have pumps with two pump gears each, see Fig 18-2. The pumps of 8- to 18-cylinder engines have three pump gears (see Fig 18-2), and the two-fold pressure and suction spaces are connected by ducts in the pump cover, where the pressure control/safety valve is also located. Identical bronze bearings are used. No outside lubrication is required. The cover is sealed by an O-ring.

Lube oil pump (3 Gears)



1.*Screw,* 2.*Gear wheel,* 3.*Pressure plate ,* 4.*Screw,* 5. *Grooves,* 6.*Pin,* 7.*Cylinder,* 9.*Piston,* 10.*Pipe,* 11.*Sealing ring,*12.*Ball,* 13.*Drain bore,* 14.*Regulating piston,* 15.*Spring retainer,* 16.*Spring,* 17.*Screw,* 20.*Conical ring elements,*

Fig 18-2

V1

18.2.1. Dismantling of lubricating oil pump

V2

1 **Remove and inspect the regulating valve** according to section 18.3.

2 **Loosen the screws (4)** and remove the pressure plate (3), according to Fig 18-2.

3 **Pull off the gear wheel (2)** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The conical ring elements come loose together with the gear wheel.)

Note!
Using an extractor will only damage the shaft (axial scratches).

4 **Withdraw the pump cover** by using two of the fastening screws (1) in the two threaded holes located in the cover.

18.2.2. Inspection of lubricating oil pump

V2

1 **Check all parts for wear** (section 06.2) and replace worn parts.

2 **Remove worn bearings** from the housing by driving them out with a suitable mandrel, from the cover by machining.

3 **Mount new bearings** (freezing is recommended) so that the bearings are three (3) mm below the cover and housing level (measure X = 3 mm), Fig 18-2A. Be careful so that bearing lubrication grooves (5) slide into the right position according to Fig 18-2C.

4 **Check the bearing diameter** after mounting. Check the gear wheel axial clearance (see section 06.2).

18.2.3. Assembling of lubricating oil pump

V2

1 **Clean all details carefully before assembling.** Check that the O-ring in the cover is intact and in position.

2 **Before reinstalling the gear wheel,** all contact surfaces should be cleaned and oiled.

3 **Reinstall the conical ring elements** (20).

Note!
Reinstall the conical ring elements exactly as situated in Fig 18-3. The conical ring elements should fall easily in place and must not jam.

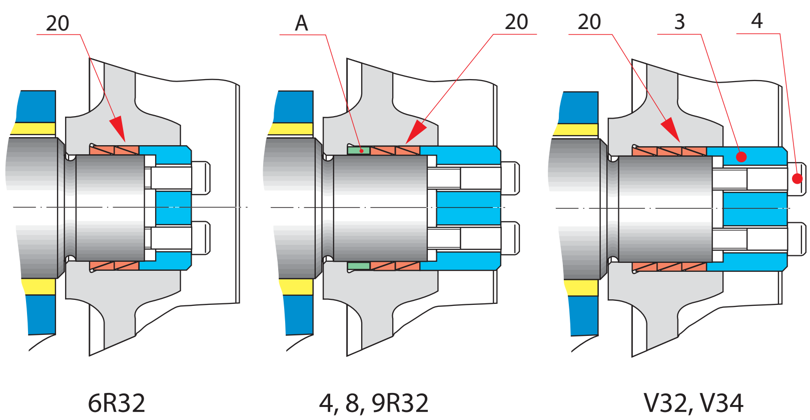
4 **Reinstall the pressure plate.**

5 **Tighten the screws a little** and check that the gear wheel is in the right position.

6 **Tighten the screws to torque** according to section 07.1.

7 **If the gear wheel (2) has been changed,** check the backlash after mounting the pump on the engine.

Mounting of gear wheel to oil pump



A.*Distance ring.* 3.*Pressure plate,* 4.*Screw,* 20.*Conical ring elements.*

Fig 18-3 V1

18.3. Lubricating oil pressure regulating valve and safety valve V2

The pressure regulating valve is mounted on the lubricating oil pump and regulates the oil pressure before the engine by returning the surplus oil direct from the pressure side of the pump to the suction side.

The pipe (10), Fig 18-2, is connected to the engine distributing pipe, where the pressure is kept constant in engines running at constant speed. This pressure actuates the servo piston (9) and the force is transferred to the regulating piston (14) through the pin (6). The spring (16) is tensioned to balance this force at the required pressure. Thus the pressure is kept constant in the distributing pipe, irrespective of the pressure in the pressure side of the pump and of the pressure drop in the system. By tensioning the spring (16) a higher oil pressure is obtained.

In engines which are running at varying speeds, the valve is arranged to give a pressure depending on the speed, according to operating pressures recommended at various speeds (section 01.1).

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 regulating piston (14) by means of the pin (6).

The valve serves as a safety valve.

18.3.1. Maintenance

V1

1 **Dismantle all moving parts.** Check them for wear and replace worn or damaged parts by new ones.

2 **Clean the valve carefully.** Check that the draining bore (13) is open.

3 **Check that no details are jamming.**

Note!
Do not forget copper sealing rings (8) and (11) when reassembling. (Part 8 is used for 4- and 6-cylinder engines, only.) If the sealings are changed, check that the thickness is correct, (8) = 2 mm, (11) = 1.5 mm, as the thickness of these sealings influences the valve function.

4 **After reassembling, check that the piston (14) closes** (especially if some details have been replaced by new ones).

18.4. Plate cooler for lubricating oil

V1

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).

18.4.1. General maintenance

V2

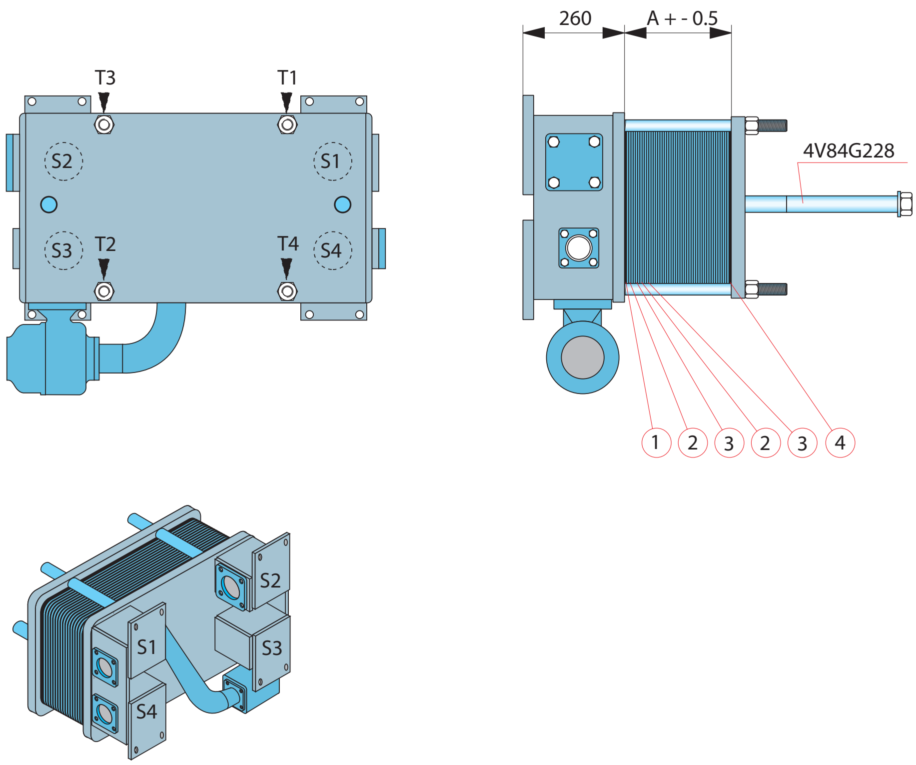
1 **Clean and test the cooler** at intervals according to chapter 04. or if the lubricating oil temperature tends to rise abnormally.

2 **Always when cleaning, check for corrosion** and test by hydraulic pressure.

Note!
It is preferable to change plates in bad condition too early, rather than too late. Water leakage to lubricating oil has serious consequences

3 **When replacing plates,** make sure that all plates are assembled in correct order. Change gaskets when necessary.

Plate oil cooler



S1 *Oil inlet,* **S2** *Water inlet,* **S3** *Oil outlet,* **S4** *Water outlet.*

1.*End plate II,* 2.*Channel plate,* 3.*Channel plate,* 4.*End plate I.*

Measure A = Q x 2.6 mm where Q = number of plates.

Example : 135 plates gives A = 135 x 2.6 mm = 351 mm

Fig 18-4

V1

18.4.2. Opening

V1

1. **Release the pressure from the cooler.**
2. **If the plate cooler is hot** wait until it has cooled to about 40°C.
3. **Drain the cooler.**
4. **Mount the tool 4V84G228** according to Fig 18-4.
5. **Slacken the nuts** in turn diagonally as shown in Fig 18-4.

Note!
During opening, the slant of the pressure plate must not exceed 10 mm (2 turns/nut).

6. **Dismantle the plate pack.**

18.4.3. Cleaning

V1

Normally the plates can be cleaned by a soft brush and water.

Solid deposits can be cleaned with a soft brush and 4 % nitrite acid. Max. temperature 60°C.

Note!
Rinse well.

18.4.4. Closing

V1

1. **Check that all sealing surfaces** (surfaces in contact with media) of the heat exchanger are clean.
2. **Check the threads of the tightening nuts.** See that they are undamaged, cleaned and smeared with a thin film of lubricating paste.
3. **Check that all plates** are in good condition.
4. **Bring the plates together** and mount the nuts.
5. **Tighten the nuts** in turn, diagonally as shown in Fig 18-4.

Note!
The slant of the pressure plate must not exceed 10 mm (2 turns/nut) during compressing.

6 **Compress to measure A.** Measure A should be checked near the bolts. Max deviation: 2 mm.

Max tightening torque: 900 Nm

.

7 **The final tightening** must be even so that the measure A is kept within +0.5 mm. Should the cooler tend to leak, the compression may be A - 0.5 mm.

8 **Procedure if measure A has not been attained** with max. tightening torque:

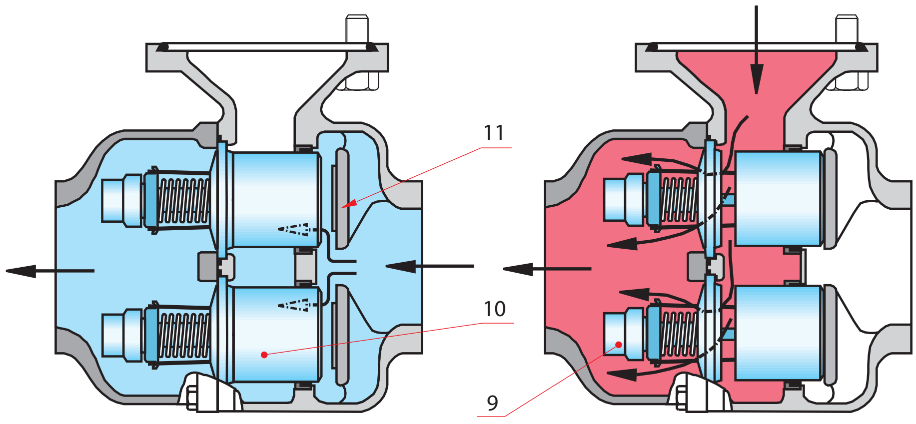
- check the number of the plates and measure A
- check that the nuts run easily. If not, clean, lubricate or change them.

18.5. Thermostatic valve

V1

The figure shows the valve in a closed position (left). When the temperature exceeds the nominal value, the contents of the elements (9) expand and force the valve unit (10) towards the seat (11), thus passing part of the oil through the cooler. This movement continues until the right temperature of the mixed oil is obtained. As the cooler becomes dirtier, the temperature will rise a few degrees, which is quite normal, because the valve needs a certain temperature rise for a certain opening to increase the oil flow through the cooler.

Thermostatic valve for oil system



9.*Element,* 10.*Valve unit,* 11.*Seat.*

Fig 18-5

V1

18.5.1. Maintenance of thermostatic valve V2

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 elements** by unscrewing the pipe after 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 section 01.1; the lower value for the lube oil temperature is the opening temperature, the higher for the fully open valve.

3 **Change the defective element.** Check O-rings and change, if necessary.

18.6. Lubricating oil main filter V2

V-Engine

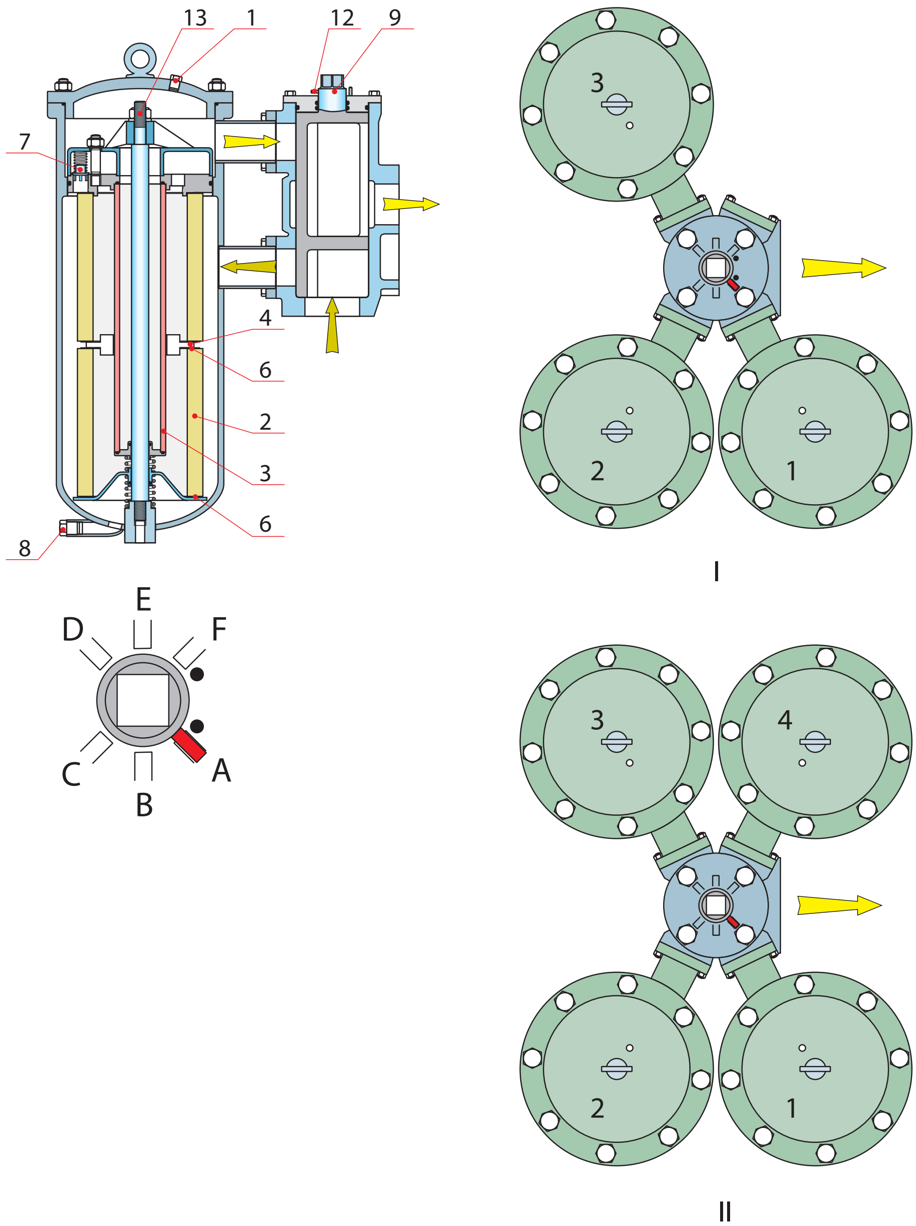
The V-engines can be provided with filters according to Fig 18-6 . In that case, 12V32 has a filter consisting of three filter units connected together. 16V32 and 18V32 have four filter units connected together.

The filters are full-flow filters, i.e. the whole oil flow passes through the filter(s). Normally, all filter units should be in operation to provide maximal filtration. When changing a cartridge during operation, one filter half can occasionally be closed.

For the V-engine, the pin (12) on the cock (9) shows the direction of the filter unit which is closed according to the table in Table 18.6.

The position of the valve ("position"), which filter units are in operation ("open") and which one is closed ("closed") are stated in the table. The black field states the position of the pin (12). Position B indicates normal operation with all filter units in service. Note that for 12 cylinder engines, the filter unit 4 is missing.

Lube oil filter for V-engine



I *12- cylinder engines,* II *16- and 18- cylinder engines.*

1.*Air screw,* 2.*Paper cartridge,* 3.*Cartridge,* 4.*Guide,* 6.*Cartridge end,* 7.*By-pass valve,* 8.*Drain plug,* 9.*Cock,* 12.*Pin,* 13.*Nut.*

Fig 18-6

V1

Position	Open	Closed
A	2, 3, 4	1
B	1, 2, 3, 4	
C	1, 3, 4	2

D	1, 2, 4	3
E	1, 2, 3, 4	
F	1, 2, 3	4

The arrows in the figures show the flow through the filters. At first, the oil flows through a cartridge (2), made of special paper, with a nominal fineness of 15 µm, then through a cartridge (3) consisting of a plated wire gauze around a perforated case. The wire gauze insert, with a mesh of 63 µm, serves as a safety filter in case of failure or by-passing of the paper insert.

The filters are provided with by-pass valves (7) over the paper cartridges. The valves open when the pressure drop exceeds 2 - 3 bar.

The filter is provided with a combined visual indicator/electrical switch connected to the automatic alarm system, which indicates a high pressure drop over the filter.

Note!
The paper cartridges should be changed as soon as possible if a high pressure drop over the filter is indicated.

18.6.1. Changing of filter cartridges and cleaning of filter

V2

Careful maintenance of the filter reduces engine wear. Change cartridges regularly (see chapter 04.) and, if the pressure drop indicator gives alarm, as soon as possible.

As the useful life of the cartridge is, to a great extent, dependent on the fuel quality, load, lubricating oil quality, centrifuging and care of centrifugal filter, experience from the installation concerned will give the most suitable intervals between changes of cartridges.

Change of cartridges and cleaning should, if possible, be done during stoppages. By closing one of the filter halves, the cartridge can, however, be changed during operation. As the load on the other cartridges (especially in 4R32) will increase, the change of cartridges should be carried out as fast as possible.

Note!
Release the pressure by opening the air vent screw (1) before the drain plug (8) is opened.

1 **Drain the filter.** Open the air vent screw (1) and the drain plug (8) and discharge the oil through the plug (8).

Do not refill the system with drained oil because it is very dirty.

2 **Open the complete cover.**

3 **Remove the paper cartridges (2)** and wire gauze inserts (3). On V-engine filters, open the nut (13).

4 **Wash the wire gauze inserts** in gas oil and check that they are intact.

5 **Clean and rinse the filter housing** carefully with gas oil.

6 **Change the paper cartridges.**

Paper cartridges cannot be cleaned.

Always keep a sufficient quantity of cartridges in stock.

7 **Check that all gaskets are intact and in position,** especially gaskets against the cartridge ends (6).

Note!
If the filter housings have been divided they must carefully be glued together. New gaskets have to be used and glued to the filter housings (both sides).

8 **Check that the guide (4) slides into position** when remounting the wire gauze inserts and paper cartridges.

Note!
Do not refill the system with drained oil because it is very dirty.

18.6.2. Cleaning of the filter by-pass valve V1

Normally, no regular maintenance is required for the by-passs valve (7), but if malfunction is suspected, the by-pass valve should be cleaned.

1 **Unscrew the plug,** which is holding the by-pass valve slide. On V-engines, remove the insert cover, unscrew the nuts and lift off the flange to have access to the by-pass valve slide.

2 **Withdraw the slide** and wash it with clean diesel oil or similar. If necessary, the slide can be brushed with a brass wire brush.

3 **Clean the slide bore** with a tube brush.

4 **Grease the slide** and check that it moves easily in the bore.

5 **Assemble the safety valve.**

Note!
Handle the slide carefully. The fingers in the end of the slide are easily damaged.

18.7. Centrifugal filter V1

A by-pass filter of the centrifugal type is provided as a complement to the main filter. For V-engines two identical filters are used.

The filter comprises a housing (7) containing a hardened steel spindle (2) on which a dynamically balanced rotor unit (3) is free to rotate. Oil flows through the housing, up the central spindle into the rotor.

The rotor comprises two compartments, a cleaning chamber and a driving chamber. Oil flows from the central tube (4) into the upper part of the rotor, where it is subject to a high centrifugal force. The dirt is deposited on the walls of the rotor in the form of heavy sludge.

The oil then passes from the cleaning compartment into the driving compartment formed by the stand-tube (13) and the lower part of the rotor, which carries two driving nozzles (6). The passage of the clean oil through the nozzles provides a driving torque to the rotor and the oil returns through the filter housing to the engine oil sump.

18.7.1. Cleaning of centrifugal filter V2

It is very important to clean the filter regularly (chapter 04.) as it collects considerable quantity of dirt. A clean centrifugal filter unloads the main filter, which gives longer lifetime for the paper cartridges.

If it is found that the filter has collected the maximum quantity of dirt (corresponds to a 18 mm thick layer) at the recommended cleaning intervals, it should be cleaned more frequently.

Clean the filter as follows, the engine running, by closing the valve on the oil delivery pipe to the filter:

1 **Slacken off the nut** on the filter cover clamp (14), unscrew the cover nut (1) and lift off the filter body cover (8).

2 **Withdraw the rotor assembly** from the spindle (2) and drain oil from the nozzles before removing the rotor from the filter body. Hold the rotor body and unscrew the rotor cover jacking nut (9), then separate the rotor cover from the rotor body.

3 **Remove the washer (10)** and stand tube (13).

4 **Remove sludge** from the inside of the rotor cover and body by means of a wooden spatula or a suitably shaped piece of wood.

5 **Clean the stand tube.**

6 **Wash all details,** for example in gas oil.

7 **Clean out the nozzles** with brass wire and compressed air. Examine the top and bottom bearings in the tube assembly to ensure that they are free from damage of excessive wear. Examine the O-ring (15) for damage. Renew, if necessary.

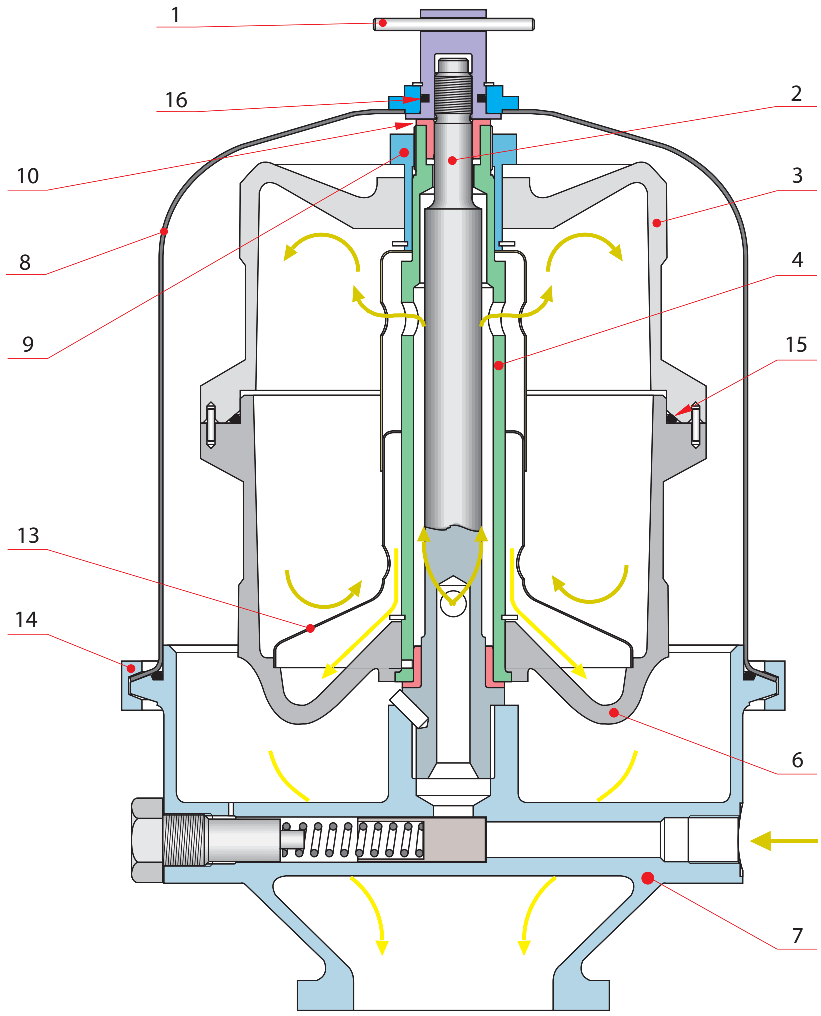
8 **Reassemble the rotor complete,** align the location pins and tighten the rotor cover jacking nut (9), tightening torque = 100 Nm.

Note!
Overtightening of the rotor cover jacking nut can lead to rotor imbalance, which will effect filter performance.

9 **Examine the spindle journals** to ensure that they are free from damage or excessive wear. Examine the O-ring (16) for damage. Renew, if necessary.

10 **Reassemble the filter completely,** checking that the rotor assembly is free to rotate, then replace the filter body cover. Tighten the cover nut and secure the filter cover clamp.

Centrifugal filter



1.*Cover nut,* 2.*Spindle,* 3.*Rotor unit,* 4.*Central tube,* 6.*Driving nozzle,* 7.*Housing,* 8.*Body cover,* 9.*Jacking nut,* 10.*Washer,* 13.*Stand-tube,* 14.*Cover clamp,* 15.*O-ring,* 16.*O-ring.*

Fig 18-7 V2

18.8. Prelubricating pump V1

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 min. value, about 2 bar, by unscrewing the adjusting screw (14) to the end position in order to prevent the electric motor from being overloaded when running with very cold oil.

The mechanical type shaft seal consists of two plane sealing surfaces facing each other - one of them (8) rotating with the shaft and the other one (6) being stationary.

18.8.1. General maintenance of prelubricating pump V1

See the manual of the manufacturer. Normally, no regular maintenance is required. After three to six years the shaft seal may have to be replaced due to ageing. Oil leaking out of the opening (5) indicates that the shaft seal is defective and has to be changed.

Take care not to damage the sealing ring faces. A slight scratch may disturb the sealing function. The rotating coal ring (8) is very fragile. Avoid touching sealing faces with fingers.

18.8.2. Dismantling of prelubricating pump V1

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). The pressing force may be relatively strong due to the rubber bellows.
7. **Tap the stationary sealing ring (6)** with the O-ring out of the front plate by using a mandrel.

8 **To remove the ball bearing (4)** from the front plate, remove first the locking ring.

Note!
Always clean the ball bearing in fresh gas oil. Protect the bearing when the pump parts are being cleaned as the used washing liquid contains dirt particles that may damage the bearing.

18.8.3. Reassembly of prelubricating pump V1

The reassembly is performed in the reversed order.

1 **Remount the ball bearing** in the front plate, the protective washer turned outwards. Lock with the locking ring.

2 **Oil the O-ring (7).** Insert the stationary sealing ring (6) in the front plate. Take care not to damage the sealing faces and that the ring enters the pin (11).

3 **Clean the drive screw** carefully and enter the sealing unit (13) without the coal ring on to the shaft. Take care that the rubber bellows are pressed against the seal spring supporting washer. Keep the seal in this position for a moment to enable the bellows to fix. A drop of lubricating oil on the drive screw shaft will facilitate reassembly.

4 **Put the coal ring into position,** the smaller sealing face upwards and the grooves matching the marks.

5 **Place the front plate (10)** over the drive screw shaft journal.

6 **Force the ball bearing inner ring** against its shoulder on the drive screw. Use a suitable sleeve matching the bearing inner ring.

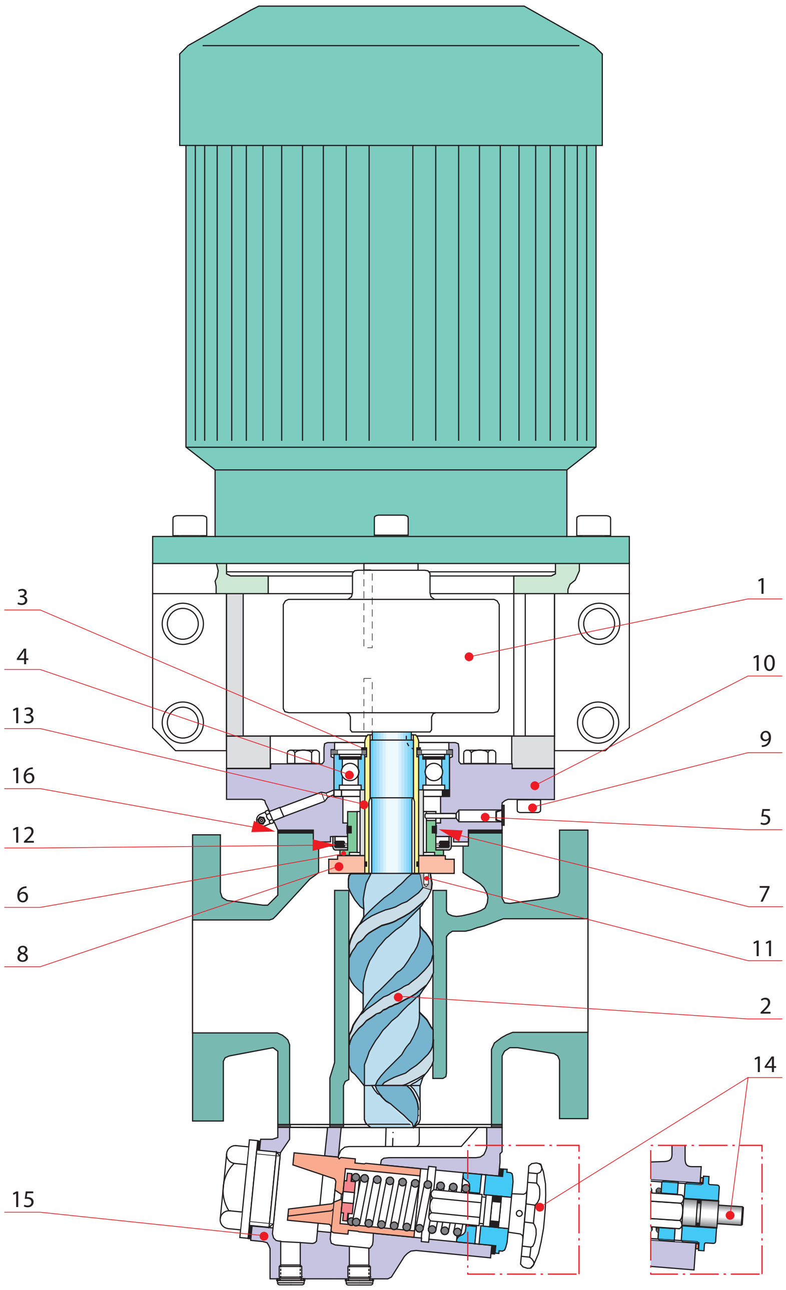
7 **Lock with the ring (3).**

8 **Install the end plate unit** and screw the set in the pump housing. Do not forget the O-ring (12) which seals between the pump housing and the front plate. Fill the ball bearing with grease.

9 **Install the coupling half (1)** on the pump shaft and fasten the pump to the bracket. Check that the clearance between the coupling halves is 2 mm.

10 **If the electric motor has been disconnected or changed,** check that it rotates in the right direction by switching on a few times.

Prelubricating pump



1.*Coupling half,* 2.*Drive screw,* 3.*Locking ring,* 4.*Ball bearing,* 5.*Opening,* 6.*Sealing ring,* 7.*O-ring,* 8.*Sealing ring,* 9.*Screw,* 10.*Front plate,* 11.*Pin,* 12.*O-ring,* 13.*Sealing unit,* 14.*Adjusting screw,* 15.*Control valve,* 16.*Gasket.*

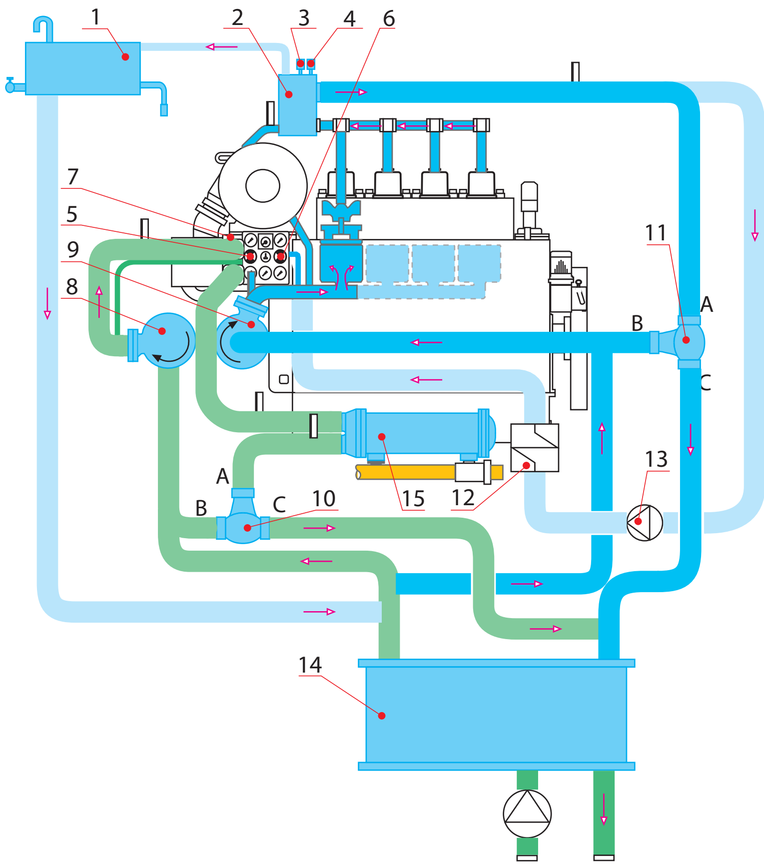
Fig 18-8 V1

19. Cooling Water System

V2

The engine is cooled by a closed circuit cooling water system, divided into a high temperature circuit (HT) and a low temperature circuit (LT). The cooling water is cooled in a separate central cooler.

Cooling water system



1. *Expansion tank* 2. *Venting box* 3. *Alarm switch* 4. *Alarm switch* 5. *Manometer* 6. *Manometer* 7. *Charge air cooler* 8. *LT-water pump* 9. *HT-water pump* 10. *LT-temperature control valve* 11. *HT-temperature control valve* 12. *Heater* 13. *Pump* 14. *Central cooler* 15. *Lube oil cooler*

Fig 19-1

V2

19.1. HT circuit

V2

The HT circuit cools the cylinders, cylinder heads and the turbochargers.

A centrifugal pump (9) pumps the water through the HT circuit. From the pump the water flows to the distributing duct, cast in the engine block.

In V-engines the water is distributed to the distributing ducts of each cylinder bank through ducts cast into the pump cover at the free end of the engine.

From the distributing ducts the water flows to the cylinder water jackets, further through connection pieces to the cylinder heads where it is forced by the intermediate deck to flow along the flame plate, around the valves to the exhaust valve seats, efficiently cooling all these components. From the cylinder head the water flows through a connection piece to the collecting pipe, further to the temperature control valve maintaining the temperature at the right level.

Parallel to the flow to the cylinders, part of the water flows to the turbochargers.

19.2. LT circuit

V2

The LT circuit consists of a charge air cooler (7) and a lube oil cooler (15) through which a pump (8), of similar design as the HT pump, pumps the water. The circuit temperature is controlled by a temperature control valve (10). The necessary cooling is gained from the central cooler (14).

However, the LT pump can alternatively also be an external, electric motor driven.

The system outside the engine can vary from one installation to another. In some applications, the lube oil cooler and the temperature control valve are not mounted on the engine.

19.3. Venting and pressure control

V1

The collecting pipes from the cylinder and turbocharger cooling system are connected to a box (2) for venting of the system. From this box the vent pipe leads to the expansion tank (1) from which the expansion pipe is connected to the inlet pipe of the pumps (8 and 9). A static pressure of 0.7...1.5 bar is required before the pumps. If the expansion tank cannot be located high enough to provide this pressure, the system is to be pressurized.

19.4. Preheating

V2

For preheating of the circuit, a heater circuit with the pump (13) and heater (12) are connected in the HT circuit before the engine. The non-return valves in the circuit force the water to flow in the right direction.

Before start, the HT circuit is heated up by a separate heater. Guidance values, see section 01.2. This is of utmost importance when starting and idling on heavy fuel.

19.5. Monitoring

V4

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 section 01.2, should not be exceeded.

Manometers (5) and (6) on the instrument panel indicate HT and LT pressures after the pumps. The pressures depend on the speed and the installation. Guidance values, see section 01.2.

The HT water outlet after the engine is provided with an alarm switch (3) and a stop switch. Main engines are provided with alarm switches for low HT and LT pressure.

For further information, see section 23.1.1.

19.6. Maintenance of cooling water system

V2

The installation - including expansion, venting, preheating, pressurizing - should be carried out strictly according to the instructions of the engine manufacturer to obtain correct and troublefree service.

The cooling water should be treated according to the recommendations in 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.

19.6.1. Cleaning

V2

In completely closed systems the fouling will be minimal if the cooling water is treated according to our instructions in section 02.3. Depending on the cooling water quality and the efficiency of the treatment, the cooling water spaces will foul more or less in the course of time. Deposits on cylinder liners, cylinder heads and cooler stacks should be removed as they may disturb the heat transfer to the cooling water and thus cause serious damage.

The need of cleaning should be examined, especially during the first year of operation. This may be done through one of the plugs in the engine block or by overhauling a cylinder liner and checking for fouling and deposits on the liner and block. The cylinder head cooling water spaces may be checked by opening the lower large plugs on the sides of the cylinder heads. The turbochargers can be checked through the covers of the water space and the coolers by removing the water boxes of the inlet water.

The deposits can be of the most various structures and consistencies. In principle, they can be removed mechanically and/or chemically as described below. More detailed instructions for cleaning of coolers are stated in section 18.4.

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 section 18.4).

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 section 02.3.

The cleaning agents should contain additives (inhibitors) to prevent corrosion of the metal surfaces. Always follow the manufacturer's instructions to obtain the best result.

After treatment, rinse carefully to remove cleaning agent residuals. Brush surfaces, if possible. Rinse again with water and further with a sodium solution of 5 % to neutralize possible acid residuals.

19.7. Water pump

V2

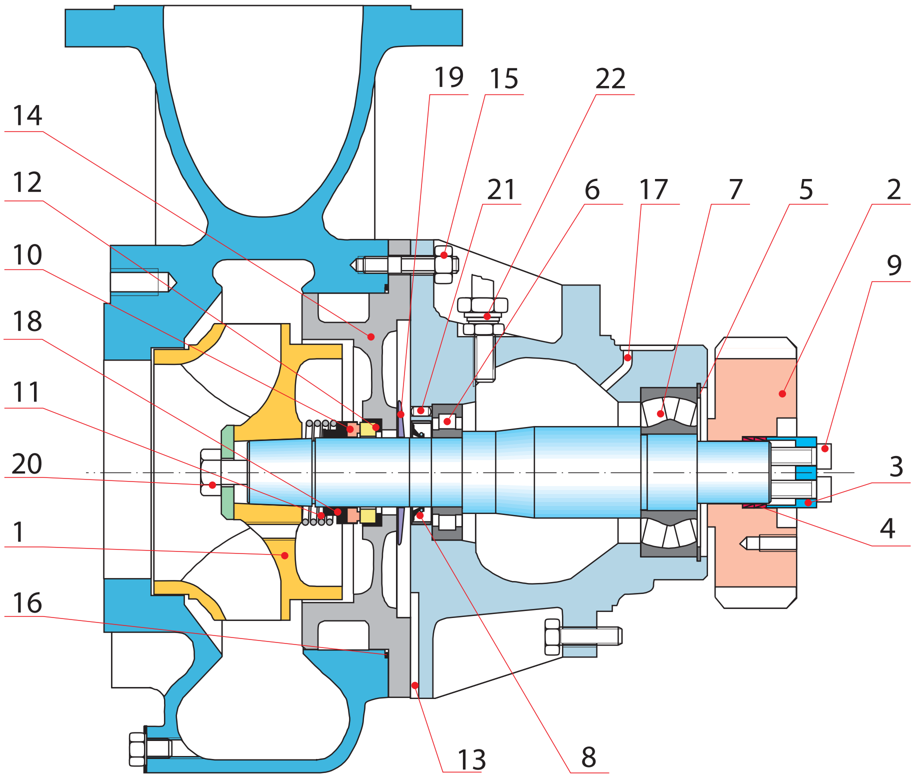
The water pump is a centrifugal pump and is driven by the gear mechanism at the free end of the engine. The shaft is made of stainless steel, the impeller (1) and the sealing ring of bronze and the remaining details of cast iron.

The shaft is mounted in two ball bearings (6) and (7), which are lubricated by oil entering through the pipe fitting (22). The radial seal (8) prevents the oil from leaking out and, at the same time, dirt and leak water from entering. Also the slinger (19) assists in this.

The gear wheel (2) is fastened to the shaft by conical ring elements (4). When the screws (9) 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 (10) rotates along with the shaft and seals against it with a protection seal (18) fixed to the ring. The spring (11) presses the rotating ring against a fixed ring (12) which seals against the housing by means of its rubber coat. Possible leak-off water from the sealing can flow out through the opening (13).

Cooling water pump



1. Impeller, 2. Gear wheel, 3. Pressure plate, 4. Conical ring elements, 5. Bearing retainer, 6. Ball bearing, 7. Ball bearing, 8. Radial seal, 9. Screw, 10. Ring, 11. Spring, 12. Fixed ring, 13. Opening, 14. Rear plate, 15. Nut, 16. O-ring, 17. Opening, 18. Protection seal, 19. Slinger, 20. Screw, 21. Locking screw, 22. Pipe fitting.

Fig 19-2 V1

19.7.1. Maintenance of the water pump V1

Check the pump at intervals according to the recommendations in chapter 04 or, if water and oil leakage occurs, immediately.

19.7.1.1. Disassembling and assembling of impeller

V2

1. **Remove the volute casing** by loosening the nuts (15).
2. **Loosen the fastening screws (20).**
3. **Pull off the impeller** by using the tool 32.83H01.
4. **When re-assembling the impeller,** coat the threads with Loctite 242 and tighten the nut to torque, see section 07.1.
5. **Check that the O-ring** (16) is intact and in position when re-installing the volute casing. Check that the volute casing is in position. The opening (17) should be turned upwards when the pump is installed.

Note!
If the bearing housing is turned wrongly, the bearings (6) and (7) will be left without lubrication. Before mounting the pump on the engine, fill up the bearing housing (17) with oil until oil flows out through the draining holes.

19.7.1.2. Disassembling and assembling of mechanical seal

V2

1. **Remove the impeller** according to section 19.7.1.1.
2. **Carefully dismantle all seal details.** Sealing rings are very fragile.
3. **Take particular care** not to damage sealing surfaces as a slight scratch may disturb the sealing function.
4. **Replace the complete seal** if it is leaky, or if sealing faces are corroded, uneven or worn. Avoid touching the sealing faces with fingers.
5. **Reassemble the details** in proper order and install the impeller according to section 19.7.1.1.

19.7.1.3. Replacing of bearings

V2

1. **Remove the pump** from the engine.
2. **Disassemble the impeller** and mechanical seal according to section 19.7.1.1 and section 19.7.1.2.
3. **Remove the rear plate** (14) by undoing the screws (15).
4. **Loosen the screws** (9) and remove the pressure plate (3).

5 **Pull off the gear wheel** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The conical ring elements (4) come loose together with the gear wheel.)

Note!
Using an extractor will only damage the shaft (axial scratches).

6 **Loosen the bearing retainer** (5) and the slinger.

7 **Remove the locking screws (21)** and mount three hexagon screws into the holes. Tighten the screws until the bearings come loose from the housing. Remove the shaft and bearings.

8 **Check the seal** (8) and the bearings for wear and damage, see section 19.7.1.2.

9 **Remove the bearings** from the shaft.

10 **Press the new bearing** (6) by its inner ring with a suitable pipe.

11 **Before fitting the bearing,** oil the collar. See Fig 19-3.

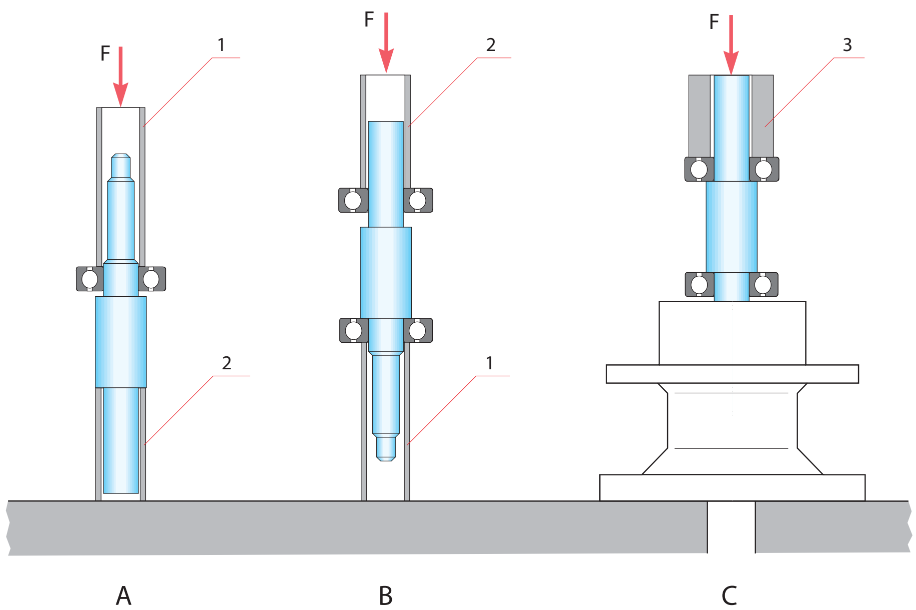
12 **Turn the shaft** according to Fig 19-3.

13 **Fit the distance ring** and oil the collar.

14 **Press the bearing** (7) by its inner ring with a suitable pipe. See Fig 19-3.

15 **Turn the bearing housing** according to Fig 19-3 and oil the outer surfaces of the bearings. Press the shaft into the housing by both the inner and outer ring of the bearing (7) with a suitable pipe.

Mounting of bearings



1-3. *Pipes 1, 2, and 3*

Fig 19-3 V1

16 **Fit the bearing retainer (5)** and tighten the screws (26).

17 **The axial clearance of the shaft** should be 0.05...0.10 mm. If necessary, use shims between the bearing (7) and the retainer (5).

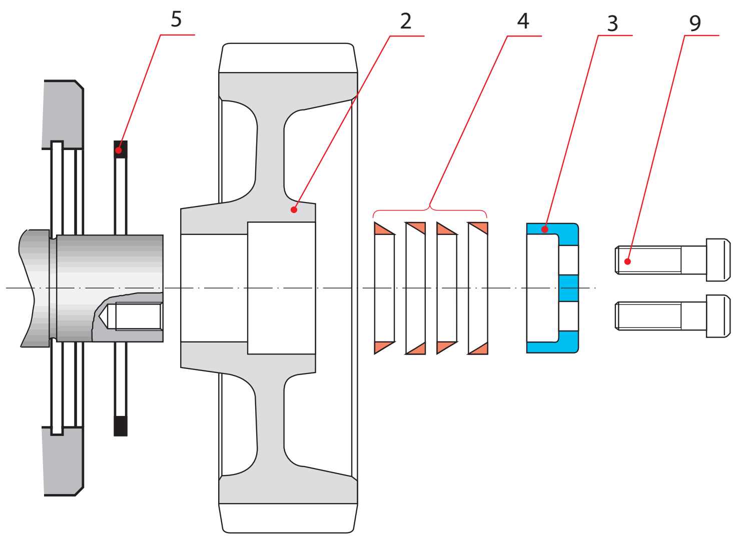
18 **Before re-installing the gear wheel,** all contact surfaces should be cleaned and oiled.

19 **Re-install the gear wheel.**

20 Re-install the conical ring elements (4).

Note!
Re-install the ring elements exactly as situated in Fig 19-4.

Mounting of gear wheel to water pump



2. Gear wheel , 3. Pressure plate ,4. Conical ring elements, 5. Bearing retainer , 9. Screw,

Fig 19-4 V1

Note!
The conical ring elements should fall easily in place and must not jam.

21 Re-install the pressure plate and the screws.

22 Tighten the screws a little and check that the gear wheel is in the right position.

23 Tighten the screws to torque according to section 07.1.

24 Re-install the seal(s) (8) , see section 19.7.1.4.

25 Mount the slinger (11)

26 Re-install the rear plate (14) as well as the mechanical seal, impeller and volute casing according to section 19.7.1.1 and section 19.7.1.2.

19.7.1.4. Replacing of radial seal V2

This will be most easily done at the same time as replacing the bearings. If, for some reason, the seal is leaky and there is no need to change the bearing, proceed as follows:

1. **Remove the volute casing** and mechanical seal according to section 19.7.1.1 and section 19.7.1.2 as well as the rear plate (14).
2. **Remove the slinger (19).** Take care not to deform the ring.
3. **Remove the seal (8)** by prying (damaging) without scratching the shaft.In connection with bearing changes the seal can easily be driven out axially.
4. **Inspect the shaft.** In case the seal has worn the shaft by more than 0.5 mm radially, the shaft should be replaced according to section 19.7.1.3.
5. **Oil the new seal** and press it in until it levels with the bearing housing.
6. **Install the rear plate (14)** , mechanical seal, impeller and the volute casing according to section 19.7.1.1 and section 19.7.1.2.

19.8. Temperature control system V2

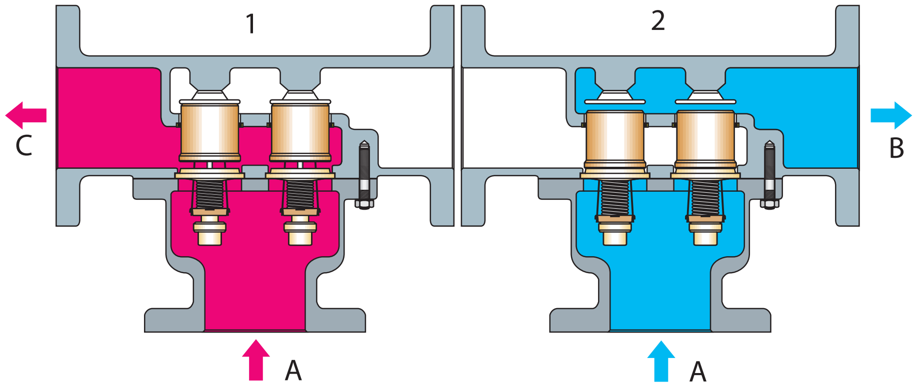
The LT and HT circuits are equipped with temperature control valves. The valves are normally mounted outside of the engine.

In some applications, the LT circuit is provided with a load dependent temperature control valve. At low load the valve controls at high temperature, and at high load it controls at low temperature by the thermostatic element(s). Temperature ranges according to section 01.2.

19.8.1. Temperature control valve V2

The thermostatic valve is equipped with positive three-way valve action in which the water is positively made to flow in the direction required. When the engine is started up and is cold, the thermostatic valve causes all of the water to be positively by-passed back into the engine, thus providing the quickest warm-up period possible. After warm up, the correct amount of water is by-passed and automatically mixed with the cold water returning from the heat exchanger or other cooling device to produce the desired water outlet temperature. If ever required, the thermostatic valve will shut off positively on the by-pass line for maximum cooling. The three-way action of the valve allows a constant water flow through the pump and engine at all times with no pump restriction when the engine is cold.

Water flow in thermostatic valve



1. *Warm engine* 2. *Cold engine* A. *From the engine* B. *By-pass* C. *To the cooler*

Fig 19-5 V1

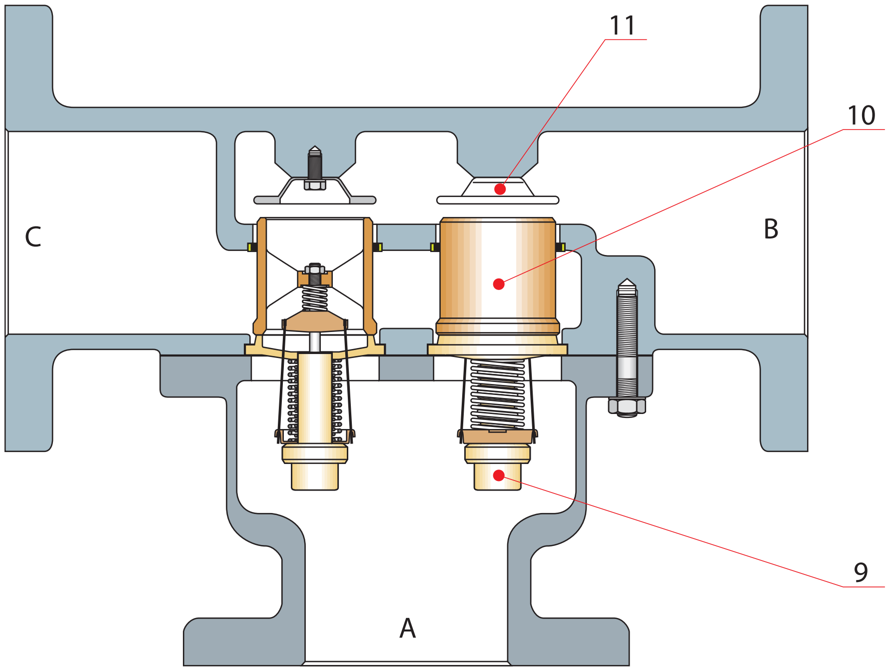
No adjustments are ever required on the thermostatic valve. The temperature is permanently set at the factory. The temperature can be changed only by changing temperature element assemblies which is easily accomplished by unscrewing the housing. The valve is entirely self-contained, and there are no external bulbs or lines to become damaged or broken. There are no packing glands to tighten and no parts to oil.

Note!
This thermostatic valve is sometimes used on both the HT & LT circuit when the system is not equipped with a load dependent temperature on the LT circuit.

The power creating medium utilizes the expansion of the element contents (9), which remains in a semi-solid form and is highly sensitive to temperature changes. Most of the expansion takes place during the melting period of approximately two minutes over a temperature change of approximately 8.5°C.

The thermostatic valve is provided with two or more elements (10), depending of the engine size. If failure of one element occurs, the remaining elements will take over with only a slight change in operating temperature. Since flow is diverted either to by-pass or heat exchanger, failure of an element would cause no change in pressure drop.

Cooling water thermostatic valve



9. *Content of the element* 10. *Element* 11. *Seat* A. *From the engine* B. *By-pass* C. *To the cooler*

Fig 19-6 V1

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 thermostatic valve in main engine installations are provided with a possibility for manual override.

19.8.1.1. Maintenance of temperature control System V2

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 section 01.1; the lower value for the water temperature is the opening temperature, the higher for the fully open valve.

3 **Change the defective element.** Check sealings and replace, if necessary.

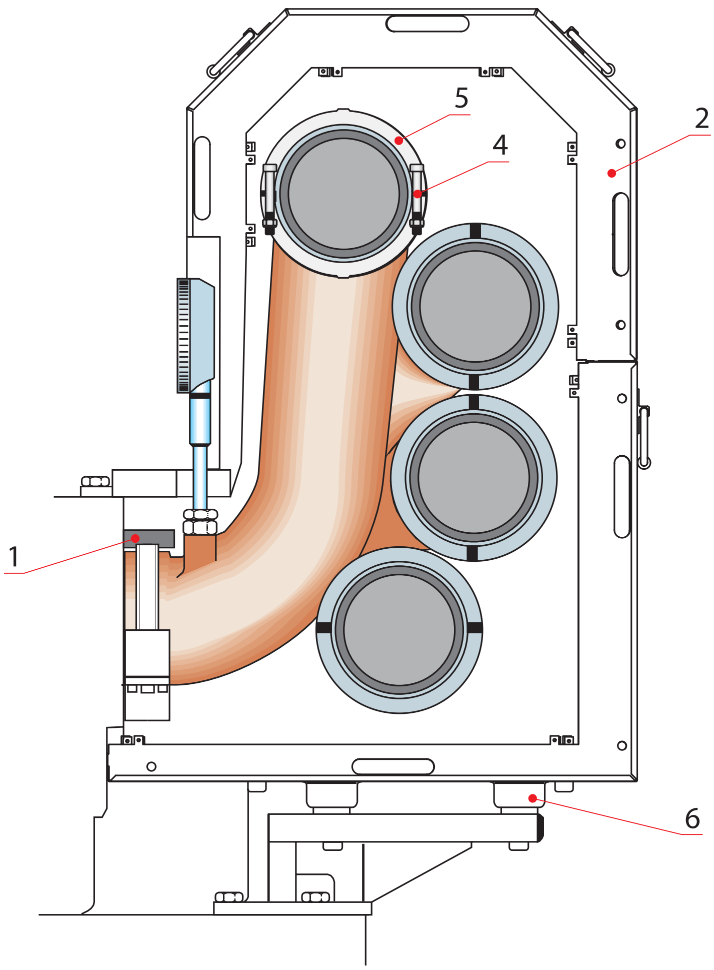
20. Exhaust System

V2

The exhaust pipes are cast of special alloy nodular cast iron, with separate sections for each cylinder, fixed by clamp rings (1). Metal bellows of multiply type absorb the heat expansion.

The complete exhaust system is enclosed by an insulation box built up of sandwich steel sheet, flexibly mounted to the engine structure. The exhaust gas temperatures can be checked from thermometers after each cylinder. Sensors for remote measuring of the temperatures after each cylinder as well as before and after the turbocharger can be mounted.

Exhaust System



1. *Clamp ring,* 2. *Insulation box panel,* 4. *Screw,* 5. *Clamp ring,* 6. *Flexible element.*

Fig 20-1

V1

20.1. Change of expansion bellows

V2

1 **Unscrew and remove the upper insulation box panel (2)** by opening the latch (3) counter-clockwise using the tool (806015), see Fig 20-2.

2 **Remove the screws (4) of the exhaust pipe clamp rings (5)** and remove the expansion bellows Fig 20-1.

3 **Check that the exhaust pipe flanges are parallel** and positioned on the same centre line .

4 **Lubricate the inner surface on the clamp rings (5)** and the screws (4) with a heat resistant grease before mounting the bellows and clamps.

5 **Mount the new bellows** and tighten the clamp screws (4) crosswise in steps to stated torque according to section 07.1.

6 **Mount the insulation box module** and tighten by turning the latch (3) some 90 degrees clockwise, using the tool (806015).

20.2. Insulation box

V2

The insulation box is mounted on flexible elements (6) to dampen vibrations thus protecting the insulation. Replace the elements by new ones, if necessary.

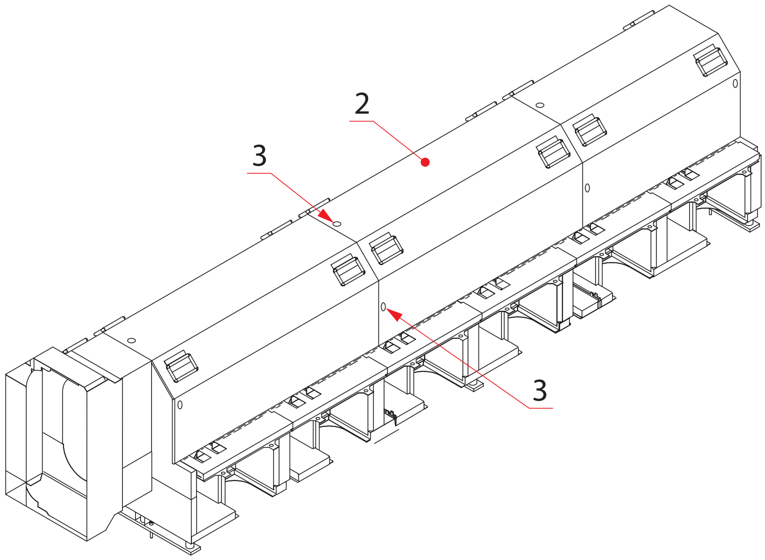
The insulation box panels do not normally need any maintenance. It is advisable though to keep the modules clean and to check that the fasteners are tightened on all modules if /when any of them is opened and e.g. a exhaust pipe bellow is replaced. Lubricate fasteners with a non-flammable and heat resistant lubricant when the module is removed.

In case any of the insulation box panels are renewed there might be small amounts of smoke in the area for approximately half an hour, caused by heating of the insulation binders. The smoke is not harmful or dangerous to anyones health.

Caution!
The insulation box is hot during engine operation and immediately after stop.

Note!
No stepping or keeping heavy tools on the insulation box.

Insulation box



2.*Insulation box panel,* 3.*Locking latch.*

Fig 20-2 V1

21. Starting Air System

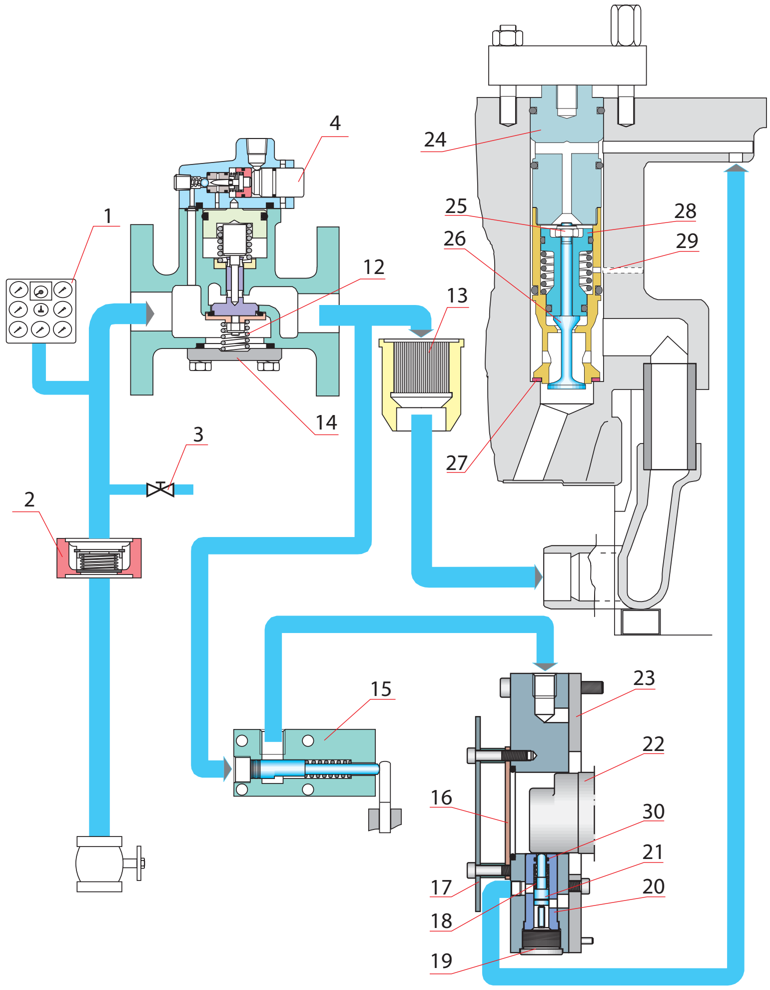
V2

The engine is started with compressed air of max. 30 bar. Minimum pressure required is 15 bar. A pressure gauge mounted on the instrument panel indicates the pressure before the main starting valve.

The inlet air pipe from the starting air receiver is provided with a non-return valve (2) and a blow-off valve (3) before the main starting valve.

The main starting valve may be operated either by the push button at manual starting, or pneumatically by a solenoid valve, mounted on the air bottle for the overspeed trip device, at remote or automatic starting of the engine.

Starting air system



1.*Pressure gauge,* 2.*Non-return valve,* 3.*Blow-off valve,* 4.*Push button,* 12.*Spring,* 13.*Flame arrester,* 14.*Flange,* 15.*Stop valve,* 16.*End plate,* 17.*Protecting plate,* 18.*Spring,* 19.*Plug,* 20.*Liner,* 21.*Piston,* 22.*Cam,* 23.*Plate,* 24.*Top piece,* 25.*Self-locking nut,* 26.*Spindle,* 28.*Piston,* 29.*Vent hole,* 30.*O-ring.*

Fig 21-1 V1

When the main starting valve opens, the starting air passes partly through the flame arrester (13) and the starting air distributing pipe to the starting valves in the cylinder heads. Partly it passes to the starting air distributor, which guides the control air to the starting valves, which open and admit starting air to flow to the various cylinders for suitable periods. V-engines have starting valves on the A-bank, only.

As a precaution the engine cannot be started when the turning gear is engaged. Starting air to the distributor is led through a stop valve (15), mechanically blocked when the turning gear is engaged, thus preventing start.

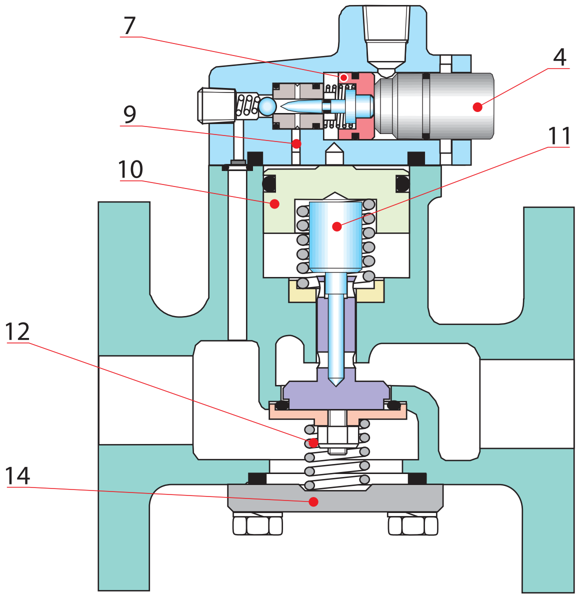
21.1. Main starting valve

V1

Inlet pressure is led through drillings to a small pilot valve with a pilot piston (7). This valve can be manually operated by the push button (4) or pneumatically operated by a solenoid valve for remote or automatic start. When opening the valve, the air flows through drillings (9) to the power piston (10), which exerts its thrust through a valve stem (11) directly on to the main valve and opens this against the load provided by a return spring (12) and inlet pressure. The inlet pressure acts under the main valve and so helps to maintain a tight seal with the valve in closed position.

The standard valve is arranged to open when energized.

Main starting valve



4.*Push button,* 7.*Piston,* 9.*Drilling,* 10.*Power piston,* 11.*Valve stem,* 12.*Spring,* 14.*Flange.*

Fig 21-2

V1

21.1.1. Maintenance of starting main valve

V1

1 **Remove the hexagon socket head screws** and remove the pilot valve assembly.

2 **Remove the pilot valve piston (7).**

3 **Clean the pilot valve** of any dirt which may block the small air passages and holes.

4 **Check all O-rings** in the pilot valve and replace if they have developed flat, become hard and brittle or been damaged in any way. Lubricate the O-rings with oil.

5 **Remove the power piston (10)** and check the O-ring. Ensure that the small vent hole to atmosphere in the cylinder under the piston is clear.

6 **When reassembling the valve** ensure that the air passage hole in the upper body flange lines up with the hole in the lower body.

7 **Remove the flange (14),** spring (12) and main valve seat complete with the valve stem (11). Examine O-rings as in step 4 above.

21.2. Starting Air Distributor V1

The starting air distributor (Fig 21-1) is of the piston type with precision machined interchangeable liners (20). The liners as well as the pistons are of corrosion resistant materials. The distributor pistons are controlled by a cam (22) at the camshaft end. When the main starting valve opens, the control pistons (21) are pressed against the cam, whereby the control piston for that engine cylinder, which is in starting position, admits control air to the power piston (28) 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, and thus the wear is insignificant.

21.2.1. Maintenance V1

Normally, the starting air distributor does not need maintenance. If it has to be opened for control and cleaning, remove the complete distributor from the engine. Certain pistons can be checked in situ.

1 **Remove the protecting plate (17)** and end plate (16). Loosen all pipes from the distributor. Remove the fastening screws and lift the distributor off.

2 **Remove the plugs (19)** at which the pistons (21) will come out forced by the springs (18). Remove plate (23).

3 **Take care not to damage the sliding surfaces of pistons and liners.**

4 **In case of a stuck piston, use thread M8** at the end of the piston to get it out, if necessary.

5 **It is recommended not to change the place of the pistons,** although they are precision machined to be interchangeable. Utilize cylinder numbers stamped at the control air connections.

6 It may be necessary to heat the distributor up to about 200°C as Loctite is used for fixation and sealing.

7 **Clean the parts and check for wear.**

8 **Clean the bore** carefully so that the new liner can be inserted by hand. Otherwise there is a risk of deformation of the liner and sticking of the piston. Replace the O-ring (30).

9 **Apply Loctite 242** on the outside surfaces when mounting the liner. Check that the openings in the liner correspond to those in the housing.

10 **Check that there is no Loctite** on the inside sliding surfaces.

11 **Apply Molykote Paste G** to the piston sliding surfaces before reassembly. Wipe off surplus paste. Check that pistons do not stick.

12 **Apply silicon sealant** to the intermediate plate (23). Do not use too much as surplus sealant will be forced into the system when tightening the fastening screws.

13 **After mounting the distributor** to the engine, but before connecting the control air pipes and end plate (16) with new O-ring, check that all pistons work satisfactorily. This can be done e.g. by connecting compressed air (working air of 6 bar) to the distributor air inlet and by turning the crankshaft. It is then possible to see whether the pistons follow the cam profile.

Caution!
Do the testing with control air pipes and starting air pipe disconnected, otherwise the engine may start.

21.3. Starting valve

V1

The valve (Fig 21-1) consists of a valve spindle (26) with a spring-loaded operating piston (28) mounted in a separate housing.

21.3.1. Maintenance

V1

Check and clean the valve in connection with overhauls of the cylinder head.

1 **Remove the fastening yoke** and pull out the valve by using the tool 4V83H77.

2 **Unscrew the top piece (24).** Use key handle on the top piece and valve housing. If using a vice for holding the valve, put the top piece in the vice so as not to deform the housing.

3 **Open the self-locking nut (25)** and remove the piston (28).

4 **Clean all parts.**

5 **Check sealing faces** of the valve and valve seat. If necessary, lap the valve by hand. See instructions for the engine valves, chapter 12, section 12.2.1. Keep the piston on the valve spindle to get guiding.

6 **If it is necessary to change the piston sealings,** take care not to deform the teflon ring, located outside the O-ring, more than necessary. The mounting is easier if the teflon ring is warmed in hot water. Lubricate the sealings and the piston with lubricating oil.

7 **After reassembling the valve,** check that the valve spindle with the piston moves easily and closes completely.

8 **Check that the vent holes (29)** in the valve and cylinder head are open.

9 **Check that the O-rings** of the valve housing are intact. Lubricate with oil.

10 **Check that the copper sealing is intact** and in position, when mounting the valve into the cylinder head.

11 **Tighten the valve** to torque stated in section 07.1.

21.4. Starting air vessel and piping

V1

The starting air system is designed to prevent explosions.

An oil and water separator as well as a non-return valve should be located in the feed pipe, between the compressor and the starting air vessel. At the lowest position of the piping there should be a drain valve. Immediately before the main starting valve on the engine, a non-return valve and a blow-off valve are mounted.

Drain the starting air vessel from condensate through the drain valve before starting.

The piping between the air vessels and the engines should be carefully cleaned when installing. Also later on they should be kept free from dirt, oil and condensate.

The starting air vessels should be inspected and cleaned regularly. If possible, they should then be coated with a suitable anticorrosive agent. Let them dry long enough.

At the same time, inspect the valves of the starting air vessels. Too strong tightening may result in damages on the seats, which in turn cause leakage. Leaky and worn valves, including safety valves, should be reground. Test the safety valves under pressure.

21.5. Pneumatic System

V2

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 automatic water separating valve (9), and furthermore, a 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 21.1, is actuated by the solenoid valve (3) at remote start. Fig 21-4 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 condensed water separated by the filter (12).

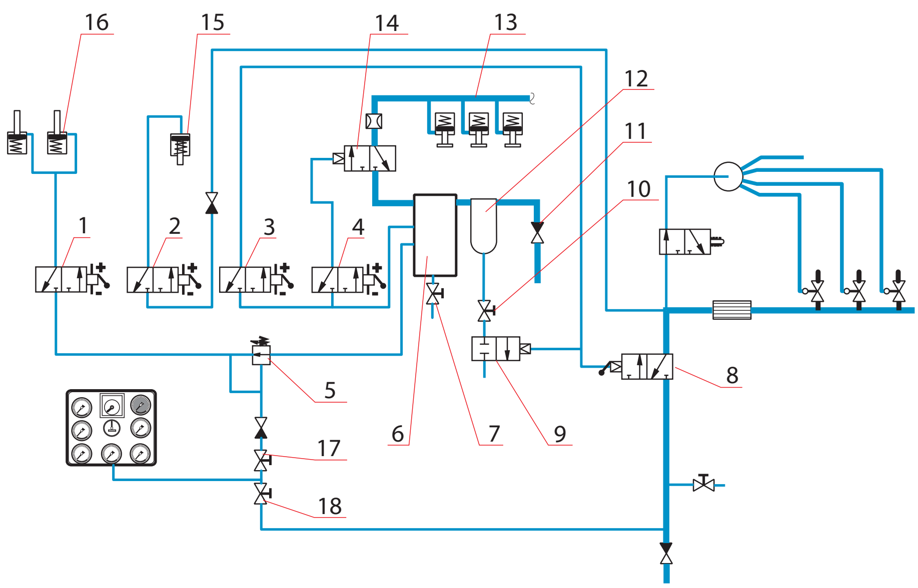
The starting fuel limiter (15) is described in detail in chapter 22, section 22.7. During the starting cycle it is automatically actuated by the solenoid valve (2), which is energized from the speed monitoring system.

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.

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.

Pneumatic system



1.*Solenoid valve,* 2.*Solenoid valve,* 3.*Solenoid valve,* 4.*Solenoid valve,* 5.*Pressure control valve,* 6.*Air vessel,* 7.*Drain valve,* 8.*Main starting valve,* 9.*Valve,* 10.*Valve,* 11.*Non-return valve,* 12.*Filter,* 13.*Pneumatic overspeed trip device,* 14.*Valve,* 15.*Starting fuel limiter,* 16.*Thermostat valve,* 17.*Open valve,* 18.*Shut-off valve.*

Fig 21-3 V1

21.5.1. Maintenance V1

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 condensed water from the vessel (6) using the draining valve (7) .

21.5.2. Check V2

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.

21.5.3. Maintenance of pneumatic components

V2

Filter(12, Fig 21-3). 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.

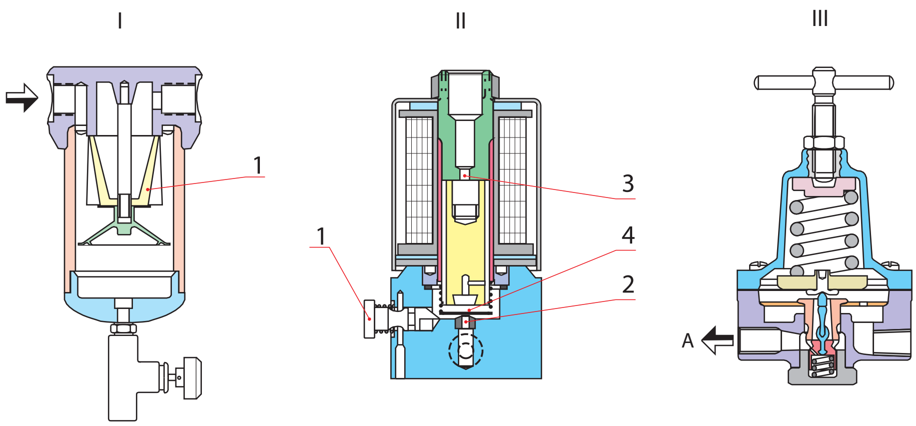
Solenoid valve(1 - 4, Fig 21-3). In case of disturbance in the electric function of the valve, test the valve by pushing the button (1). Should there be a mechanical malfunction, open the valve using a special tool.

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(9, Fig 21-3). Clean the valve if there is any disturbance. The valve can temporarily be disconnected by shutting the valve (10).

Pressure control valve(5, Fig 21-3). The pressure control valve requires no maintenance. Should there be a malfunction, change it.

Pneumatic components



I. Filter: *1. Insert.*

II. Solenoid valve: *1.Button, 2.Bore, 3.Bore, 4.Gasket.*

III. Pressure control valve.

Fig 21-4

V1

22. Control Mechanism

22.1. Overview of Control Mechanism V1

During normal operation the engine speed is controlled by a governor (18) which regulates the injected fuel quantity to correspond with the load.

The regulation movement is transferred to the regulating shaft (10) through a spring-loaded rod (16), which enables stop or limit functions to be transferred to the regulating shaft, irrespective of the governor position. In V-engines the regulating shafts of the cylinder banks are connected with rods in such a way, that the two regulating shafts work synchronously together.

The movement from the regulating shaft, to the injection pump fuel racks (1), is transferred through the regulating lever (4) and the spring (3), which presses the pin (2), at the end of the fuel rack, against the regulating lever. The torsion spring (3) enables the regulating shaft and, consequently, the other fuel racks to be moved to a stop position, even if one of the racks has jammed. In the same way the torsion spring (5) enables the regulating shaft to be moved towards fuel-on position, even if an injection pump has jammed in a no-fuel position. This feature can be of importance in an emergency situation.

The engine can be stopped by means of the stop lever (6). When the stop lever is moved to stop position, the lever (8) actuates the lever (7) forcing the regulating shaft to stop position.

The engine is provided with two independent overspeed trip devices, an electro-pneumatic device with tripping speed about 15 % above the nominal speed, and a mechanical device with tripping speed about 18 % above the nominal speed. The electro-pneumatic device moves every fuel rack to a no-fuel position by means of a pneumatic cylinder on every injection pump. The cylinder actuates the pin (2) at the fuel rack. The mechanical device actuates the lever (14) moving the regulating shaft to stop position. Both the electro-pneumatic and the mechanical device can be tripped manually also, see section 22.5 and section 22.6.

When starting, a fuel limiter will automatically limit the movement of the regulating shaft to a suitable value. A pressure air cylinder limits the position of the lever (11), see section 22.7.

The indicator (12) indicates the fuel rack position.

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 lubricating oil pressure, too high circulating water temperature, or at any other desired function.

Next to the governor there is a fixed mechanical limiter affecting the regulating shaft directly by means of the lever (13).

22.2. Maintenance of Control Mechanism V1

Note!
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 minimal friction.** Regularly clean and lubricate racks, bearings (also self-lubricating bearings (9)) and ball joints with lubricating oil.

b) **The system should be as free from clearances** as possible. Check clearances of all connections. Total clearance may correspond to max. 0.5 mm of injection pump fuel rack positions.

c) **Check regularly** (see recommendations in chapter 04) the adjustment of the system; stop position, overspeed trip devices and starting fuel limiter, see section 22.3.1.

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, and that all locking elements like pins, retainer rings, locking plates are in their positions. Check according to pos. a) - c) .

22.3. Check and adjustment

22.3.1. Stop lever stop position

V1

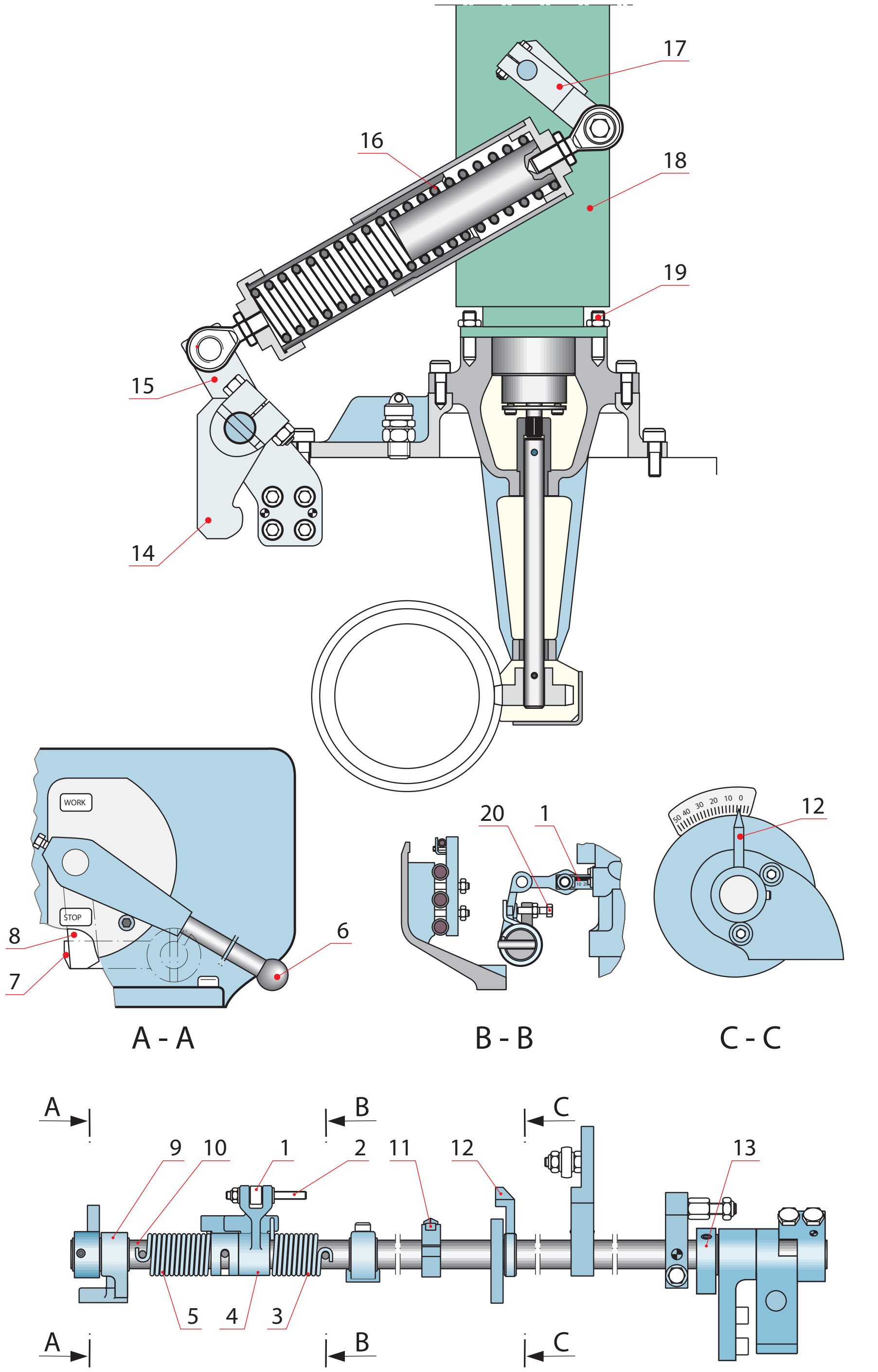
a) Check:

- Set the terminal shaft lever (17) in the max. fuel position and the stop lever (6) in the stop position.
- Check that the fuel rack position of all injection pumps is less than 3 mm.

b) Adjustment:

- Set the stop lever in the stop position and check that the lever (7) contacts the lever (8) 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 2 mm by adjusting the screws (20).

Control mechanism



1. Injection pump fuel rack, 2. Pin, 3. Spring, 4. Lever, 5. Spring, 6. Stop lever, 7. Lever, 8. Lever, 9. Bearing, 10. Regulating shaft, 11. Lever for starting fuel limiter, 12. Indicator, 13. Lever, 14. Lever for mechanical overspeed trip device, 15. Lever, 16. Spring-loaded rod, 17. Lever for governor, 18. Governor, 19. Screw, 20. Adjusting screw.

Fig 22-1 V1

22.3.2. Governor stop position

V1

a) **Check:**

- Move stop lever into work position.
- Set the governor terminal shaft lever in the stop position.
- Check that the fuel rack positions are 2 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 2 mm is obtained.
- If changing the governor, see section 22.4.

22.3.3. Mechanical overspeed trip device

V1

a) **Check of stop position**

- Set the stop lever in the work position and the terminal shaft lever in the max. fuel position.
- Release the overspeed trip device manually.
- Check that the fuel rack positions are less than 3 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.

22.3.4. Electro-pneumatic overspeed trip device V1

a) **Check of stop position**

- Set the stop lever in the work position and the terminal shaft lever in the max. fuel position.
- Release the overspeed trip device manually.
- Check that the fuel rack positions are less than 3 mm.

b) **Adjustment of stop position**

- The electro-pneumatic overspeed trip device requires no adjustment.
- If a fuel rack position of less than 3 mm cannot be obtained, check for wear.
- Temporarily, an adjustment to a lower fuel rack position can be made by putting a thin washer under the plug (9).

c) **Check and adjustment of tripping speed**

- See section 22.6.2.

22.3.5. Starting fuel limiter V1

a) **Check of limit position**

- Set the stop lever in work position and the terminal shaft lever in max. fuel position.
- Connect pressure air to the cylinder (2) by solenoid valve (2), Fig 21-3, at which the limiter cylinder (2) will turn the regulating shaft to the limit position.
- Check the fuel rack position. Suitable limitation is dependent on the installation, normally about 26 mm.

b) **Adjustment of limit position**

- Connect pressure air to the cylinder (2).
- Loosen the fastening screw (3) of the limitation lever.
- Turn the regulating 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 V1

Check that the indicator corresponds to the fuel rack positions. If not, loosen the grub screw and adjust the indicator to the correct value.

22.4. Speed governor V1

The engine can be equipped with various governor alternatives depending on the kind of application. Concerning the governor itself, see the attached governor instruction book.

22.4.1. Hydraulic governor drive V1

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:

- radial and axial clearances of bearings
- gear clearance
- oil drillings and nozzle to be open
- gears and serrated coupling sleeve to be firmly fastened to the shaft
- serrations of coupling sleeve and governor drive shaft for wear.

Change worn parts.

22.4.2. Removal of governor V1

1 **Loosen the terminal shaft lever (17)** and governor electrical connection.

2 **Open the screws (19)** and pull the governor vertically upwards. The governor must not fall or rest on its driving shaft.

22.4.3. Mounting of governor

V1

When mounting the same governor, check that the mark on the lever (17) corresponds to that of the shaft. **Check the setting according to section 22.3.1**.

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 the position according to Fig 22-2 (in counter-clockwise direction seen from the driving end).

3 **Mount the terminal shaft lever (17)** as follows, Fig 22-2.

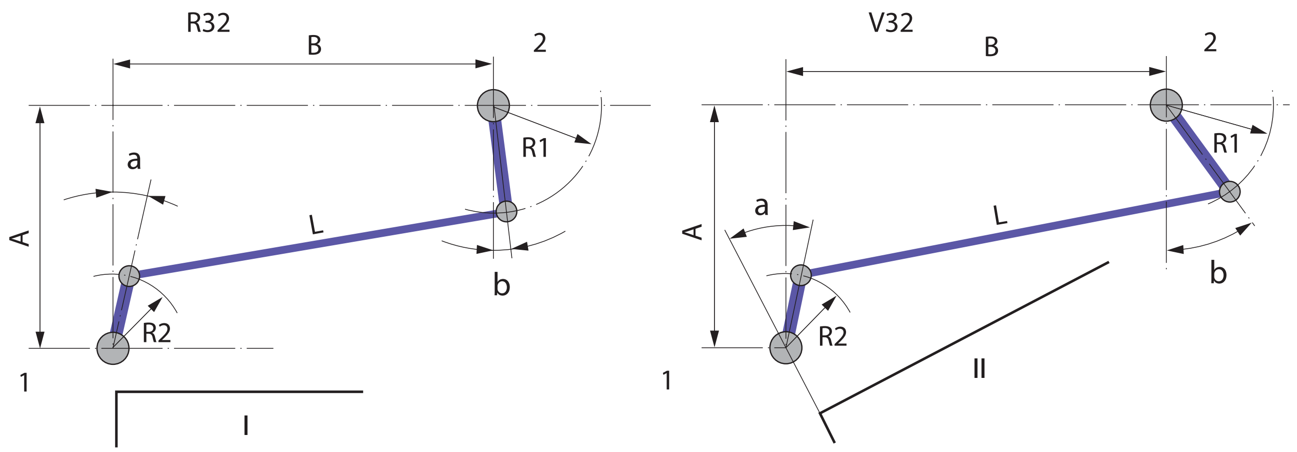
4 **Lock the fastening screw** and mark the position of the terminal shaft lever with a mark on the shaft corresponding to that of the lever.

5 **Move the fuel rack** into the position according to Fig 22-2.

6 **Adjust the spring-loaded rod length** to fit between the levers (17) and (15). Do not forget to secure the nuts.

7 Check according to section 22.3.1

Governor shaft settings



1. *Control shaft* 2. *Governor shaft* I. *Engine block R32* II. *Engine block V32*

Fig 22-2

V1

Governor basic settings: Woodward										
Engine type	Gover-nor type	A (mm)	B (mm)	L (mm)	R1 (mm)	R2 (mm)	α (°)	β (°)	Rack h (mm)	Gover-nor indi-cator
4R32	UG10	281.1	325.5	(420)	65	50	0	50±5	7.5	1.5
R32	PGA	101	460.1	(450)	90	50	13.5	0±3.75	7.5	1.7
	PGG									
	EGB									
	PGEG									
V32	PGA	244.4	319.5	(365)	90	50	30.2	25±3.75	7.5	1.7
	PGG									
	EGB									
	PGEG									

22.5. Mechanical overspeed trip device

V1

The overspeed trip device is of the centrifugal type. It will trip when the engine speed exceeds the nominal speed, see test records and chapter 06., section 06.1.3. The tripping mechanism is fastened directly 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) at the set tripping speed. The weight (2) is then 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.

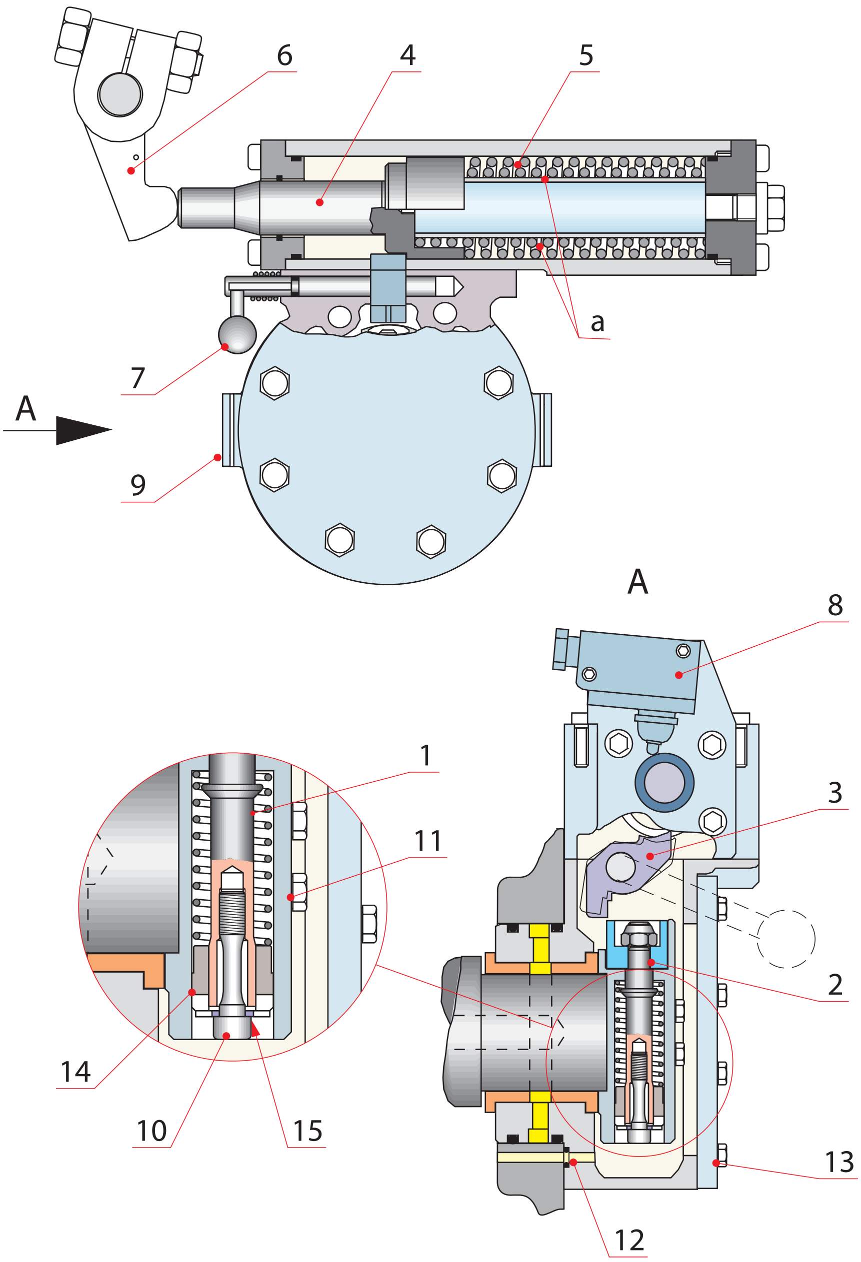
The force is transferred to the regulating shaft by the lever (6) and a claw coupling on the regulating shaft, and the regulating shaft is turned to the stop position.

The overspeed trip device may be tripped manually by the lever (7).

The engine cannot be restarted before the lever (6) has been manually 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.

Mechanical overspeed trip device



1. Spring, 2. Weight, 3. Latch, 4. Spindle, 5. Working spring, 6. Lever, 7. Lever, 8. Micro switch, 9. Plug, 10. Locking screw, 11. Screw, 12. Drain hole, 13. Screw, 14. Adjusting screw, 15. Slotted washer.

a. In 8- to 18-cylinder engines only.

Fig 22-3 V1

22.5.1. Check of tripping speed

V1

Check the tripping speed at idle by increasing the engine speed above the nominal speed by slowly forcing the lever (15, Fig 22-1) with a suitable wrench in direction from the engine. When the nominal speed is reached and exceeded, the governor begins to decrease the fuel setting, i.e. the control shaft must be forced against the force of the governor. Retension the working spring of the overspeed trip device manually by means of the lever (14). Use the tool 808010 or a steel bar or pipe with the outside diameter of max. 22 mm. Engine cannot be started before the mechanical overspeed device is reset.

Note!
Do not increase the engine speed by more than 40 RPM above the tripping speed.

The specified tripping speed, see test records and chapter 06., section 06.1.3.

Note!
The tripping speed stated in chapter 06., section 06.1.3 is for a preheated engine, it may differ on an engine which has reached normal operation temperature.

Note!
When checking the specified tripping speed, the electro-pneumatic overspeed trip device must be adjusted to a speed of 40 RPM above the tripping speed of the mechanical overspeed trip device. Do not forget to readjust it to the normal tripping speed, see .

22.5.2. Adjustment of tripping speed (Fig 22-3)

V1

1 **Remove the plug (9).**

2 **Turn the crankshaft** until the locking screw (10) is in front of the opening.

3 **Loosen the locking screw (10).** If a higher tripping speed is desired, tense the spring by screwing the adjusting screw (14) in by the adjusting tool 846030. If a lower tripping speed is desired, screw the screw outwards.

4 **Tighten the locking screw (10)** to the stated torque, see section 07.13.1.

5 **Mount the plug (9)** and check the tripping speed according to instruction above.

6 **The spring can be replaced** through the opening of the plug, if necessary.

22.5.3. Maintenance V1

1 **Remove the tripping mechanism** by removing the screws (11).

2 **Remove the spindle** (4) with piston and spring (5).

Note!
Be very careful when removing the spring (5). Use tool 837020

3 **Check all moving parts** for wear and replace with new ones, if necessary.

4 **Check that the drain hole** (12) open.

5 **Tighten the screws (11) to torque** when assembling and lock with steel wire.

6 **Tighten the screws (13) to torque.**

7 **Use tool 837020 when mounting the spring.**

8 **Check the tripping speed** according to section 22.5.1.

22.6. Electro-pneumatic overspeed trip device V1

The overspeed trip device is electronically controlled. Air of max. 30 bar is used as operating medium. The specified tripping speed, see test records and chapter 06., section 06.1.3.

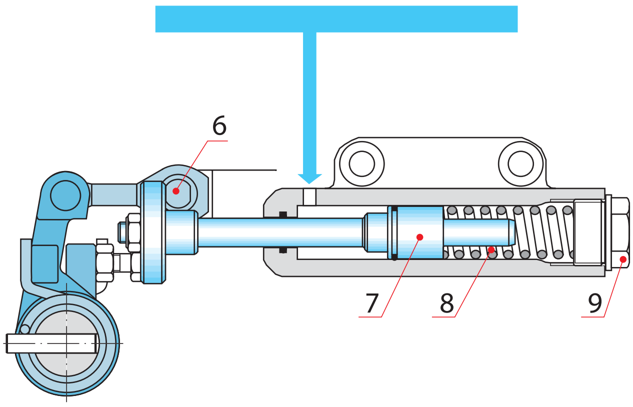
The three-way solenoid valve (4), Fig 21-3, gets the stop signal for overspeed from the electronic speed measuring system. The solenoid is also connected to the stop system.

When the solenoid valve (4) opens, air is fed to the three-way valve (14), Fig 21-3, which conveys pressure air to the cylinders (13, Fig 21-3), one for each injection pump. The piston of the air cylinder actuates the pin on 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 spring (8), Fig 22-4.

The solenoid valve (4) can also be operated manually.

Electro-pneumatic overspeed trip device



6. Pin, 7. Piston, 8. Spring, 9. Plug.

Fig 22-4 V1

22.6.1. Check and adjustment of stop position V1

a) **Check of stop position**

- Set the stop lever in the work position and the terminal shaft lever in the max. fuel position.
- Release the overspeed trip device manually.
- Check that the fuel rack positions are less than 3 mm.

b) **Adjustment of stop position**

- The electro-pneumatic overspeed trip device requires no adjustment.
- If a fuel rack position of less than 3 mm cannot be obtained, check for wear.

Temporarily, an adjustment to a lower fuel rack position can be made by putting a thin washer under the plug (9).

22.6.2. Check of tripping speed V1

Check the tripping speed at idle by increasing the engine speed above the nominal speed by slowly bending the lever (15) with a suitable wrench in direction from the engine. When the nominal speed is reached and exceeded, the governor begins to decrease the fuel setting, i.e. the control shaft must be forced against the governor force.

Note!
Do not increase the engine speed by more than 60 RPM above the tripping speed.

The specified tripping speed, see test records and chapter 06., section 06.1.3.

22.6.3. Adjustment of tripping speed V1

Adjustments will be made in the box of the electronic speed measuring system, see instructions for speed measuring system, section 23.2.1.

22.6.4. Maintenance

V1

a) **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 sealing's.

b) **Air cylinder,**Fig 22-4

- Check for wear.
- Check the tightness of the piston. Replace sealings by new ones, if necessary. Take care not to deform the teflon ring outside the O-ring.
- Lubricate the sealings and piston with lubricating oil.
- Check that the piston does not stick.

22.7. Starting fuel limiter

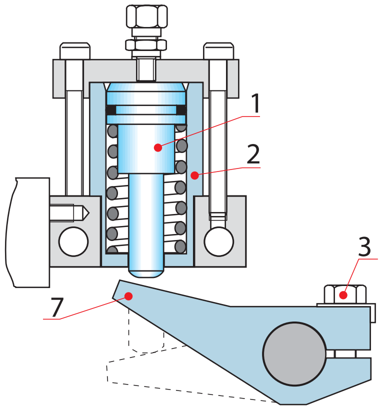
V1

Always when starting either automatically, remotely or manually, a limiter will automatically limit the injected fuel quantity.

Always when the engine is not operating (and provided with auxiliary voltage), the three-way solenoid valve (2), Fig 21-3, is energized connecting 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 to the limiting cylinder. The piston (1) is then forced out limiting the fuel injection by a lever (7), which is fastened to the regulating shaft. As the engine reaches 100 RPM below the nominal speed relay in the speed measuring system de-energizes the solenoid valve (2), Fig 21-3. The de-energizing is delayed two seconds so that the engine will reach nominal speed before the limitation is cut off.

On main engines started up to a lower speed, a lower de-energizing speed has to be used.

Starting fuel limiter



1. Limitation piston, 2. Cylinder, 3. Screw, 7. Lever.

Fig 22-5 V1

22.7.1. Check and adjustment of limitation

V1

a) **Check of limit position**

- Set the stop lever in work position and the terminal shaft lever in max. fuel position.
- Connect pressure air to the cylinder (15) by the solenoid valve (2), Fig 21-3, at which the limiter cylinder (2) will turn the regulating shaft to the limit position.
- Check the fuel rack position. Suitable limitation is dependent on the installation, normally about 26 mm.

b) **Adjustment of limit position**

- Connect pressure air to the cylinder (2).
- Loosen the fastening screw (3) of the limitation lever.
- Turn the regulating 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.

22.7.2. Check of function

V1

1 **Check that the limitation is achieved** as soon as the main starting valve opens.

2 **Check that the correct limitation is achieved** during the acceleration period.

3 **The limitation is cut off at 100 RPM below nominal speed** delayed for two seconds. This can best be checked during the acceleration period. When the limitation cut of speed is reached and exceeded, the piston of the starting fuel limiter is returned to its normal position, with a delay of two seconds. The delay can electrically be checked according to section 23.2.3.2 On main engines a cut-off speed lower than the minimum running speed is used.

22.7.3. Maintenance

V1

1 **If the limitation gradually retires** before the three-way solenoid valve (2), Fig 21-3, releases the pressure, 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 the piston before assembly.
- 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 manufacturer's instruction, section 23.1.1.

3 **If the limiter does not work,** check the coil. If the coil is undamaged, check that the cylinder (15) or three-way valve (2) does not stick.

4 **The three-way valve** normally requires no maintenance. If the coil has broken, e.g. due to over voltage, 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 22.7.1 and section 22.7.2**

23. Instrumentation and Automation

23.1. Monitoring equipment mounted on the engine

23.1.1. Instrument panel

V4

The instrument panel (1, Fig 23-1 and Fig 23-2) 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 the engine	PT301
• fuel oil before the engine	PT101
• lube oil before the engine	PT201
• HT water pressure before the engine	PT401
• LT water pressure before the engine	PT451
• charge air	PT601
Instrument for engine speed	ST173/SI173
Running hour counter	KI791

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

V4

- exhaust gas thermometer for each cylinder (2) (only marine engines)
- lube oil before (3) and after (4) the lube oil cooler
- HT water before (5) and after (6) the engine
- HT water after the turbocharger (7)

- charge air in the air receiver (8)
- LT water before (9), between (10) and after the coolers (11)
- fuel before the engine (12)

Erroneous and damaged thermometers are to be replaced by new ones at the first opportunity.

Monitoring equipment, In-line engine

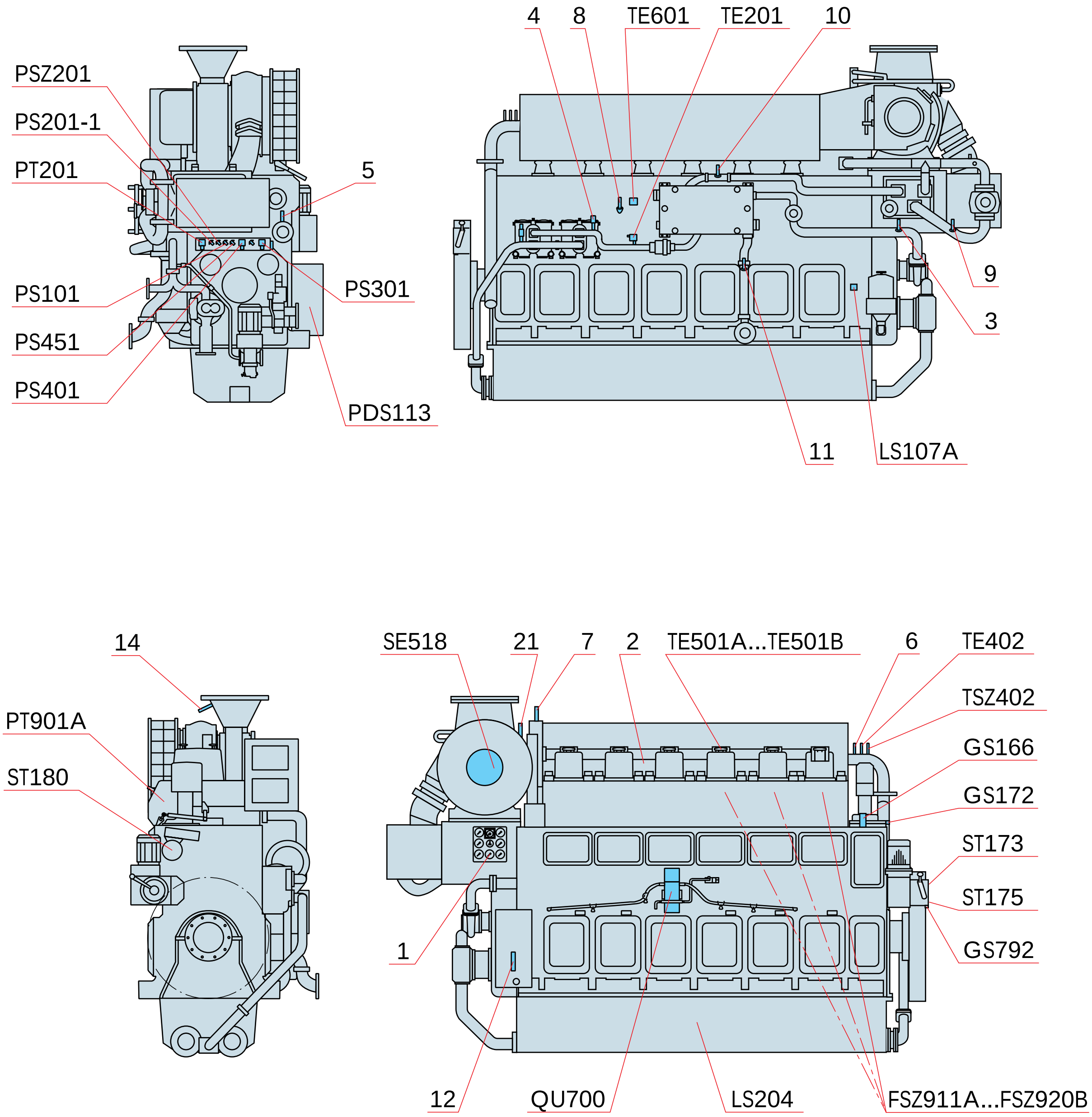


Fig 23-1

V1

Monitoring equipment, V-engine

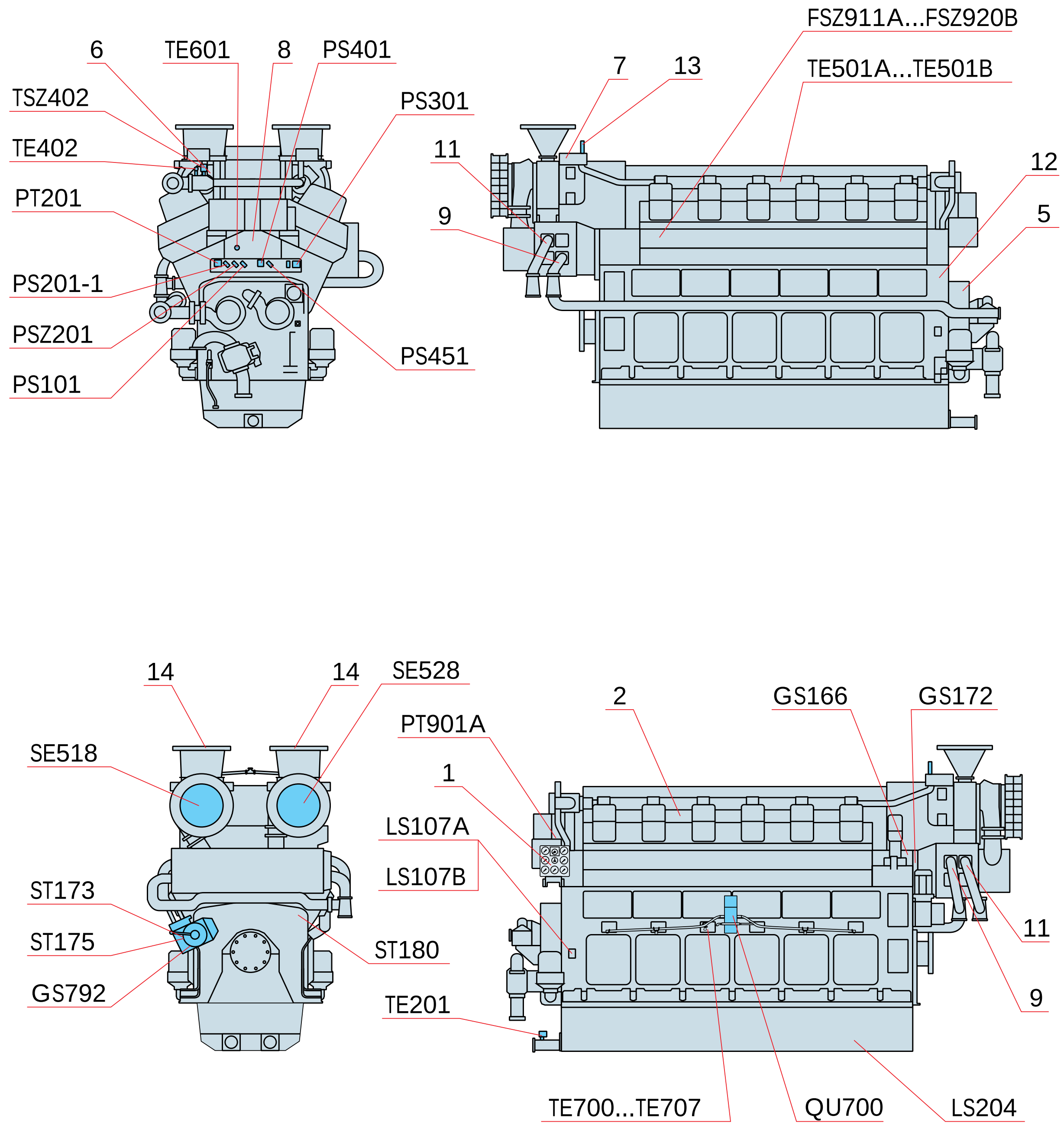


Fig 23-2

V1

23.1.3. Combined visual pressure drop indicators and alarm switches

V4

- Too high pressure drop across the lube oil filter when mounted on the engine (PDS243).
- Too high pressure drop over the fuel filter when mounted on the engine (PDS113).

23.1.4. On/off switches

V4

a) **Alarm switches:** A standard system for alarm switches has been developed for VASA 32. In the system a distinction is made between marine- and power plant engines.

Sensor type: A= analogue, B= binary, Adv.= advanced- and Ext.= extended system.

Pressure sensors						
Function	Code	Type	Marine	DPP		
				Basic	Adv.	Ext.
Fuel oil pressure, inlet	PT101	A	X		X	X
Prelube oil pressure, low	PS201-1	B	X			
Lube oil pressure, inlet	PT201	A	X		X	X
Lube oil pressure, inlet, **stop**	PSZ201	B	X		X	X
Starting air pressure, inlet	PT301	A	X		X	X
HT-water pressure, inlet	PT401	A	X		X	X
LT-water pressure, inlet	PT451	A	X		X	X
Charge air pressure CAC, outlet	PT622	A	X		X	X

Pressure sensors						
Function	Code	Type	Marine	DPP		
				Basic	Adv.	Ext.
Fuel oil pressure, inlet	PS101	B		X		
Fuel oil pressure, start of stand-by pump	PS110	B	X			
Lube oil pressure, inlet	PS201	B		X		
Pre. lube oil pressure, inlet	PS201-1	B		X		
Start block from lub. oil pressure (Only 4R32 with starting motor)	PS201-2	B	X			
Lube oil pressure start of stand-by pump	PS210	B	X			
Starting air pressure, inlet	PS301	B		X		
HT-water pressure, inlet	PS401	B		X		
HT-water pressure start of stand-by pump	PS410	B	X			
LT-water pressure, inlet	PS451	B		X		
LT-water pressure start of stand-by pump	PS460	B	X			
Control high/low load, if load dep. LT-term	PS622-2	B	X			
Lube oil pressure, inlet, **stop**	PSZ201	B		X		
HT-water pressure low (load reduction)	PSZ401	B	X			

Temperature sensors						
Function	Code	Type	Marine	DPP		
				Basic	Adv.	Ext.

Temperature sensors						
Fuel oil temperature, inlet	TE101	A	X		X	X
Lube oil temperature, inlet	TE201	A	X	X	X	X
Lube oil temperature, outlet	TE202	A			X	X
HT-water temperature, inlet	TE401	A			X	X
HT-water temperature, outlet	TE402	A	X	X	X	X
LT-water temperature, inlet	TE451	A			X	X
LT-water temperature, outlet	TE452	A			X	X
HT-water temperature, outlet, **stop**	TSZ402	B	X	X		X
Charge air temperature CAC, outlet	TE601	A	X	X	X	X
Charge air temperature CAC, outlet, **stop**	TSZ601	B	X	X		X
High exhaust temperature after each cylinder and TC, R32 and V32 — A-bank	TE501A ... TE509A	A	X	X		
High exhaust temperature after each cylinder and TC, V32 — B-bank	TE501B... TE509B	A	X	X		
Main bearing temperature	TE700 ... TE710	A	X	X	X	X
High exhaust temperature after each exhaust gas valve, R32	TE51CA, TE51DA... TE59CA, TE59DA	A	X			X
High exhaust temperature after TCA, R32 and V32	TE517	A	X		X	X
High exhaust temperature after TCB, V32	TE527	A	X		X	X
High exhaust temperature after each exhaust gas valve, V32	TE51CA, TE51DA... TE59CB, TE59DB	A	X		X	X

Other sensors						
Function	Code	Type	Marine	DPP		
				Basic	Adv.	Ext.
Fuel leakage, block alarm, free end, R32 and V32 A-bank	LS107A	B	X	X	X	X
Fuel leakage, block alarm, driving end, R32 and V32 A-bank	LS108A	B	X			
Fuel leakage, block alarm, free end, V32 B-bank	LS107B	B	X	X	X	X
Fuel leakage, block alarm, driving end, V32 B-bank	LS108B	B	X			
Injection pipe leak alarm system, R32 and V32 A-bank	LS103A	B	X			

Other sensors						
Injection pipe leak alarm system, V32 B-bank	LS103B	B	X			
Fuel oil filter pressure drop, only in R32	PDS113	B	X	X		
Fuel oil filter pressure drop, only in R32	PDT113	A	X			X
Alarm low lubricating oil level (If wet sump)	LS204	B	X	X	X	X
Lubricating oil filter, pressure drop, only in R32	PDS243	B	X	X		
Lubricating oil filter, pressure drop, only in R32	PDT243	A	X			X
Turning gear engaged	GS792	B	X	X	X	X
Fuel rack position	GT165	B			X	
Start lever in stop position	GS171	B			X	
Mechanical overspeed trip released	GS172	B	X	X	X	X
Start lever not in run position, optional if gas engine	GS177	B	X			X
Crankcase pressure	PT700	A	X		X	X
Sealing oil pressure, optional if gas engine	PT786	A	X			X
High pressure in annular pipe, optional if gas engine	PS921	B	X			X

Optional if nozzle cooling system (only diesel engines)						
Function	Code	Type	Marine	DPP		
				Basic	Adv.	Ext.
Nozzle oil pressure, inlet	PS131	B		X	X	X
Nozzle oil temperature, inlet	TS131	B		X	X	X
Nozzle oil temperature, outlet	TS132	B		X	X	X

Cylinder liner						
Function	Code	Type	Marine	DPP		
				Basic	Adv.	Ext.
Cylinder liner temperature, if WECS	TE711A... TE793B	A			X	

b) **Stop switches:** The following switches for automatic stop are mounted on the engine as standard:

- too low lube oil pressure (PSZ201)
- too high cooling water temperature (TSZ402)

c) **Other switches:** The following switches can be supplied as extra equipment:

- fuel oil temperature before the engine
- LT water temperature before the engine
- charge air pressure

- air pressure before the engine
- electro-pneumatic overspeed trip device

The switches may, due to continuous development, differ from the above stated standard system.

23.1.4.1. Check of switches

V1

All switches are pre-adjusted at the factory.

Check the function of all switches at intervals recommended in chapter 04. If any switch is suspected 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 inserted into liquid, e.g. oil, which is slowly heated.

Watch at which temperature the micro switch breaks. The correct temperature is stated in section 01.1 . 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.
- Carefully open the pipe union nut on the pressure switch so that the pressure switch gives a signal.

The correct pressure is stated in section 01.1. and is normally stamped on the switch as long as it has not been adjusted to another pressure.

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.

c) **Pressure drop indicator:** When checking the fuel and lube oil switch it is enough when the connection before the filter is accessible.

When checking the alarm pressure of the switch an adjustable overpressure device and a manometer are to be connected to the switch connection before the filter (the higher pressure).

The pressure is raised until the indicator at the end of the switch operates and the manometer pressure can be read.

The pressure is to be 1.5 ± 0.3 bar.

d) **Other micro switches:** These switches can easily be checked when the engine is out of operation, e.g.

- The mechanical overspeed trip device is tripped manually (chapter 22., section 22.5) and should give alarm.
- The control shaft is turned until the load indicating switch operates. Check which load this corresponds to.

Caution!
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 fault should be remedied immediately.

23.1.5. Transducers for remote measuring

V4

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
- lube oil before and after the oil cooler
- HT water before and after the engine
- HT water before and after the turbocharger
- inlet LT water
- exhaust gases for the individual cylinders
- exhaust gases before (13) and after (14) the turbocharger.

b) **Pressures:** The connection points are located at the pipes of the respective manometers on the instrument panel.

- charge air
- lube oil before the engine
- inlet LT water
- fuel oil after the filter
- starting air
- HT water before the engine

c) **Miscellaneous:**

- transducers for turbocharger speed (SE518, SE528)
- detector for crankcase smoke (QU700)
- load indicator

In the instrument specification supplied with the engine documentation, it is specified which transducers should be installed, as to type as well as to manufacturing.

23.2. Despemes Speed Measuring System for Diesel Engine

V1

23.2.1. Introduction

V1

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

V1

23.2.2.1. Diesel engine speed

V1

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

V1

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

V1

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

V1

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

V1

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

V1

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 **n_{DE} measuring converter with relay function**

for engine speed.. C2

3 **Relay I**

3 speed-controlled relay functions with optional delay............ C3

4 **n_{TC} 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

V1

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:..±100 mV

Ambient temperature:...- 25 ... + 71°C

Short-circuit-proof:...by current limitation

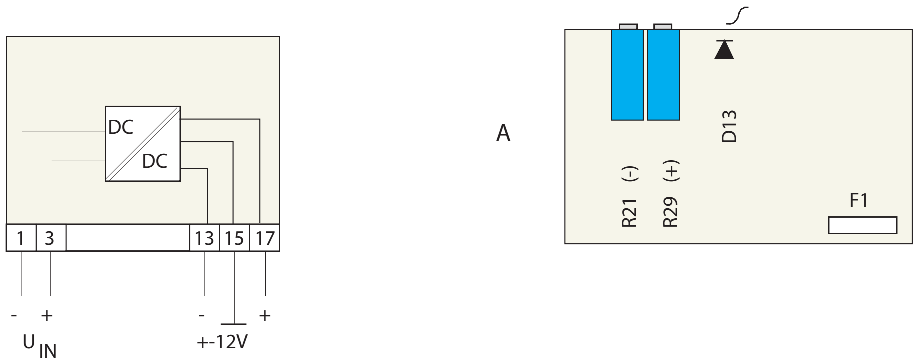
Isolation voltage:..2 kV, 50 Hz, 1 min

....5 kV, 1.2/50 µs

Fuse:...1.6 A, 5 x 20 mm

The power supply is short-circuit-proof and overheating protected. A green light emitting diode indicates that voltage is provided.

Power supply C1



A. *O/P adjust*

Fig 23-3 V1

23.2.3.2. C2, n_{DE} measuring converter with relay function for the engine speed

V1

a) **Theory of operation:** The speed sensor is a 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.

b) **Adjustment procedures:**

- The analog speed measuring signal 0 - 10 VDC

The card is accurately precalibrated at the factory. Nevertheless, if a recalibration is required, there is a potentiometer, P501, at the utmost left hand side of the card. When turning CW, 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 n_{DE}-card amplification:**

$$n_{max} \text{ (rpm)} = U_{max} \text{ [V DC]}$$

2 **Calculate corresponding output voltage at specified relay switching speed:**

$$U_x \text{(V DC)} = \frac{n_x \text{(rpm)} \times U_{max} \text{(V DC)}}{n_{max} \text{(rpm)}}$$

3 **Adjust P502 to the calculated TP4 voltage:** Ex: VASA 32: Specified switching speed: 620 rpm

$$1000 \text{ rpm} \mathrel{\hat{=}} 10 \text{V DC}$$

$$U_{620} = \frac{620 \text{ rpm} \times 10 \text{ V DC}}{1000 \text{ rpm}} = 6.2 \text{ V}$$

Adjust the TP4 voltage to 6.2 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.

Technical 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

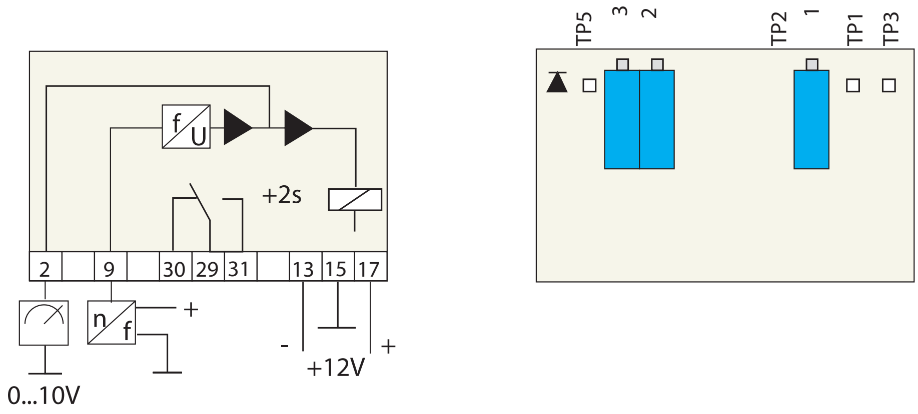
....24 V DC/1.0 A

Test

Test point:..Approx. 80 % of full scale

Ambient temperature:...- 25...+71°C

n_{DE} measuring converter C2



1. *Output* 2. *Switchpoint* 3. *Delay*

Fig 23-4 V1

23.2.3.3. C3, Relay Card

V1

a) **Theory of operation:** The card includes three relays each relay having two change-over contacts. The output voltage from the n_{DE}-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.

PT601, TP1..relay nDE1

P602, TP2..relay nDE2

P603, TP3..relay nDE3

1 **Determine the amplification of the n_{DE}-card:**

$$n_{max}\ (rpm) = U_{max}\ [V\ DC]$$

(n_{max} is normally 1000 rpm and U_{max} 10 VDC on VASA 32)

2 **Calculate the voltage corresponding** the rotation speed at which the relay switches on.

$$U_x\,(V\ DC) = \frac{n_x\,(rpm) \times U_{max}\,(V\ DC)}{n_{max}\,(rpm)}$$

3 **Adjust the channel potentiometer** to the calculated value of the TP voltage.

By short-circuiting TP3 on the n_{DE}-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).

Technical specification

Inputs:

Supply voltage:.. +12 V, 0, -12 V

Current consumption:... max 60 mA

Control voltage:.. 0...10 V DC

Outputs:

3 relays, each having two changeover contacts.

Switchpoint:................................. 0...100 % of the measuring range

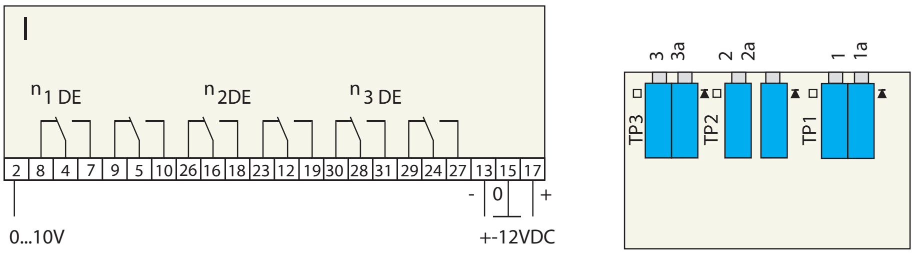
Delay:... 0...30 sec.

Breaking capacity:... 110 V DC/0.3 A

.... 24 V DC/1.0 A

Ambient temperature:... -25...+71°C

Relay Card C3



I. *Relay* 1. *Delay 1* 1a. *Switchpoint 1 adj.* 2. *Delay 2* 2a. *Switchpoint 2 adj.* 3. *Delay 3* 3a. *Switchpoint 3 adj.*

Fig 23-5 V1

23.2.3.4. C4, TC-card: Measuring converter for one alt. two turbochargers

V1

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 a frequency counter.

The square wave frequency signal is converted to a speed-proportional voltage 0...10 V. This 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.

P701 : n_{TC1}

P711 : n_{TC2}

When turning the pot. CW, 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

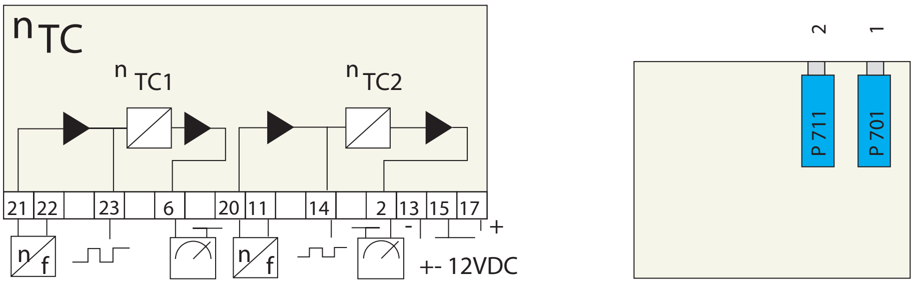
....10 mA, short-circuit-proof

Voltage:.......................................0...10 V, 15 mA, short-circuit-proof

Unlinearity:..± 0.1 %

Temperature dependence:..< 0.03 %/K

TC-card C4



1. *Output 1* 2. *Output 2*

Fig 23-6

V1

23.2.3.5. C5 Relay II

V1

a) **Theory of operation:** The card consists of 3 voltage-controlled relays, each having one change-over contact.

Any 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) **Technical 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

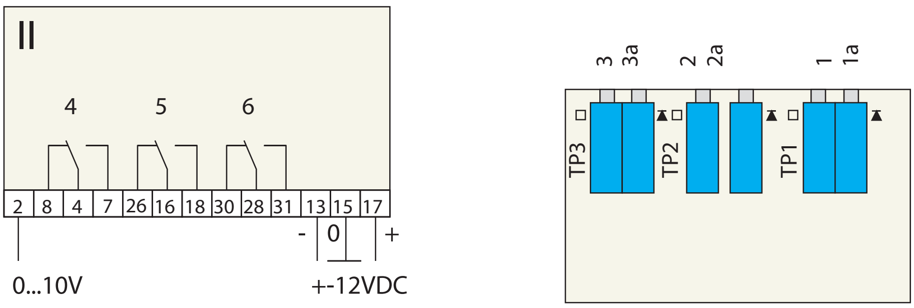
Delay:...0...30 sec

Breaking capacity:...110 V DC/0.3 A

....24 V DC/1.0 A

Ambient temperature:...-25...+71°C

Relay II C5



II. *Relay* 1. *Delay 1* 1a. *Switchpoint 1 adj.* 2. *Delay 2* 2a. *Switchpoint 2 adj.* 3. *Delay 3* 3a. *Switchpoint 3 adj.*

Fig 23-7

V1

23.2.4. Engine Speed Sensor

V1

a) **Theory of operation:** The sensor is an inductive, touchfree proximity 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 it and tighten it well to the shown sensing displacement (see Fig 23-8).

Engine speed sensor

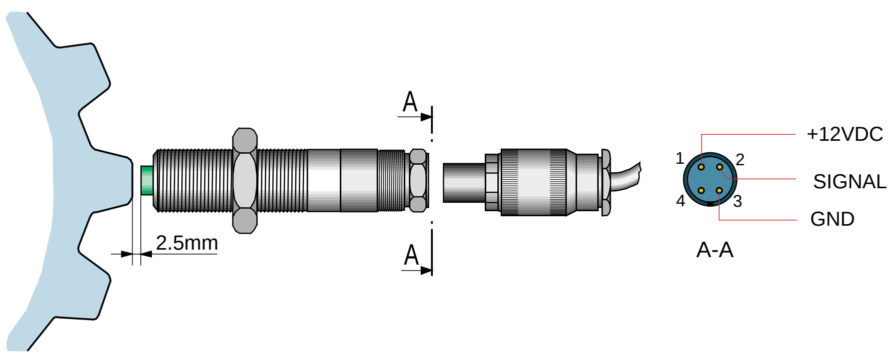


Fig 23-8

V1

The output signal (terminal 55 in the electronic box or TP1 on the n_{DE}-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.

23.2.5. Turbocharger Speed Sensor

V1

a) **Theory of operation:** This sensor is magnetic, therefore it does not require any voltage supply.

The sensor head is split 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 these types 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 2 turns.

Note!
The engine must not run while the sensor is mounted.

23.2.6. Adjustments of the Despemes cards

V1

Adjustments of the Despemes cards						
Card Desig-nation	Function	Adj.	Measured at V	Measured at Hz	Ind.	Remarks
C1 DC/DC	Power supply	R21/ R29			LED	Adjustment not recommended
C2 n_{DE}	Rot. speed of engine	P501	TP2	TP1	Tach	1000 RPM=417 Hz=10 VDC
	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

Adjustments of the Despemes cards						
C3 Relay card	Relay 1: Engine running (300 rpm)	P601	TP1		LED 1	Hour count., prelub. control blocking signals, diagram A
	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 n_{TC}	Rot. speed of turbocharger	P701	TP2	TP1	Tach	30.000 RPM=3.000 Hz=10 VDC (Setting valid for ABB, VTR-type turbochargers).
	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 are 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.

Despemes box, internal layout

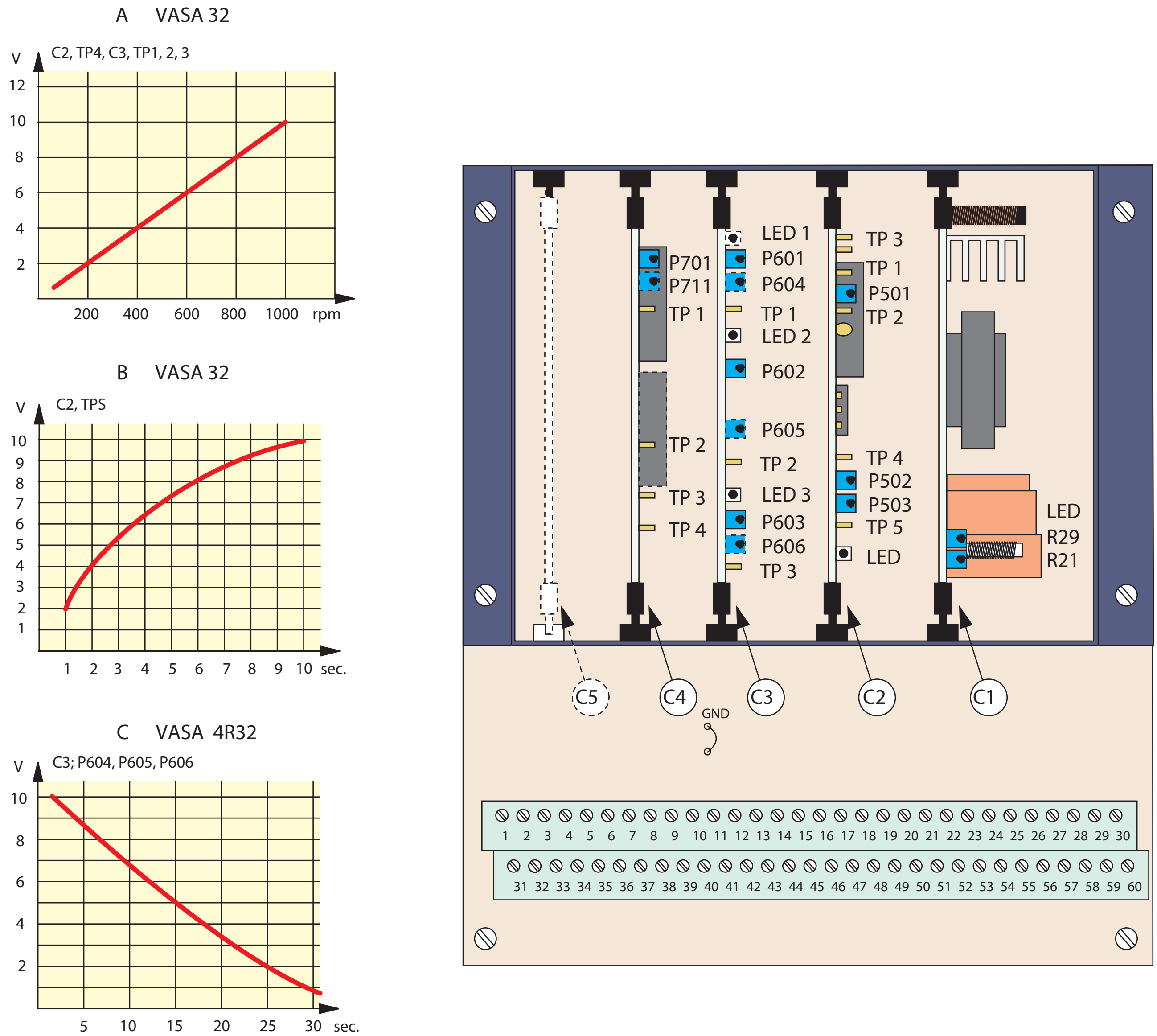


Fig 23-9

V1

23.2.7. Governor Speed Sensor

V1

a) **Theory of operation:** This sensor is magnetic, therefore it does not require any voltage supply.

The sensor causing a sinusoidal output voltage when a magnetic material passes its sensing head. The metal housing is threaded to 5/8"-18. The sensor is mounted on the bracket of the electrical turning device, see Fig 23-10.

When the flywheel rotates and the teeth of the gear rim pass the sensor head, a sinusoidal voltage is generated.

b) **Mounting the sensor:** Screw the sensor completely in. Unscrew it and tighten it well to the shown sensing displacement, see Fig 23-10.

Note!
The engine must not run while the sensor is mounted.

Governor speed sensor

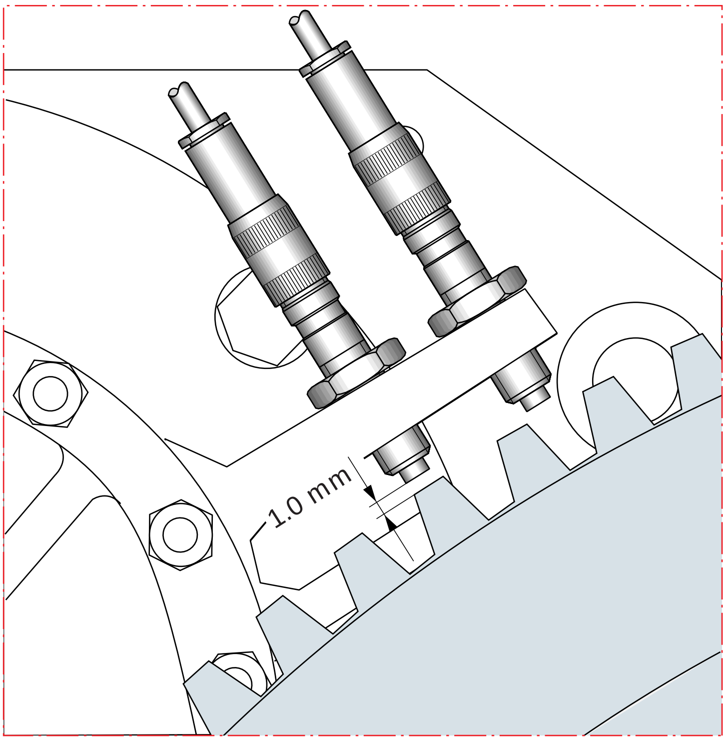


Fig 23-10

V1

23.2.8. Troubleshooting procedures

V1

1. Power supply DC/DC

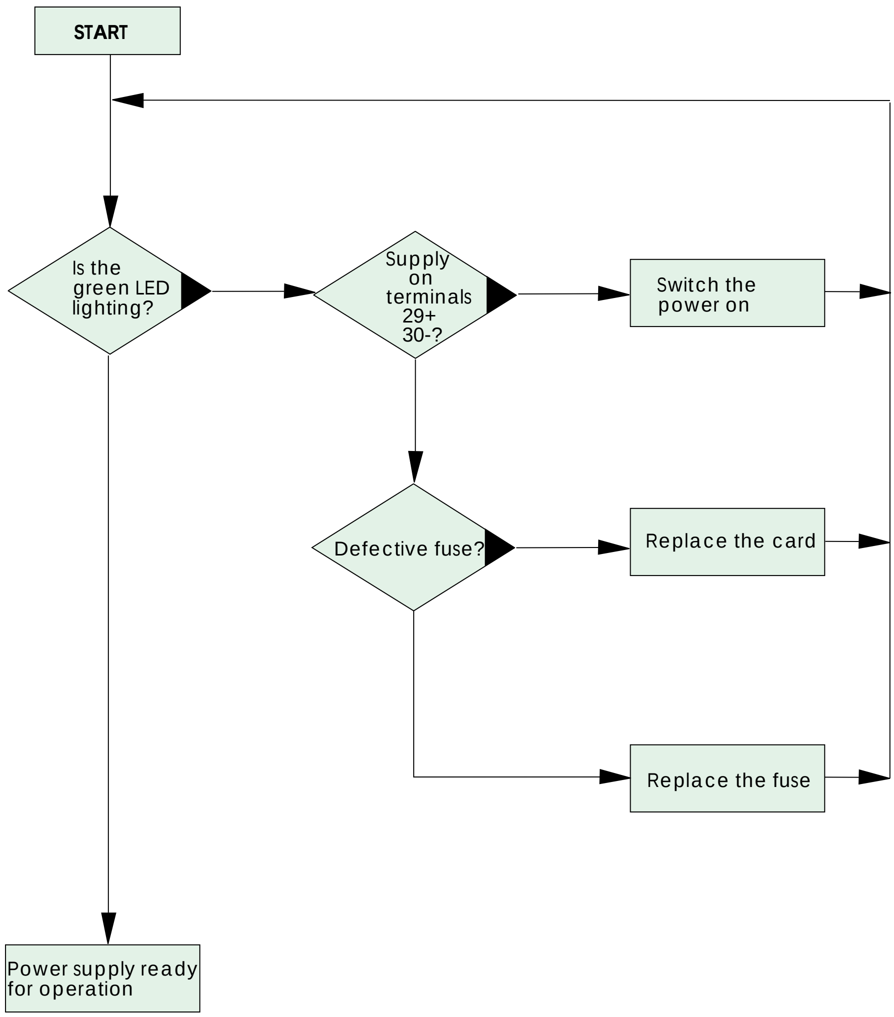


Fig 23-11

V1

Power supply			
	Polarity	Terminal	Card connector
Operating voltage	+	29	3
	-	30	1
Output	+12 V	24	17
	GND	26	15
	-12 V		13

2. n_{DE}-measuring converter with relay function

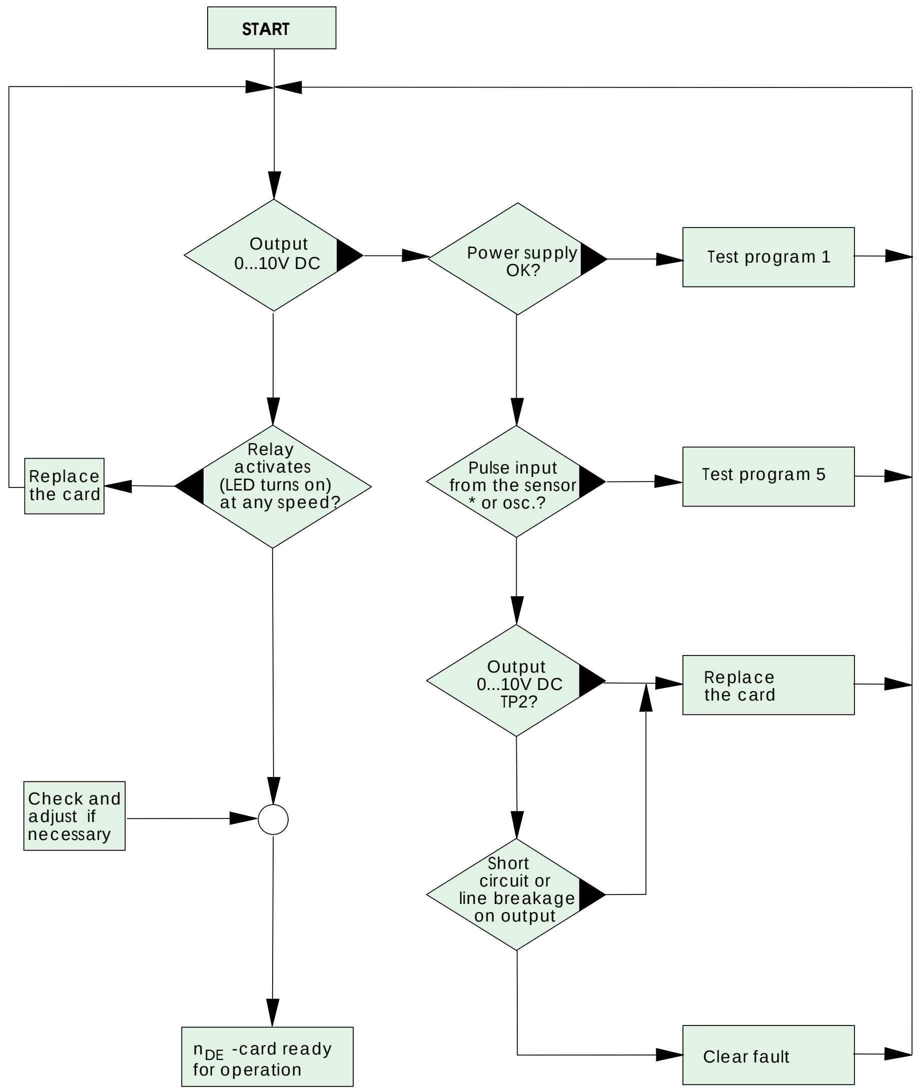


Fig 23-12 V1

n_{DE}-measuring converter		
	Terminal	Card connector
Frequency in	55(+)	9
	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.

3. Relay card

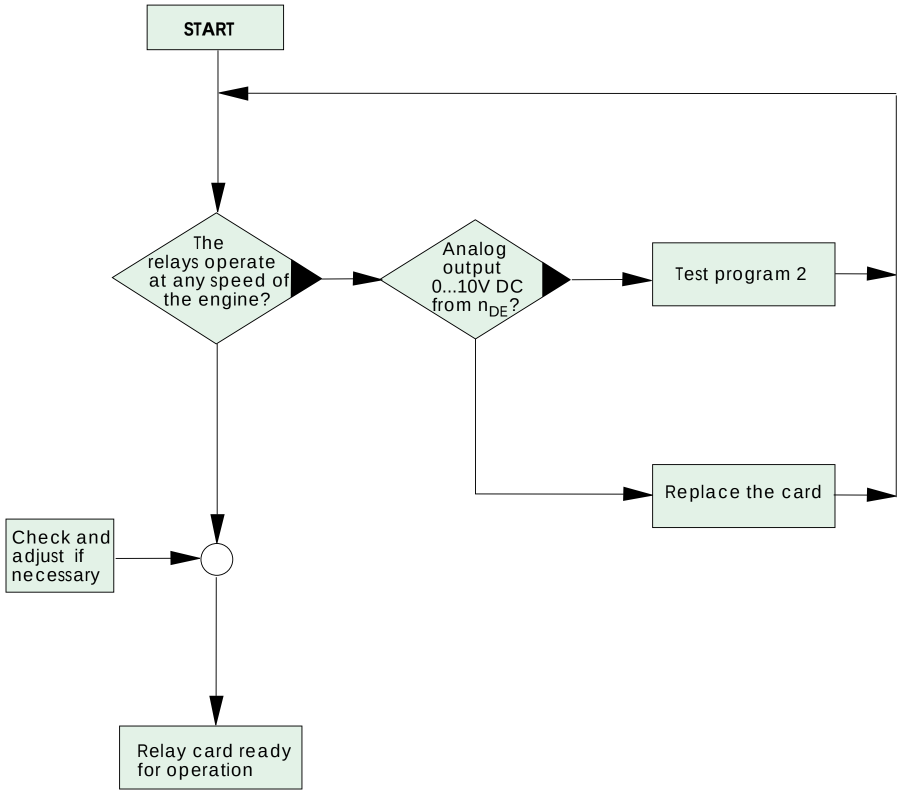


Fig 23-13

V1

4. n_{TC}-measuring converter with 2 channels

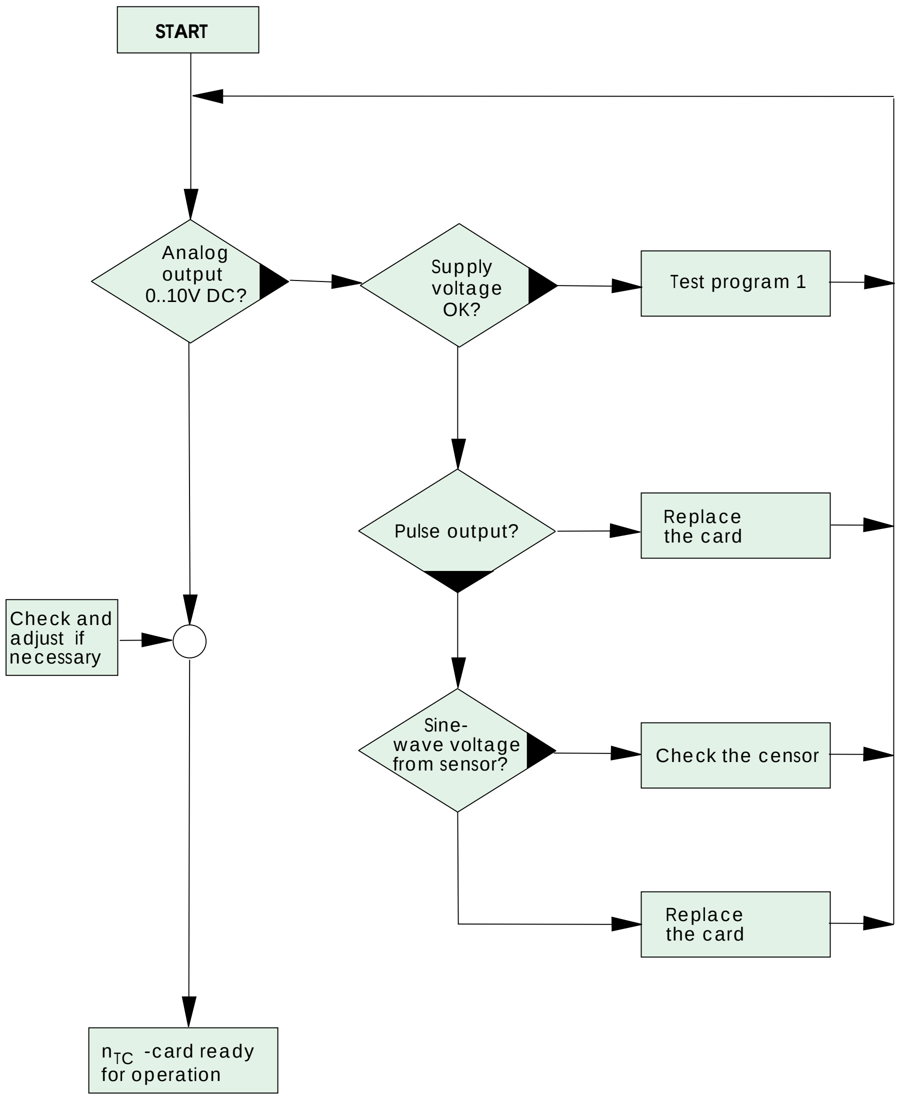


Fig 23-14 V1

n_{TC}-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	6	2

5. Engine speed sensor

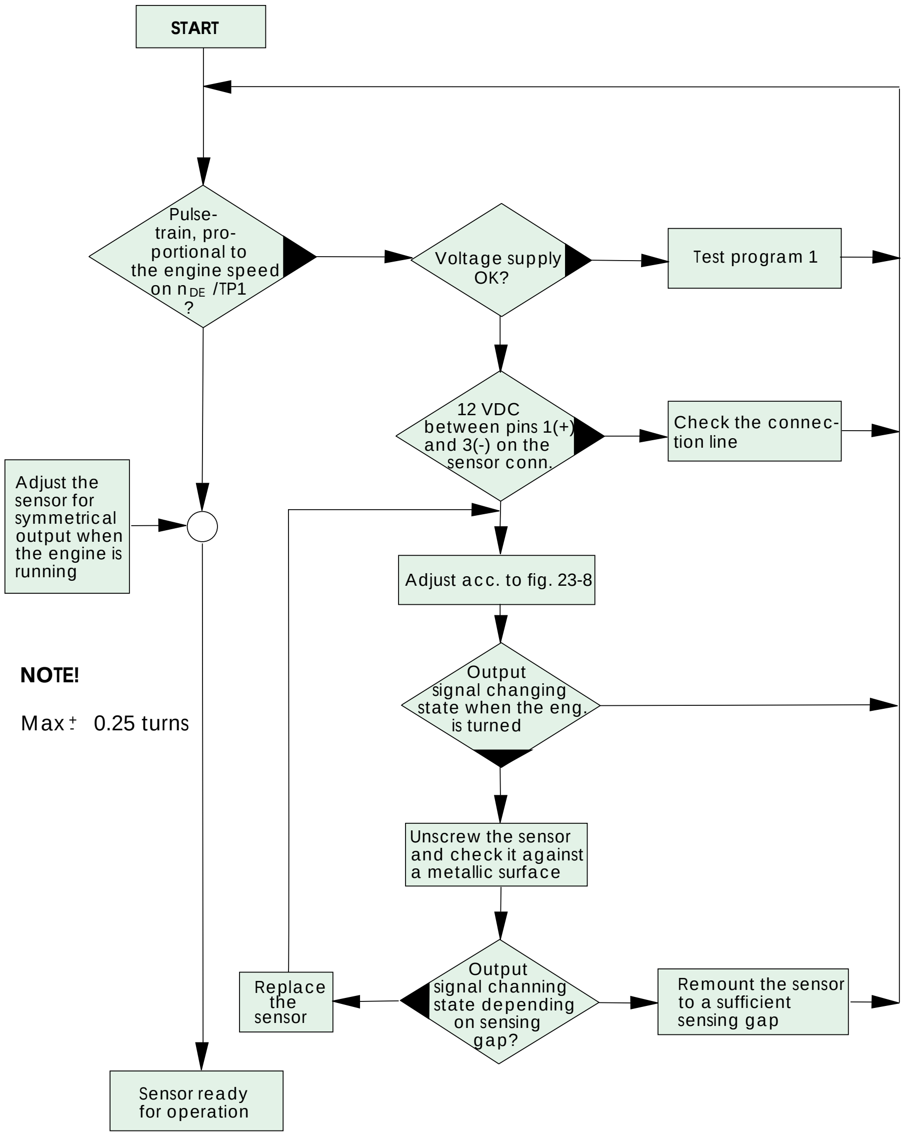


Fig 23-15 V1

23.3. Maintenance of electrical contacts V1

To prolong the lifetime of electrical contact surfaces and to provide proper electrical connection under all conditions and to maintain a high availability of the WECS system.

The maintenance is carried out by applying contact lubricants to electrical contact surfaces. For best result the contact surface should be cleaned with aerosol electrical contact cleaner before applying the lubricant.

Contact lubricants are specially formulated greases and oils that reduce friction and enhance the electrical performance of current carrying metal interfaces in switches and connectors. They also exhibit a neutral pH thereby avoiding surface corrosion.

Note!
Prior to use read the product information.

Warning!
To avoid shock or possible fire, disconnect power to any system before applying conductive lubricant. Insure positive and negative contacts remain isolated. Improper use can result in shorting, arcing, or shock.

Wärtsilä recommends to regulary every 2000 - 4000 running hours or every 6 month maintain the electrical connector contact surfaces with contact lubricant. The contact treatment greases listed below can be ordered from Wärtsilä.

The recommended chemicals are:

- Electrolube SGB20S 20 ml Syringe, part No. 387 022.

  This paste is recommend to be used on the contact surfaces of main electronics connectors and sensor connectors.

  Same active substance as SGB200D but in different consistence, i.e. paste instead of aerosol.

- Electrolube SGB200D 200 ml Aerosol (Flammable), part No. 387 021.

  This spray is recommended to be used on contact surfaces of main electronic (SMU, DCU, RM, MCU and oil mist detector) connectors. Since it is an aerosol there are special requirements of transport handling.

- Chemtronics CW7100 6.5 g Syringe, part No. 387 023.

  This is a heavy duty paste. The electrical conductivity is very high due to the 100 % silver filled grease, see caution below. Should be used on problem sensor and power contact surfaces where SGB grease is not sufficient.

Caution!
Care should be taken since this chemical is very conductive and will cause short-circuit/earth fault if wrongly applied. Must be placed directly on the contact surface and in very small amounts.