INSTRUCTIONS

Engine Operation and Maintenance Manual (O&MM)

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WÄRTSILÄ

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00. Contents, instructions, terminology

00.1 About this manual

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This manual is intended for engine operating and maintenance personnel. The manual contains technical data, maintenance instructions and instructions for correct and economical operation of the engine. It also contains instructions for personal protection and first aid, as well as, for handling fuel, lubricating oil and cooling water additives during normal operation and maintenance work.

The reader is assumed to have basic knowledge of engine operation and maintenance. Such information is therefore not provided in this manual.

This manual is supplemented by the spare parts catalogue including sectional drawings or exterior views of all components (partial assemblies).

Wärtsilä engines are equipped as agreed on in the sales documents. This manual may contain descriptions of components that are not included in every delivery. No claims can therefore be made on Wärtsilä on the basis of the contents of this manual.

The system diagrams (fuel system, lubricating oil system, cooling water system and so on) included in this manual are only indicative and do not cover every installation. For detailed system diagrams, see the installation-specific drawings.

NOTE

In all correspondence with Wärtsilä and when ordering spare parts, the engine type and the engine number found on the engine name plate must be stated. The exact engine design is defined by the engine number.

00.2 General operation and maintenance instructions

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- Read this manual carefully before starting to operate or maintain the engine.
- Keep an engine log book for every engine.
- Observe utmost cleanliness and order in all maintenance work.
- Before dismantling, check that all concerned systems are drained and the pressure is released. After dismantling, immediately cover holes for lubricating oil, fuel oil, and air with tape, plugs, clean cloth or similar material.
- When replacing a worn out or damaged part with a new one, check for markings on the old part, for instance, identification marking, cylinder or bearing number, and mark the new part with the same data at the same location. Enter every exchange in the engine log along with the reason for the exchange clearly stated.
- In marine applications, all changes which may influence the NOx emission of the engine, for instance, change of components and engine settings, must be recorded in the "Record Book of Engine Parameters" according to "Annex VI to MARPOL 73/78".
- After assembly, check that all bolts, screws and nuts are tightened and locked according to the instructions in this manual. Check that all shields and covers are fully functional, in their places and closed.

NOTE

Preventive maintenance is important when it comes to fire protection. Inspect fuel lines, lubricating oil lines and connections regularly.

00.3 Terminology

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The most important terms used in this manual are explained below.

Driving end and free end

The **driving end** is the end of the engine where the flywheel is located.

The **free end** is the end opposite to the driving end.

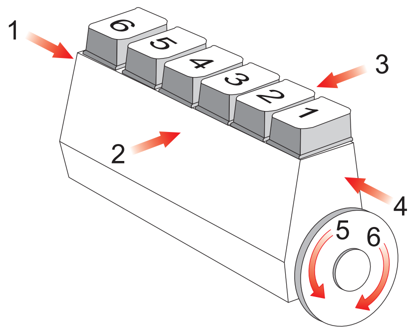
Operating side and rear side

The **operating side** is the longitudinal side of the engine where the instrument panel (Local Display Unit) or operating devices are located.

The **rear side** is the longitudinal side of the engine opposite to the operating side.

Cylinder designation

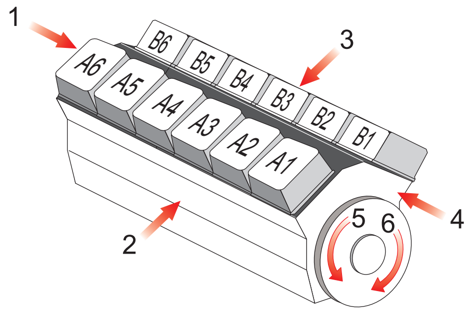
According to ISO 1204 and DIN 6265, the cylinder designation begins at the driving end.



1 Free end
2 Operating side
3 Rear side
4 Driving end
5 Counterclockwise rotation
6 Clockwise rotation

Fig 00-1 Terminology and cylinder designations (inline engine)

In a V-engine the cylinders in the left bank, seen from the driving end, are termed A1, A2, and so on, and in the right bank B1, B2 and so on.



1	Free end	4	Driving end
2	Operating side, A bank	5	Counterclockwise rotation
3	Rear side, B bank	6	Clockwise rotation

Fig 00-2 Terminology and cylinder designations (V-engine)

Rotational direction

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

Counterclockwise rotating engine: looking at the engine from the driving end, the crankshaft rotates counterclockwise.

Top Dead Centre and Bottom Dead Centre

Bottom Dead Centre (BDC), is the bottom turning point of the piston in the cylinder.

Top Dead Centre (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, which in a four-stroke engine comprises two crankshaft rotations, the piston reaches TDC twice:

- **TDC at scavenging:** This occurs when the exhaust stroke of a working cycle ends and the suction stroke of the next one begins. Both the exhaust and inlet valves are slightly open and scavenging takes place. If the crankshaft is turned to and fro near this TDC, both the exhaust and inlet valves will move.
- **TDC at firing:** This occurs after the compression stroke and before the working stroke. Slightly before this TDC, the fuel injection takes place (on an engine in operation). All valves are closed and will not move if the crankshaft is turned. When watching the camshaft and the injection pump, it is possible to notice that the pump tappet roller is on the lifting side of the fuel cam.

High-pressure pumps and accumulators (CR engines)

On an in-line engine, the Common Rail (CR) pumps and accumulators are numbered 1, 2, 3, and so on, starting from the driving end, that is, not according to the cylinder numbers.

On a V-engine, the left side bank pumps and accumulators are termed A1, A2, and so on, and the right bank equipment B1, B2, and so on, starting from the driving end.

Turbocharger definitions for V-engines

- Turbocharger on A-bank side is defined as Turbocharger A **(TC A)**.
- Turbocharger on B-bank side is defined as Turbocharger B **(TC B)**.

Engines with two-stage turbocharging have high-pressure and low-pressure turbochargers:

- High-pressure turbocharger on A-bank side is defined as **TC HP A**.
- Low-pressure turbocharger on A-bank side is defined as **TC LP A**.
- High-pressure turbocharger on B-bank side is defined as **TC HP B**.
- Low-pressure turbocharger on B-bank side is defined as **TC LP B**.

00.4 Designations and markings

00.4.1 Bearing designation

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Main bearings

The shield bearing (nearest the flywheel) is No. 0, the first standard main bearing is No. 1, the second No. 2, and so on.

NOTE

During maintenance use a permanent marker pencil to mark any removed bearing caps on the rear with their designated position number according to designation procedure.

Fig 00-3 Bearing designation

Thrust bearings

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 (inner).

Camshaft gear bearings

The bearing bushes are designated 00 (outer) and 0 (inner).

Upper and lower bearing shells

In bearings where both the shells are identical, the upper one should be marked with "UP".

00.5 Risk reduction

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Read this manual before installing, operating, or servicing the engine and related equipment. Failure to follow the instructions can cause personal injury, loss of life, or damage to property.

Use proper personal safety equipment, for example, gloves, hard hat, safety glasses and ear protection in all circumstances. Missing, unsuitable or defective safety equipment may cause serious personal injury or loss of life.

All electronic equipment is sensitive to electrostatic discharge (ESD). Take all necessary measures to minimize or eliminate the risk of equipment being damaged by ESD.

00.5.1 Use of symbols

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This manual contains different kinds of notes emphasized with symbols. Read them carefully. They contain warnings of possible danger or other information that you must take into consideration when performing a task.

WARNING

Warning means there is a risk of personal injury.

WARNING - ELECTRICITY

Electricity warning means there is a risk of personal injury due to electrical shocks.

CAUTION

Caution means there is a risk of damaging equipment.

NOTE

Note contains important information or requirements.

00.5.2 General identified hazards

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The table below lists general hazards, hazardous situations and events which are to be noticed during normal operation and maintenance work. The table lists also the chapters in this manual which are concerned by the respective hazard.

Identified hazard, hazardous situation or event	Concerned chapters	Protection and safety equipment	Notes
Dropping parts during maintenance work	4, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	Personal protection equipment, e.g. hard hat, shoes to be used.	
Turning device engaged during maintenance work and operated unintentionally	3, 4, 10, 11, 12, 13, 14, 16		
Crankcase safety explosion valves opening due to crankcase explosion	3, 10, 23		
Running engine without covers	3, 4, 10, 11, 12, 13, 14, 16, 21, 22		
Risk of ejected parts in case of major failure	3, 4, 10, 11, 12, 13, 14, 22		
Contact with electricity during maintenance work if power not disconnected	4, 11, 17, 18, 21, 22, 23		
Electrical hazard if incorrect grounding of electrical equipment	3, 4, 11, 17, 18		
Ejection of components or emission of high pressure gas due to high firing pressures	3, 4, 12, 13, 14, 16, 21		
Risk of ejected parts due to break down of turbocharger	3, 15		
Overspeed or explosion due to air-gas mixture in the charge air	3, 4, 15		Suction air must be taken from gas free space.
Ejection of fuel injector if not fastened and turning device engaged	4, 12, 16		
Engine rotating due to engaged gear box or closed generator breaker during overhaul	3, 4, 10, 11, 12, 13, 14, 16		
Fire or explosion due to leakage in fuel /gas line or lube oil system	3, 4, 16, 17, 18, 20		
Inhalation of exhaust gases due to leakage	3, 15, 20		Proper ventilation of engine room/ plant is required.
Inhalation of exhaust gas dust	4, 8, 10, 11, 12, 15, 20		
Explosion or fire if flammable gas/vapour is leaking into the insulation box	3, 20		Proper ventilation and/or gas detectors are required in the engine room.

Continued on next page

Identified hazard, hazardous situation or event	Concerned chapters	Protection and safety equipment	Notes
Touching of moving parts	3, 4, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 23		
Risk of oil spray from high pressure hoses	3, 4, 8, 10, 11, 12, 13, 14, 15, 16, 18, 19, 21, 22	Personal protection equipment, e.g. hard hat, safety glasses to be used.	

00.5.3 Hazards due to moving parts v1

- Running the engine without covers and coming in contact with moving parts
- Touching pump parts during unintentional start of electrically driven pump motor
- Turbocharger starting to rotate due to draft if not locked during maintenance
- Thrusting a hand into the compressor housing when the silencer is removed and the engine is 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
- Accidental rotation of the crankshaft if the turning device is not engaged during maintenance work, for instance, because it has been removed for overhaul
- Mechanical breakage (for example of a speed sensor) due to incorrect assembly of the actuator to the engine or faulty electrical connections.

00.5.4 Hazards due to incorrect operating conditions v2

- Overspeed or explosion due to air-gas mixture in the charge air
- Overspeed due to air-oil mist mixture in the charge air
- Malfunction of crankcase ventilation
- Crankcase explosion due to oil mist mixing with air during inspection after an oil mist shutdown
- Crankcase safety explosion valves opening due to a crankcase explosion.

00.5.5 Hazards due to leakage, breakdown or improper component assembly v5

- A fuel pipe bursting and spraying fuel.
- A control oil pipe bursting and spraying oil (Common Rail)
- VIC housing bursting and spraying oil (if equipped with VIC)

- Leakage of:
  - Fuel at joints on the low and/or high pressure side
  - Lubricating oil
  - High pressure water on direct water injection(DWI) engines
  - HT water
  - Charge air
  - Exhaust gas
  - Pressurised air from air container, main manifold or pipes
- Fire or explosion due to leakage from a fuel or gas line
- Fire or explosion due to flammable gas/vapour (crude oil) 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 engine block or piping
  - High pressure fluid due to breakdown of hydraulic tool
  - Gas due to high firing pressures
  - High pressure fluid due to breakdown of HP sealing oil pipe
  - High pressure air from compressed air supply pipes during maintenance of pneumatically operated equipment
  - Cooling water or fuel/lubricating oil if sensor is loosened while the circuit is pressurised
  - Leaks during maintenance work
- Oil spray if running without covers
- Ejection of fuel injector or prechamber if not fastened and:
  - The turning device is engaged and turned.
  - The engine turns due to closed generator breaker or coupling.

00.5.6 Electrical hazards

v3

- Fire or sparks due to damage or short circuit in electrical equipment
- Contact with electricity during maintenance work if power not disconnected
- Hazards due to incorrect grounding of electrical equipment
- Electrical shocks because electrical cables or connectors are damaged
- Electrical shocks because electrical equipment is dismantled with the power connected

- Incorrectly wired or disconnected emergency stop switch
- Overload of a control system component due to incorrect electrical connections, damaged control circuitry or incorrect voltage
- Engine out of control due to a failure in the shutdown circuitry
- Unexpected startup or failed stop
- 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, an incorrect electrical connector or leakage in a pipe connection

CAUTION

All electronic equipment is sensitive to electrostatic discharge (ESD). Take all necessary measures to minimize or eliminate the risk of equipment being damaged by ESD.

00.5.7 Other hazards v2

- Slipping, tripping or falling
- Improper treatment of water additives and treatment products
- Touching the insulation box, turbocharger, pipes, exhaust manifold, or other unprotected parts without protection during engine operation
- Dropping parts during maintenance work
- Starting maintenance work too early, thus, causing burns when handling hot components
- Neglecting use of cranes and/or lifting tools
- Not using proper tools during maintenance work
- Not using correct protecting outfits when handling hot parts, thus, causing burns
- Contact with fuel, lubrication oil or oily parts during maintenance work
- Exposure to high noise levels
- Touching or removing turbocharger insulation too soon after stopping the engine
- Ejection of preloaded springs when dismantling components

00.6 Welding precautions

00.6.1 Personal safety when welding v1

It is important that the welder is familiar with the welding safety instructions and knows how to use the welding equipment safely.

00.6.1.1 Welding hazards and precautions v3

General work area hazards and precautions

- Keep cables, materials and tools neatly organised.
- Connect the work cable as close as possible to the 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.
- Never touch gas cylinders with the electrode.
- Keep gas cylinders upright and chained to support.

Precautions against electrical shock

WARNING - ELECTRICITY
Electrical shock can kill.

- Wear dry hole-free gloves. Change when necessary to keep dry.
- Do not touch electrically “hot” parts or electrode with bare skin or wet clothing.
- Insulate the welder from the work piece and ground using dry insulation, for example, rubber mat or dry wood.
- If in a wet area the welder cannot be insulated from the work piece 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.

Precautions against fumes and gases

WARNING
Fumes and gases can be dangerous.

- Use ventilation or exhaust fans to keep the 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 or exhaust fans where special ventilation is required.
- Use special care when welding in a confined area.
- Do not weld with inadequate ventilation.

Precautions against welding sparks

WARNING
Welding sparks can cause fire or explosion.

- Do not weld on containers which have held combustible materials. Check the containers before welding.
- Remove flammable material 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 you weld overhead.

Precautions against arc rays

WARNING
Arc rays can burn eyes and skin.

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

Precautions when welding in confined spaces

- Ensure that the ventilation is adequate, especially if the electrode requires special ventilation or if welding causes the formation of gas that may displace oxygen.
- If the welding machine cannot be insulated from the welded piece and the electrode, use semi-automatic constant-voltage equipment with a cold electrode or a stick welder with voltage reducing device.
- Provide the welder with a helper and plan a method for retrieving the welder from the enclosure in case of an emergency.

00.6.2 Protecting equipment when welding v2

The main principles for protecting equipment when welding are:

- Preventing uncontrolled current loops
- Radiation protection
- Preventing the spread of welding splatter
- Switching off or disconnecting all nearby electrical equipment when possible

00.6.2.1 Preventing uncontrolled current loops v1

Always check the welding current path. There should be a direct route from the welding point back to the return connection of the welding apparatus.

The main current always flows 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. It must not include electronic components.

Pay attention to the connectivity of the return connection clamp. A bad contact might cause sparks and radiation.

00.6.2.2 Radiation protection v2

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

To avoid such damages:

- Keep all cabinets and terminal boxes closed during welding.
- Protect sensitive equipment by means of shielding with a grounded (earthed) conductive plate.
- 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.

00.6.2.3 Prevention of damage due to welding splatter v2

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; for example: short-circuits, leaks.

00.6.3 Welding precautions for engine control system v3

CAUTION

⚠ All electronic equipment is sensitive to electrostatic discharge (ESD). Take all necessary measures to minimize or eliminate the risk of equipment being damaged by ESD.

00.6.3.1 UNIC precautions checklist v3

Take the following precautions before welding in the vicinity of a UNIC control system:

Procedure

1 **Deactivate the system.**

Disconnect all external connectors from the power module and from the external interface connectors (XM#).

2 **Disconnect all connectors of any electronic modules located close to (approximately within a radius of 2 m) the welding point.**

3 **Close the cabinet covers and all the distributed units.**

4 **Protect cables, sensors and other equipment from splatter with a proper metal sheet as far as possible.**

00.7 Hazardous substances v1

Fuel oils, lubricating oils and cooling water additives are environmentally hazardous. Take great care when handling these products or systems containing these products.

00.7.1 Fuel oils v3

Fuel oils are mainly non-volatile burning fluids, but they may also contain volatile fractions and present a risk of fire and explosion.

The fuel oils may cause long-term harm and damage in water environments and contaminate the soil and ground water.

Prolonged or repetitive contact, for example, of polyaromatic hydrocarbons with the skin may cause irritation and increase the risk of skin cancer. Fumes that are irritating for eyes and respiratory organs, such as hydrogen sulphide or light hydrocarbons, may be released during loading or bunkering.

NOTE

Refer to the safety instructions provided by the fuel oil supplier.

00.7.1.1 Safety precautions for fuel oil handling v1

- Isolate the fuel oils from ignition sources, such as sparks from static electricity.
- Avoid breathing evaporated fumes, for instance, during pumping and when opening storage tanks. The fumes may contain toxic gases, for instance, hydrogen sulphide. Use a gas mask if necessary.
- Keep the handling and storage temperatures below the flash point.
- Store the fuel in tanks or containers designed for flammable fluids.
- Note the risk of methane gas formation in the tanks due to bacterial activities during long-term storage. Methane gas causes risk of explosion, for instance, when unloading fuel and when opening storage tanks. When entering tanks, there is a risk of suffocation.
- Do not release fuel into the sewage system, water systems or onto the ground.
- Cloth, paper or any other absorbent material used to soak up spills are a fire hazard. Do not allow them to accumulate.
- Dispose of any waste containing fuel oil according to directives issued by the local or national environmental authorities. The waste is hazardous. Collection, regeneration and burning should be handled by authorised disposal plants.

00.7.1.2 Personal protection equipment for fuel oils v4

Protection of respiratory organs	• Respirator with combined particle and gas filter against oil mist • Respirator with inorganic gas filter against evaporated fumes (for example hydrogen sulphide)
Hand protection	• Strong, heat and hydrocarbon resistant gloves (nitrile rubber for example)
Eye protection	• Goggles if splash risk exists
Skin and body protection	• Facial screen and covering clothes as required • Safety footwear when handling barrels • Protective clothing if hot product is handled

00.7.1.3 First aid measures for fuel oil accidents v3

Inhalation of fumes	Move the victim to fresh air. Keep the victim warm and lying still. Give oxygen or mouth to mouth resuscitation if needed. Seek medical advice after significant exposure or inhalation of oil mist.

Skin contact	If the oil was hot, cool the skin immediately with plenty of cold water. Wash immediately with plenty of water and soap. Do not use solvents as they will disperse the oil and might cause skin absorption. Remove contaminated clothing. Seek medical advice if irritation develops.
Eye contact	Rinse immediately with plenty of water, for at least 15 minutes. Seek medical advice. If possible, keep rinsing until eye specialist has been reached.
Ingestion	Rinse the mouth with water. Do not induce vomiting as this may cause aspiration into the respiratory organs. Seek medical advice.

00.7.2 Lubricating oils v2

Fresh lubricating oils are normally not particularly toxic but they should be handled with care.

Used lubricating oils may contain significant amounts of harmful metal and PAH (polyaromatic hydrocarbon) compounds. There is a risk of long term contamination of the soil and the ground water.

NOTE

Refer to the safety information provided by the supplier of the lubricating oil.

00.7.2.1 Safety precautions for handling lubricating oil v1

When handling lubrication oils:

- Ensure adequate ventilation if there is a risk of vapours, mists or aerosols releasing. 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 lubricating oils.
- Use only equipment (containers, piping, etc.) that 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.
- Cloth, 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 containing lubricating oil is hazardous and must 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.

00.7.2.2 Personal protection equipment for lubricating oils v3

Hand protection	Use 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 clothes as required. Use safety footwear when handling barrels. Wear protective clothing when handling hot products.

00.7.2.3 First aid measures for accidents with lubricating oil v3

Inhalation of fumes	Move the victim to fresh air. Keep the victim warm and lying still.
Skin contact	Wash immediately with plenty of water and soap or cleaning agent. Do not use solvents (the oil is dispearsed and may be absorbed into the skin). Remove contaminated clothing. Seek medical advice if irritation develops.
Eye contact	Rinse immediately with plenty of water, and continue for at least 15 minutes. 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.

00.7.3 Cooling water additives, nitrite-based v2

Cooling water additives 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 decrease in blood pressure. Skin and eye contact with the undiluted product can produce intense irritation. Diluted solutions may be moderately irritating.

NOTE

Refer to the safety information provided by the supplier of the product.

00.7.3.1 Safety precautions for handling cooling water additives v1

- Avoid contact with skin and eyes.
- Keep the material away from food and drinks. Do not eat, drink or smoke while handling it.
- Keep the material in a 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.

00.7.3.2 Personal protection equipment for cooling water additives v3

Respiratory protection	Normally no protection is required. Avoid exposure to product mists.
Hand protection	Wear rubber gloves (PVC or natural rubber for example).
Eye protection	Wear eye goggles.
Skin and body protection	Use protective clothing and take care to minimise splashing. Use safety footwear when handling barrels.

00.7.3.3 First aid measures for accidents with cooling water additives v3

Inhalation	In the event of over exposure to spray mists, move the victim to fresh air. Keep the victim warm and lying still. If the effects persist, 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 the mouth with water. Make the victim drink milk, fruit juice or water. Do not induce vomiting without medical advice. Immediately seek medical advice. Never give anything to drink to an unconscious person.

00.7.4 Fly ashes and exhaust gas dust v2

NOTE

See the safety instructions before starting to overhaul the exhaust gas system, or engine components that have been in contact with exhaust gases.

00.7.4.1 Precautions for handling fly ashes and exhaust gas dust v2

When handling fly ashes, exhaust gas dust or any contaminated components, observe the following requirements and precautions:

- Avoid inhaling and swallowing fly ashes and dusts. Prevent eye and skin contacts.
- Avoid spreading and spilling the fly ashes and dusts to the environment.
- Take measures to avoid spreading the dust in the surrounding area when opening the manholes of the exhaust gas system, especially the Selective Catalytic Reduction (SCR) system (if included). Avoid spreading dust when handling exhaust gas system components.
- Take care that the ventilation is suitable when collecting dust arisen during the machining and cleaning of the components.
- Apply appropriate disposal instructions for flue gas dust spillage. The dust collected from the exhaust gas system must be considered as hazardous waste. It must be treated according to the local regulations and legislation.

00.7.4.2 Personal protection equipment for fly ashes and exhaust gas dust v4

Respiratory organ protection	Use P3 filter respirator against toxic particles. 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	Use gloves.
Eye protection	Wear goggles.
Skin and body protection	Wear covering clothes.

Use proper protection also when machining or cleaning engine components that have been in contact with exhaust gases.

00.7.4.3 First aid measures for fly ash and exhaust gas accidents v3

Inhalation of ashes	Move the victim to fresh air. Keep the victim warm and lying still. Give oxygen or mouth to mouth resuscitation if needed. Seek medical advice after a significant exposure.
Skin contact	If the ash is hot, cool the skin immediately with plenty of cold water. Wash immediately with plenty of water and soap. Do not use solvents as it disperses the ash and may cause skin absorption. 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 the mouth with water. Do not induce vomiting as it may cause aspiration into respiratory organs. Seek medical advice.

00.7.5 Lead in bearings v1

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

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

00.7.6 Fluoride rubber products

00.7.6.1 Precautions when handling fluoride rubber products v3

Normal sealing applications

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 maintained.

When changing O-rings of valve seats

Always wear protective rubber gloves when changing the O-rings of the valve seats.

When handling the remains of burnt fluoride rubber

When handling the remains of burnt fluoride rubber, for instance, when changing O-rings after a valve blow-by, 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 of.

Grinding dust

Dust and particles originating from grinding or abrasion (wear) of fluoride rubber may when burned form toxic degradation products. Smoking must therefore be prohibited in areas where fluoride rubber dust and particles are present.

In case of fire

When burned fluoride rubber can cause the formation of toxic and corrosive degradation products, for example, hydrofluoric acid, carbonyl fluoride, carbon monoxide, and carbon fluoride fragments of low molecular weight.

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 state remains must be considered extremely corrosive.

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

Use of fluoride rubber products at temperatures above 275°C (527°F)

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

00.7.6.2 Personal protection equipment for fluoride rubber products v4

Hand protection	• Impenetrable acid-proof gloves (neoprene or PVC)
Inhalation protection	• Breathing mask

00.7.6.3 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.

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01. Main Data, Operating Data and General Design

01.1 Main data for Wärtsilä 32

v6

Cylinder bore .... 320 mm
Stroke .... 400 mm
Piston displacement per cylinder .... 32.17 l

Table 01-1 Firing order

Engine type	Clockwise rotation	Counter clockwise rotation
6L32	1-5-3-6-2-4	1-4-2-6-3-5
7L32	1-3-5-7-6-4-2	1-2-4-6-7-5-3
8L32	1-3-7-4-8-6-2-5	1-5-2-6-8-4-7-3
9L32	1-7-4-2-8-6-3-9-5	1-5-9-3-6-8-2-4-7

NOTE

Normally the engine rotates clockwise.

Table 01-2 Approximate lubricating oil volume in the engine (marine)

Engine type	Wet sump [m^3]	Between max. and min. marks (litre/mm)
6L32	1.6	2.9
7L32	1.8	3.3
8L32	2.0	3.7
9L32	2.3	4.2

Table 01-3 Approximate cooling water volume in the engine in liters (engine only)

Engine type	Volume [l]	
	HT	LT
6L32	410	140
7L32	460	160
8L32	510	170
9L32	560	180

Table 01-4 Lubricating oil volume in litre

Equipment	Volume (L)
Turning device (LKV132)	8.5 - 9.5
Speed governor	1.4 - 2.2 [1]

[1]) The lubricating oil volume is depending of the governor type. See manufacturers instruction

01.2 Recommended operating data

v5

Guidance values to normal operation at nominal speed. See also installation-specific modbus list.

Temperatures (°C)		
	Normal values	Alarm (stop) limits
Load	100 %	0 - 100 %
Lube oil before engine	60-65	70 (80) 2)
Lube oil after engine	10 - 13 higher	
HT water after engine	91 - 96 1)	105 (110) 2)3)
HT water before engine	5 - 8 lower	50
HT water rise over turbocharger xx)	8 - 12	
LT water before charge air cooler	28 - 38	45 (60) 5)
Charge air in air receiver	50 - 60	75
Exhaust gas after cylinder	See test records	500 (520) 2)
Exhaust gas before turbocharger		-
Preheating of HT water	50 (MDO) 70 (HFO)	45
Cylinder liner temp.	130 - 150	160 (180) 2)
Main bearing temp.	90 - 100	110 (120) 2)

Gauge pressures (bar)		
	Normal values	Alarm (stop) limits
Load	100 %	0 - 100 %
Lube oil before engine at a speed of 600 RPM (10.0 r/s)	4.5	3.0 (2.0)
720 RPM (12.0 r/s) - 750 RPM (12.5 r/s)	5.0 - 5.5	3.0 (2.0)
HT/LT water before HT/LT pump (static)	0.7 - 1.5	
HT water before engine	2.5 + static press. 1)	1.5 + static press. (2) 2) 4)
LT water before charge air cooler	2.5 + static press. 1)	1.5 + static press.
Fuel before engine	7 -8 (HFO/LFO)	4
Fuel before engine, Common Rail	11 -12 (HFO/LFO)	4
Compressed air (start & control air)	max. 30	18

Continued on next page

Gauge pressures (bar)		
	Normal values	Alarm (stop) limits
Load	100 %	0 - 100 %
Charge air (CAC, outlet)	See test records	3

Other pressures (bar)		
	Normal values	Alarm (stop) limits
Load	100 %	0 - 100 %
CAC, pressure difference		75 mbar
Crankcase pressure		3 mbar
Firing pressure	See test records	
Opening pressure of safety valve on fuel feed pump	12 bar	
Opening pressure of safety valve on lube oil pump	6 - 8	
Lube oil filter pressure difference	0.8 - 1.8	0.8 (first) 1.8 (second alarm)

1)Depending on speed and installation

2)Load reduction, main engine

3)Stop, auxiliary engine

4)Stop, on GL installation, main engine

xx)In case of water cooled turbocharger

5) Only in special conditions

Engine speed and overspeed tripping settings

Electro-pneumatic tripping speed	
Nominal speed	UNIC automation
720 RPM	828 ± 10 RPM
750 RPM	862 ± 10 RPM

01.3 Reference conditions v2

Reference conditions according to ISO 3046/I (1995):

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)

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

Reduction factor = (a + b + c) %

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

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

c= 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

v5

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

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

The charge air receiver as well as the cooling water heater are cast into the engine block. 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 cooled only in the upper part. The cooling effect is optimised to give the correct temperature of the inner surface.

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

The main bearingsare fully interchangeable trimetal or bimetal half shell bearings which can be removed by removing the main bearing cap.

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

The connecting rodsare of a three-piece design, known as "Marine type connecting rods".

The connecting rod is forged and machined of alloyed steel and is split horizontally in three parts to allow removal of piston and connecting rod parts. All connecting rod bolts are hydraulically tightened to minimize the relative movement between mating surfaces.

The big end bearings are fully-interchangeable trimetal or bimetal half-shell bearings.

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

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

The cylinder head,made of nodular 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 valvesare 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, with Nimonic or stellite seats and chromium-plated stems, seal against the directly-cooled valve seat rings.

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

The camshaftsare composed of one-cylinder pieces with integrated cams.

The engine is available with two different fuel injection systems: **common rail fuel injection** and **conventional fuel injection.**

- The common rail system consists of one fuel oil **high pressure pump** and one **fuel accumulator** per two cylinders.
- The conventional fuel system consists of **injection pumps** that have separated roller followers and can be changed by adjusting the base measure with the tappet screw. The pumps and piping are located in a closed space which is heat-insulated for running on heavy fuel.

The turbochargeris normally located at the free end of the engine.

The charge air cooleris of a self-supported type.

The lubricating oil systemincludes a gear pump, an automatic oil filter, centrifugal filter for cleaning the back-flush oil, a cooler with thermostat valve 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 to the cylinders is controlled by a starting air distributor run by the camshaft.

The instrumentation and automation is handled by Engine control system.

Alternatively the, instrumentation and automation can also be handled by the plant control system.

The cooling water systemincludes built-on cooling water pumps and thermostatic valves.

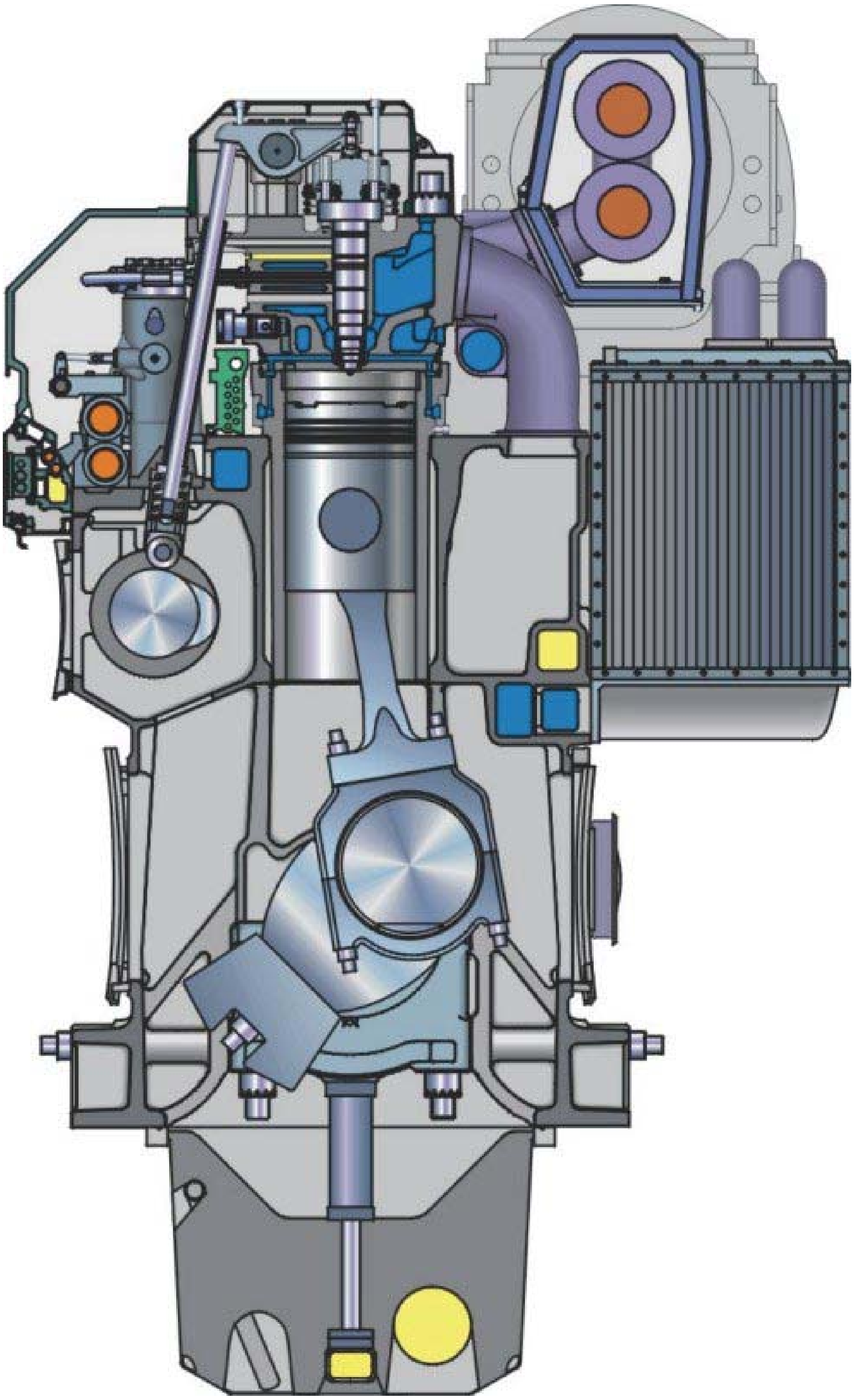

Fig 01-1 Cross-section of Wärtsilä 32, in-line engine

02. Fuel, lubricating oil, cooling water

02.1 Fuel

v6

The Wärtsilä® medium-speed diesel engines are designed to operate on heavy fuel (residual fuel) and will operate satisfactorily on blended (intermediate) fuels of lower viscosity, as well as on distillate fuel.

NOTE

Do not use fuels that have lower or bigger viscosity values than the ones given by the engine manufacturer, because they cause fuel injection plunger or fuel nozzle needle seizure.

NOTE

In certain installations, the limit values may differ from the ones given here. The valid values for a particular installation are stated in the sales contract and in the documentation delivered with the engine. If the limit values are exceeded during the guarantee period, the engine guarantee is void.

For detailed information on the fuel quality requirements, see the fuel specification at the end of this chapter.

02.1.1 Comments on fuel characteristics

02.1.1.1 Fuel viscosity

v4

Viscosity is not a measure of the fuel quality, but it determines the complexity of the fuel heating and handling system. The limit values for fuel viscosity at the point of injection are given in the fuel specification.

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 worst case makes it impossible to reach full engine output. The standard engine fuel system is laid out for max. 700 cSt at 50°C.

The possible remedial actions against too low viscosity are to specify minimum viscosity when ordering fuel (LFO), or to design or modify the fuel systems to maintain an appropriate minimum viscosity by cooling.

02.1.1.2 Fuel density

v1

The density influences mainly on the fuel separation. Separators can remove water and to some extent solid particles from fuels with densities up to 991 kg/m^3 at 15°C. There are also separators on the market that can clean fuel with densities up to 1010 kg/m^3 at 15°C.

The separator disc must be chosen according to the fuel density. It is important that the separator has enough capacity if it is used for fuel with a very high density. A bad separation leads to abnormal wear due to the presence of particles and water.

CAUTION

Fuels with a low viscosity in combination with a high density usually have bad ignition properties.

02.1.1.3 Ignition quality of the fuel

v2

Heavy fuels may have very low ignition quality, which causes:

- Trouble at start and low load operation, particularly if the engine is not sufficiently preheated.
- Long ignition delay
- Fast pressure rise
- very high maximum pressures
- Increase of mechanical load, which damages severely engine components such as piston rings and bearings
- Deposits on the piston top, on the exhaust valves, in the exhaust system, and on the turbine nozzle ring and turbine blades
- Decreased turbocharger efficiency and increased thermal load due to turbocharger fouling

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

NOTE

Advancing the injection timing causes that the fuel is injected at lower compression temperature, increasing the ignition delay.

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.

Calculation of ignition quality

Ignition quality is neither 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, such as Diesel Index, Cetane Index and Cetane Number. The ignition quality of a heavy fuel oil can be roughly determined by calculating the Calculated Carbon Aromaticity Index (CCAI).

You can calculate the CCAI using the density ρ (kg/m^3) at 15°C and the kinematic viscosity v_k at 50 °C, according to the following formula:

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

NOTE

An increasing CCAI value indicates decreased ignition quality

You can also determine The CCAI using the nomogram. However, the accuracy is limited.

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 currently most bunkers remain in the 840 to 870 range.

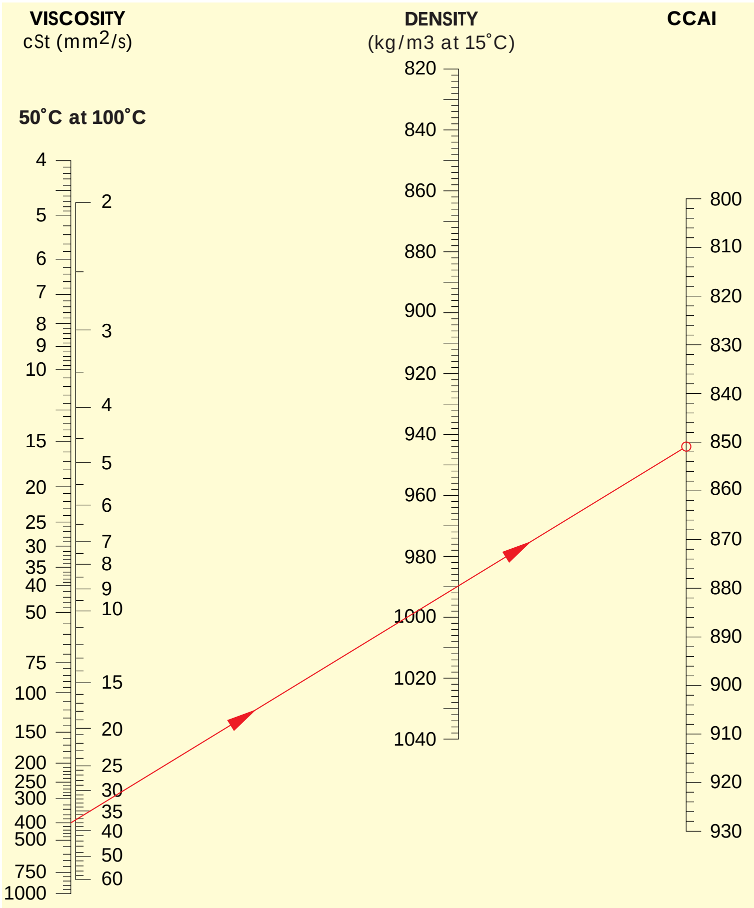

Fig 02-1 Nomogram

Because the CCAI is not an exact tool for judging fuel ignition, there are other rough guidelines:

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

02.1.1.4 Water content in the fuel v1

Water may come from several different sources: it can be fresh, salty or originated from condensation in the installation's bunker tanks.

- If the water is sweet and very well emulsified in the fuel: when the amount of water increases, the effective energy content of the fuel decreases. This means, the oil consumption increases.
- 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.

CAUTION

Water content higher than 0.3% before engine may cause problems in the injection system.

02.1.1.5 Sulphur content in the fuel v2

The sulphur in the fuel causes cold corrosion and corrosive wear, especially at low loads. Together with vanadium and sodium in the form of sulphates, it also contributes to the formation of deposits in the exhaust system. These deposits cause high temperature corrosion.

For maximum operating economy, limit the maximum continuous output as much as the operating conditions allow if the fuel has, or is suspected to have high vanadium (above 200 ppm) and sodium content. Also limit the low load operation as much as the operating conditions allow if the fuel has, or is suspected to have high sulphur (above 3% m/m), carbon (Conradson carbon above 12% m/m) and/or asphaltene (above 8% m/m) content. Avoid idling.

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, the lubricity additives are also used by fuel manufacturers and marketers in order to improve the lubricity properties of the 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 highfrequency reciprocating rig (HFRR)". The recommended maximum limit for this HFRR test, also typically specified in other industrial applications, is 460 microns.

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

02.1.1.6 Ash content in the fuel v1

Different ash components can cause different problems.

Aluminium and silicon oxides originate from the refining process, and can cause severe abrasive wear on injection pumps, nozzles, cylinder liners and piston rings.

Vanadium and sodium oxides, mainly sodium vanadyl vanadates, are formed during the combustion. These react with oxides and vanadates in other ash components, for example nickel, calcium, silicon and sulphur. The melting temperature of the mixture may be such, that deposits form on valves, in the exhaust gas system, or in the turbocharger. The deposit formation increases at increased temperatures and engine outputs:

- Deposits in valves are so corrosive in the molten state, that they destroy the protective oxide layer and lead to hot corrosion and a burned valve.
- Deposits and hot corrosion in turbochargers cause a low turbocharger efficiency, especially if they are located on the nozzle ring and turbine blades.
- Deposits in the exhaust gas system disturb gas exchange, letting less air flow through the engine, and thus increasing the thermal load on the engine.

When running on high ash fuels, it is important to:

- Have an efficient fuel separation.
- Clean the turbocharger regularly with water.
- Have a strict quality control of the bunkered fuel 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.

02.1.1.7 Carbon residue content in the fuel v1

High carbon residue content causes deposit formation in the combustion chamber and in the exhaust system, especially at low loads.

- Deposits on injection nozzle tips disturb the fuel atomization 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. This causes for example, increased blow-by of combustion gases down to the crank case, which in turn increases lubricating oil fouling.
- Deposits in the exhaust gas system and in the turbocharger disturb the gas exchange and increase the thermal load.

02.1.1.8 Asphaltene content in the fuel v1

Asphaltenes are complex, highly aromatic compounds with a high molecular weight. They usually contain sulphur, nitrogen and oxygen, and metals like vanadium, nickel, and iron.

High asphaltene content may contribute to deposit formation in the combustion chamber and in the exhaust system, especially at low loads. High asphaltene content indicates that a fuel may be difficult to ignite and that it burns slowly.

If the fuel is unstable, the asphaltene may precipitate from the fuel and block filters and cause deposits in the fuel system, as well as excessive centrifuge sludge.

02.1.1.9 Fuel flash point v3

Crude oils have often a low flash point (high vapour pressure). A low flash point does 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. Special explosion proof equipment and separators can be used in extreme cases.

Other consequences of having a low flash point are cavitation and gas pockets in the fuel pipes. These can be avoided by keeping the pressure high in the fuel handling system.

NOTE

SOLAS regulations and classification societies demand the use of fuels with a flash point higher than 60°C.

02.1.1.10 Fuel pour point v3

The pour point tells below which temperature the fuel does not flow, and determines how easy it will be to handle the fuel.

02.1.2 Fuel treatment v1

The required fuel treatment outside the engine includes:

- Heating the fuel to obtain correct viscosity
- Purifying the fuel by centrifuging it
- Checking the fuel viscosity.

02.1.2.1 Fuel heating

v2

To minimise the risk of wax formation, keep the fuel temperature about 10 °C above the minimum storage temperature indicated in the fuel oil viscosity-temperature diagram.

To compensate for heat losses between heater and engine, keep the temperature after the final heater 5 - 10 °C above the recommended temperature before injection pumps.

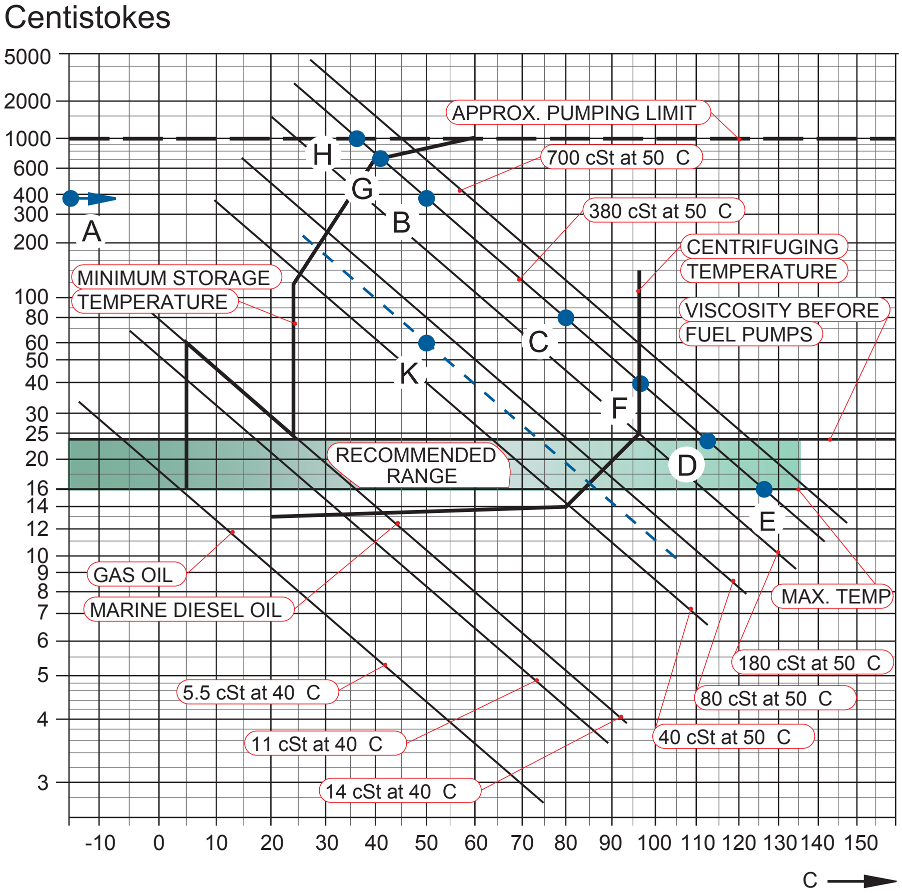

Fig 02-2 Fuel oil viscosity-temperature diagram

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.*

You can convert from various current and obsolete viscosity units to centistokes using the viscosity conversion diagram.

NOTE

The diagram should be used only for conversion of viscosities at the same temperature.

Use the same temperatures when entering the viscosity/temperature point into the Fuel oil viscosity-temperature diagram.

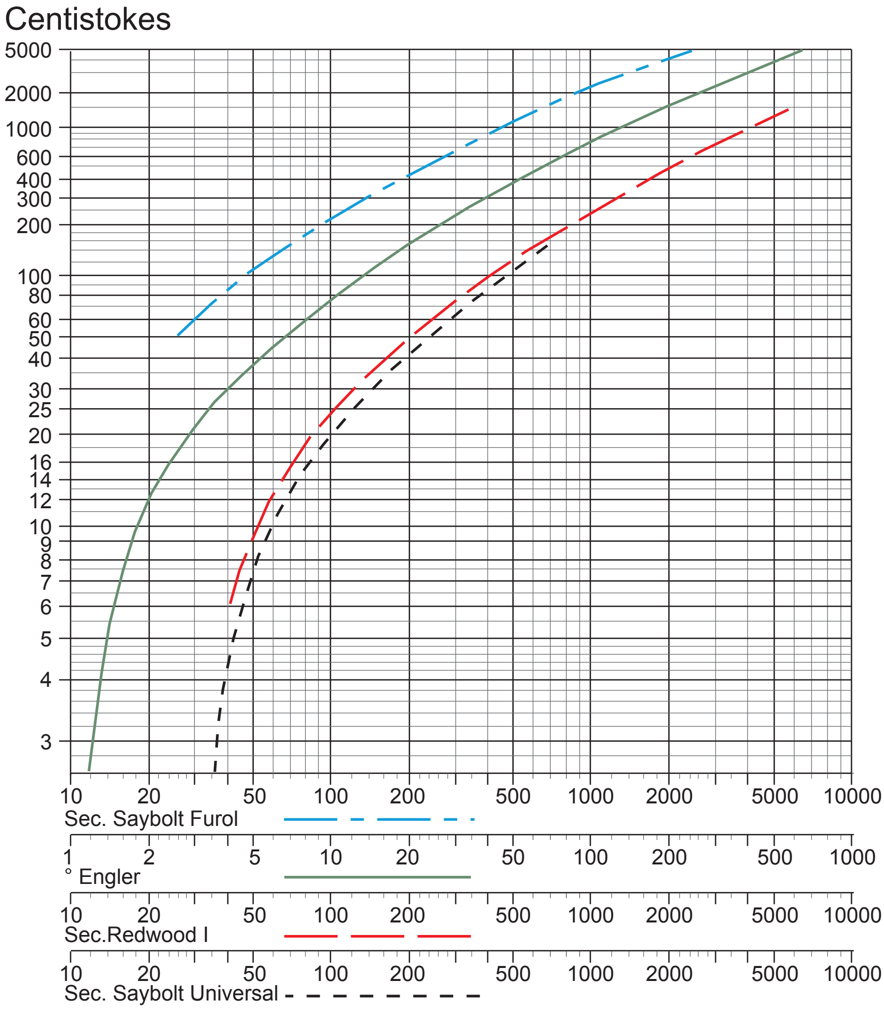

Fig 02-3 **Viscosity conversion diagram**

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

02.1.2.2 Fuel separation

v2

Related topics

Fuel heating.. 02-6

Before entering the engine, heavy fuel oil, and also a mixture of heavy fuel and distillate fuel must be purified in an efficient centrifugal separator. Even if pure distillate fuel is used, separation is still recommended as the fuel may be contaminated in the storage tanks.

Heat the fuel before separation. Check the recommended temperature from the fuel oil viscosity-temperature diagram.

When deciding on separator type and capacity, take the fuel viscosity and density into account.

NOTE

Do not exceed the separator's recommended flow rates for the fuel in use. The lower the flow rate, the better the efficiency.

For the recommended separator flow rates, see the separator manufacturer's instructions.

The separator's rated capacity can be used if the fuel viscosity is less than 12 cSt at the separation temperature. The marine gas oil viscosity is normally less than 12 cSt at 15°C.

02.1.2.3 Viscosity control v1

An automatic viscosity controller, or a viscosimeter, should be installed to maintain the correct fuel injection viscosity before the fuel enters the engine's fuel system.

02.1.3 Fuel blending v1

To avoid problems with stability and incompatibility that are caused by the precipitation of heavy components in the fuel, do not blend fuels from different bunker stations unless you know the fuels are compatible.

If such problems occur, never add distillate fuel since this may increase precipitation. A fuel additive with powerful dispersing characteristics may help until a new fuel delivery takes place.

The characteristics of heavy fuels blended from residuals from modern refinery processes, such as catalytic cracking and visbreaking, may approach at least some of the limit values of the fuel characteristics.

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

To avoid some of the difficulties that may occur when operating on heavy fuels blended from cracked residuals, ensure sufficient separating capacity. For the best and most disturbance-free results, use a purifier and a clarifier in series. Alternatively, the main and stand-by separators can be run in parallel, but this requires correct gravity disc choice and a constant flow and temperature control to achieve optimum results. The flow rate through the separators should not exceed the maximum fuel consumption by more than 10%.

Also ensure sufficient heating capacity to keep the separating and injection temperatures at the recommended levels. It is important that the temperature fluctuations are as small as possible (±2°C before the separator) when separating high viscosity fuels with densities approaching or exceeding 991 kg/m3 at 15°C.

02.2 Lubricating oils v4

Lubricating oil is an integral part of the engine.

All lubricating oils that are validated for use in Wärtsilä engines have gone through a validation test according to the engine manufacturer's procedure.

NOTE

Use of non-validated lubricating oils during the engine warranty period without special agreement with the engine manufacturer makes the engine guarantee void.

NOTE

Do not blend different oil brands unless validated by the oil supplier. During the warranty period, also the engine manufacturer's validation is required.

For detailed information on the lubricating oil quality requirements and a list of validated lubricating oils, see the lubricating oil specification at the end of this chapter.

02.2.1 Lubricating oil treatment v2

It is very important to check the lubricating oil quality at regular intervals to ensure the oil remains in good condition.

CAUTION

Prevent lubricating oil contamination during transport and storage.

02.2.1.1 Lubricating oil separation v6

Separation removes water and impurities, such as insoluble material and wear particles, from the engine lubricating oil. The separation efficiency affects the lubricating oil condition and the need for refreshing the oil.

When operating on HFO, lubricating oil separation is required. When operating on LFO, the lubricating oil separation is optional.

Before separation, preheat the oil to 95°C.

For optimal separation result, the flow rate mentioned by the separator manufacturer shall be used. For the older design separators, a 20% flow rate calculated from the rated capacity is recommended. To achieve an optimal separation result, the separator shall be capable of passing the entire oil volume in circulation 4-5 times every 24 hours at the recommended flow rate.

If the separator has a gravity disc, select it according to the lubricating oil density at the separation temperature.

For the separator's optimal performance, follow the operation instructions given by the separator manufacturer.

CAUTION

Defects on automatic, "self-cleaning" separators may cause a water control valve failure that leads to a rapid increase in the oil's water content.

02.2.1.2 Taking and analysing oil samples v2

Take oil samples regularly according to the maintenance schedule and have them analysed to check the condition of the oil. The results from the oil analysis, and the way they change over time, can be used for adjusting the required oil refreshing interval and oil quantity.

To be representative of the oil in circulation, the sample should be taken with the engine in operation at the sampling cock located immediately after the oil filter on the engine.

NOTE

Take samples before, not after, adding fresh oil.

Procedure

1 **Take the oil samples in a clean container holding 0.75 - 1 litre.**

Before taking the oil sample, rinse the container with the same oil.

2 **Send the sample to the oil supplier for analysis.**

See the instructions for handling oil samples.

3 **Compare the analysis results with the condemning limits for used lubricating oil and the guidance values for fresh lubricating oil of the brand in question.**

The condemning limits must not be exceeded. If the analyse values are close to the limits, the engine oil refreshing must be intensified.

NOTE
Record the analysis results and observe how they change over time. Sudden large changes in these parameters can be a sign of abnormal operation of the engine or the lubricating oil system.

02.2.2 Handling oil samples

v2

Related topics

When taking fuel oil or lubricating oil samples the importance of proper sampling cannot be over-emphasised. The accuracy of the analysis results depends significantly on proper sampling and the results will be only 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
- The location where 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 included in the attachments.

WARNING

Observe personal safety precautions when taking and handling fuel oil and lubricating oil samples.

02.2.2.1 Dispatch and transportation

v4

Handle the dispatching of the fuel oil and lubricating oil samples at site. That way the results are achieved faster. Additionally, it is illegal to carry fuel oil samples as personal luggage on normal aeroplanes.

Procedure

1 **Place the bottle with the "Ziploc" bag inside the IATA carton box.**

Fold the box according to the assembly instructions given on the box. Enclose the fully completed Chief Engineer's Report Form and a copy of the "Bunker Delivery Receipt" before closing the last flap. The Chief Engineer's Report Form should state clearly for whom the sample is being tested.

2 **Label the IATA carton box.**

Ensure that the sample is forwarded to the nearest DNVPS laboratory (check the DNVPS Air Courier Directory).

3 **Complete the courier dispatch instructions on the side of the IATA carton box.**

Follow the delivery instructions of the company which will receive and analyse the sample. Complete the Pro Forma Invoice Form and tape it to the outside of the IATA carton box.

4 **Hand the IATA carton box for dispatch.**

- Hand the box to the shipping agent and give him all the necessary information for the dispatch. Remind the shipping agent to call the courier company for pick-up as soon as he gets ashore.

  OR

- Call the direct number of the courier company as indicated in the Air Courier Directory. Request urgent pick-up, if necessary, and complete the Airway Bill when the courier arrives.

Postrequisites

NOTE

Wärtsilä can provide support with the interpretation of the analysis results and advice on possible corrective actions.

02.3 Cooling water

v4

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

Before treatment, the water must be limpid and meet the specifications given in this manual. Further, the use of an approved cooling water additive or treatment system is mandatory.

If there is a risk of freezing, please contact the engine manufacturer for use of anti-freeze chemicals.

CAUTION

Do not use glycol in the cooling water unless it is necessary.

For detailed information on the cooling water quality requirements and a list of validated additives, see the cooling water specification at the end of this chapter.

02.3.1 Cooling water treatment

v2

Ask the supplier of the treatment product for instructions about treatment procedure, dosage and concentration control. Most suppliers provide a test kit for the concentration control. Additionally, frequent laboratory analysis of cooling water at three months interval is recommended to ensure safe engine operation.

Water drained from the system during maintenance work should be collected, stored and reused.

If there is risk of frost when the cooling water is drained, ensure that pressure and temperature sensors are drained of water to prevent them form damaging.

To compensate for evaporated water, add untreated water. If treated water is added, the content of additives may gradually become too high. Use treated water, however, to compensate for leakage or other losses.

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

02.3.2 Cooling water additives

v6

Related topics

Safety precautions for handling cooling water additives..00-15
Personal protection equipment for cooling water additives...00-16

Use additives from well-known and reliable suppliers with vast distribution nets. Follow thoroughly the instructions of the supplier.

CAUTION

Do not use emulsion oils, phosphates and borates (sole).

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

Table 02-1 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

Continued on next page

Additive	Advantages	Disadvantages
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
Organic and inorganic synergistic based	- non-toxic	- more expensive than sodium nitrite and molybdate based additives - big active quantities by mass

In an emergency, if compounded additives are not available, the cooling water can be treated 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.

Nitrite based cooling water additives are so called anodic inhibitors. To serve their purpose, they require proper dosing and maintenance. The nitrite of the additive is as such a salt and it will increase the conductivity of the water. The conductivity, on the other hand, is one of the main parameters affecting the corrosion rate. Once a corrosion process has started, the higher the conductivity the higher is the corrosion rate.

If the conditions (nitrite level, chlorides, pH, etc.) in a system are such that the nitrite based additive is no longer able to protect the entire surface, local corrosion may occur rapidly in the areas that are not protected. The corrosion rate may even be much greater than it would be with no additive at all present in the system. See the schematic graph of the corrosion rate as a function of the nitrite dosage in the figure below. Observe that the position of the peak (= dangerous condition for corrosion) is not constant, but moves along the x-axis depending on the cooling water temperature, pH, chloride & sulphate contents, and so on.

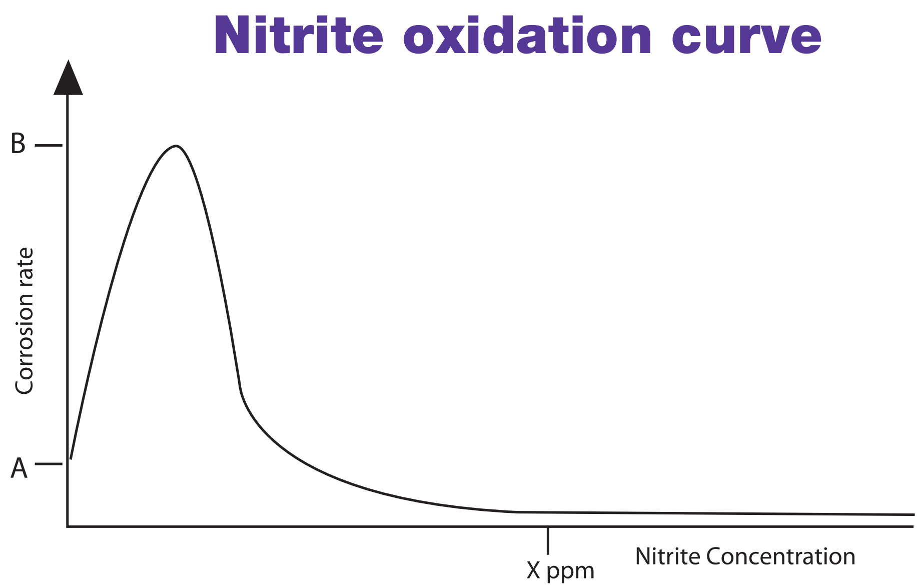

Fig 02-4 **Corrosion rate as a function of nitrite concentration**

To give full protection, the nitrite level should be kept above X ppm. The actual value of the concentration depends on the supplier of the additive. A permanent low level leads to an accelerated corrosion rate.

02.4 Distillate and heavy fuel specification

WÄRTSILÄ	© Wärtsilä Corporation Finland Technology	FUEL CHARACTERISTICS Wärtsilä Vasa 32LN, Wärtsilä 32, WAuxpac 32					
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Subtitle	Product	Made	23.12.1994		Page	Document No	Rev
Performance Manual	WV32LN, W32, WA32	Appd.	15.12.1995		1 (5)	4V92A0459	i
Revised date: 05.12.2013				D-message No.: 242572			

FUEL CHARACTERISTICS

1. Maximum limits for fuel characteristics

The diesel engines Wärtsilä® Vasa 32/32LN and Wärtsilä® 32 are designed and developed for continuous operation, without reduction in the rated output, on fuels with the characteristics specified hereafter.

Light fuel oil and heavy fuel oil specifications are based on the ISO 8217:2012(E) standard with some internal modifications, while the crude oil specification has been prepared in-house, but anyway following in wide extent the limit values specified for heavy fuel oil quality.

In addition to the limit values stated in the tables included hereafter, it has to be taken into account concerning all specified fuel qualities (Light fuel oil, Heavy fuel oil, Crude oil) that:

- The fuel shall not contain any additive at the concentration used in the fuel, or any added substance or chemical waste that jeopardizes the safety of installation or adversely affects the performance of the machinery or is harmful to personnel or contributes overall to additional air pollution.
- For maximum fuel temperature before the engine, see the Installation Manual.

Light fuel oil:

The fuel specification is based on the ISO 8217:2012(E) standard and covers the fuel grades ISO-F-DMX, DMA, DMZ and DMB.

The distillate grades mentioned above can be described as follows:

- DMX: A fuel which is suitable for use at ambient temperatures down to –15 °C without heating the fuel. Especially in merchant marine applications its use is restricted to lifeboat engines and certain emergency equipment due to reduced flash point, but the low flash point not meeting the SOLAS requirement can also prevent the use in other marine and power plant applications unless the fuel system is built according to special requirements allowing the use. Also the low viscosity (min. 1,400 mm²/s) can prevent the use in Wärtsilä® engines unless a fuel can be cooled down enough to meet the injection viscosity limit included in Table 1.
- DMA: A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field.
- DMZ: A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field. An alternative fuel grade for engines requiring a higher fuel viscosity than specified for DMA grade fuel.
- DMB: A general purpose fuel which may contain trace amounts of residual fuel and is intended for engines not specifically designed to burn residual fuels. It is generally designated MDO (Marine Diesel Oil) in the marine field.

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Characteristics	Unit	ISO-F-DMA	ISO-F-DMZ	ISO-F-DMB	Test method reference
Kinematic viscosity before injection pumps, min. [h] Kinematic viscosity before injection pumps, max. [h]	mm^2/s [a] mm^2/s [a]	2,0 24	2,0 24	2,0 24	- -
Kinematic viscosity at 40 °C, min. Kinematic viscosity at 40 °C, max.	mm^2/s [a] mm^2/s [a]	2,000 6,000	3,000 6,000	2,000 11,00	ISO 3104
Density at 15 °C, max.	kg/m^3	890,0	890,0	900,0	ISO 3675 or ISO 12185
Cetane index, min.	-	40	40	35	ISO 4264
Sulphur, max. [b]	% m/m	1,50	1,50	2,00	ISO 8754 or ISO 14596
Flash point, min.	°C	60,0	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	0,5	0,5	0,5	ASTM D664
Total sediment by hot filtration (Total sediment existent), max.	% m/m	-	-	0,10 [d]	ISO 10307-1
Oxidation stability, max.	g/m^3	25	25	25 [e]	ISO 12205
Carbon residue, micro method on the 10 % v/v distillation residue, max. Carbon residue, micro method, max.	% m/m	0,30 -	0,30 -	- 0,30	ISO 10370 ISO 10370
Pour point (upper), max. [c] - winter quality - summer quality	°C	 -6 0	 -6 0	 0 6	ISO 3016
Appearance	-	Clear and bright [i]		[d, e, f]	-
Water max.	% v/v	-	-	0,30 [d]	ISO 3733
Ash, max.	% m/m	0,010	0,010	0,010	ISO 6245
Lubricity, corrected wear scar diameter (wsd 1,4) at 60 °C, max. [g]	µm	520	520	520 [f]	ISO 12156-1

a) 1 mm^2/s = 1 cSt.

b) If not within the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.

c) Purchasers shall ensure that this pour point is suitable for the equipment on board / at the plant, especially if the ship operates / plant is located in cold climates.

d) If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required.

e) If the sample is not clear and bright, the test cannot be undertaken and hence the oxidation stability limit shall not apply.

f) If the sample is not clear and bright, the test cannot be undertaken and hence the lubricity limit shall not apply.

g) The requirement is applicable to fuels with a sulphur content below 500 mg/kg (0,050 % m/m).

h) Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2012(E) standard.

i) If the sample is dyed and not transparent, then the water limit and test method ISO 12937 shall apply.

<u>Heavy fuel oil:</u>

The fuel specification "HFO 2" is based on the ISO 8217:2012(E) standard and covers the fuel categories ISO-F-RMA 10 – RMK 700. Additionally, the engine manufacturer has specified the fuel specification "HFO 1". This tighter specification is an alternative and by using a fuel fulfilling this specification, longer overhaul intervals of specific engine components are guaranteed (See the Engine Manual of a specific engine type).
For maximum fuel temperature before the engine, see the Installation Manual.

Characteristics	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Kinematic viscosity bef. inj. pumps [d]	mm^2/s [b]	20±4	20±4	-
Kinematic viscosity at 50 °C, max.	mm^2/s [b]	700,0	700,0	ISO 3104
Density at 15 °C, max.	kg/m^3	991,0 / 1010,0 [a]	991,0 / 1010,0 [a]	ISO 3675 or ISO 12185
CCAI, max. [f]	-	850	870	ISO 8217, Annex F
Sulphur, max. [c, g]	% m/m	Statutory requirements		ISO 8754 or ISO 14596
Flash point, min.	°C	60,0	60,0	ISO 2719
Hydrogen sulfide, max.	mg/kg	2,00	2,00	IP 570
Acid number, max.	mg KOH/g	2,5	2,5	ASTM D664
Total sediment aged, max.	% m/m	0,10	0,10	ISO 10307-2
Carbon residue, micro method, max.	% m/m	15,00	20,00	ISO 10370
Asphaltenes, max. [d]	% m/m	8,0	14,0	ASTM D3279
Pour point (upper), max. [e]	°C	30	30	ISO 3016
Water, max. Water bef. engine, max. [d]	% v/v	0,50 0,30	0,50 0,30	ISO 3733 or ASTM D6304-C [d]
Ash, max.	% m/m	0,050	0,150	ISO 6245 or LP1001 [d,i]
Vanadium, max. [g]	mg/kg	100	450	IP 501, IP 470 or ISO 14597
Sodium, max. [g] Sodium bef. engine, max. [d, g]	mg/kg	50 30	100 30	IP 501 or IP 470
Aluminium + Silicon, max. Aluminium + Silicon bef. engine, max.[d]	mg/kg	30 15	60 15	IP 501, IP 470 or ISO 10478
Used lubricating oil [h] - Calcium, max. - Zinc, max. - Phosphorus, max.	 mg/kg mg/kg mg/kg	 30 15 15	 30 15 15	 IP 501 or IP 470 IP 501 or IP 470 IP 501 or IP 500

a) *Max. 1010 kg/m^3 at 15 °C, provided the fuel treatment system can reduce water and solids (sediment, sodium, aluminium, silicon) before engine to the specified levels.*
b) *1 mm^2/s = 1 cSt.*
c) *The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.*
d) *Additional properties specified by the engine manufacturer, which are not included in the ISO 8217:2012(E) standard.*
e) *Purchasers shall ensure that this pour point is suitable for the equipment on board / at the plant, especially if the ship operates / plant is located in cold climates.*

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f) Straight run residues show CCAI values in the 770 to 840 range and are very good ignitors. Cracked residues delivered as bunkers may range from 840 to – in exceptional cases – above 900. Most bunkers remain in the max. 850 to 870 range at the moment. CCAI value cannot always be considered as an accurate tool to determine fuels' ignition properties, especially concerning fuels originating from modern and more complex refinery processes.

g) Sodium contributes to hot corrosion on exhaust valves when combined with high sulphur and vanadium contents. Sodium also strongly contributes to fouling of the exhaust gas turbine blading at high loads. The aggressiveness of the fuel depends on its proportions of sodium and vanadium, but also on the total amount of ash. Hot corrosion and deposit formation are, however, also influenced by other ash constituents. It is therefore difficult to set strict limits based only on the sodium and vanadium content of the fuel. Also a fuel with lower sodium and vanadium contents than specified above, can cause hot corrosion on engine components.

h) The fuel shall be free from used lubricating oil (ULO). A fuel shall be considered to contain ULO when either one of the following conditions is met:

- *Calcium > 30 mg/kg and zinc > 15 mg/kg OR*
- *Calcium > 30 mg/kg and phosphorus > 15 mg/kg*

i) The ashing temperatures can vary when different test methods are used having an influence on the test result.

Crude oil:

Note:
- The use of crude oils is judged case by case by the product group and if the fuel does not fulfil the specification below, a NSER is required.
- The use of crude oil is limited to the applications specifically adopted for the purpose.

Characteristics	Unit	Limit	Test method reference
Kinematic viscosity bef. inj. pumps, min. bef. inj. pumps, max.	mm^2/s [a)]	2,0 [e)] 24 [e)]	-
Kinematic viscosity at 50 °C, max.	mm^2/s [a)]	700,0	ISO 3104
Density at 15 °C, max.	kg/m^3	991,0 / 1010,0[b)]	ISO 3675 or ISO 12185
CCAI, max.	-	870	ISO 8217, Annex F
Water bef. engine, max.	% v/v	0,30	ISO 3733 or ASTM D 6304-C
Sulphur, max. [c)]	% m/m	4,50	ISO 8754 or ISO 14596
Ash, max.	% m/m	0,150	ISO 6245 or LP1001 [f)]
Vanadium, max.	mg/kg	450	IP 501, IP 470 or ISO 14597
Sodium, max. Sodium bef. engine. max.	mg/kg	100 30	IP 501 or IP 470
Aluminium + Silicon, max. Aluminium + Silicon bef. engine, max.	mg/kg	30 15	IP 501, IP 470 or ISO 10478
Calcium + Potassium + Magnesium bef. engine, max.	mg/kg	50	IP 501 or IP 500 for Ca and ISO 10478 for K and Mg
Carbon residue, micro method, max.	% m/m	20,00	ISO 10370
Asphaltenes, max.	% m/m	14,0	ASTM D3279
Reid vapour pressure, at 37.8 °C, max.	kPa	65	ASTM D323
Pour point (upper), max.	°C	30	ISO 3016

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Cloud point, max. or Cold filter plugging point, max.	°C	60 d)	ISO 3015 IP 309
Total sediment aged, max.	% m/m	0,10	ISO 10307-2
Hydrogen sulfide, max.	mg/kg	5,00	IP 399 or IP 570
Acid number, max.	mg KOH/g	3,0	ASTM D664

a) *1 mm²/s = 1 cSt.*

b) *Max. 1010 kg/m³ at 15 °C, provided the fuel treatment system can reduce water and solids (sediment, sodium, aluminium, silicon, calcium, potassium, magnesium) before engine to the specified levels.*

c) *Notwithstanding the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations.*

d) *Fuel temperature in the whole fuel system including storage tanks must be kept during stand-by, start-up and operation 10 – 15 °C above the cloud point in order to avoid crystallization and formation of solid waxy compounds (typically paraffins) causing blocking of fuel filters and small size orifices. Additionally, fuel viscosity sets a limit to cloud point so that fuel must not be heated above the temperature resulting in a lower viscosity before the injection pumps than specified above.*

e) *Viscosity of different crude oils varies a lot. The min. limit is meant for low viscous crude oils being comparable with distillate fuels. The max. limit is meant for high viscous crude oils being comparable with heavy fuels.*

f) *The ashing temperatures can vary when different test methods are used having an influence on the test result.*

02.5 Liquid biofuel specification

WÄRTSILÄ	© Wärtsilä Corporation Finland Technology	LIQUID BIOFUEL CHARACTERISTICS Wärtsilä 20, 32, 46, 34DF, 50DF						
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Subtitle	Product	Made	19.06.03		Page	Document No	Rev	
Performance Manual	W20, W32, W46, W34DF, W50DF	Appd.	26.08.03		1 (4)	4V92A1414	d	
Revised date: 13.03.2012			D-message No.: 217530					

FUEL CHARACTERISTICS

1. Maximum limits for liquid biofuel characteristics

The Wärtsilä® diesel engine types, W 20, W 32 and W 46 are designed and developed for continuous operation, without reduction in the rated output, on liquid biofuels with the properties included in the Table 1 and 2. The Wärtsilä® Dual Fuel engine types W 34DF and W 50DF are designed and developed for continuous operation, without reduction in rated output, on liquid biofuels included in the Table 1 and 2 when those are used as a main / back-up fuel. If a liquid biofuel is planned to be used as a pilot fuel in the W 34DF and W 50DF engine types, only the products fulfilling the specification included in the Table 2 are allowed to be used. Additionally, liquid biofuels typically have lower heating value than fossil fuels, why the capacity of fuel injection system must be checked case by case.

The specification included in the Table 1 is valid for straight liquid biofuels, like palm oil, coconut oil, copra oil, rapeseed oil, jatropha oil, fish oil, etc.

Renewable refined liquid biofuels, including both the 1st and the 2nd generation biofuels, which are manufactured by using transesterification or hydrogenation processes, can contain both vegetable and / or animal based feedstock and do normally show out very good physical and chemical properties. Biodiesel can be used provided that the specification included in the Table 2 is fulfilled. International standards ASTM D 6751-06 or EN 14214:2008 (E) are typically used for specifying biodiesel quality. Hydrotreated vegetable oils (HVO) have even a better quality than biodiesel, but the density is low and does not meet the EN 590 standard requirement. Thus due to low density and its influence on injected fuel volume the use of HVO has to be confirmed case by case.

Acceptable storage period for liquid biofuels can be significantly shorter than storage period specified for fossil fuels. Some biodiesel manufacturers are referring to max. one month storage period. After that acidity starts to increase leading to faster oxidation rate of the fuel.

Blending of different fuel qualities:

Straight liquid biofuels must not be mixed with fossil fuels, but have to be used as such.

Mixing of straight liquid biofuel and distillate fuel will increase the risk of cavitation in the fuel system, since required fuel temperature before engine is normally 80 - 90 °C. At this temperature light fractions of distillate fuel have already started to evaporate.

Mixing of straight liquid biofuel with heavy fuel will increase the risk of biofuel component polymerization leading to formation of gummy deposits, since the use of heavy fuel would require much higher operating temperature than the use of straight liquid biofuel, i.e. normally above 100 °C in order to achieve a proper fuel injection viscosity.

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Renewable biodiesel / HVO on the other hand can be mixed with fossil distillate fuel. Fossil fuel being used as a blending component has to fulfil Wärtsilä's distillate fuel specification found for different engine types from the documents: V92A0459, V92A0572, V92A0941, DAAE 064795, V92A1300 and DAAR000083.

Required fuel temperatures:

Straight liquid biofuel temperature before an engine is an utmost important operating parameter. Too low temperature will cause solidification of fatty acids leading to clogging of filters, plug formation in the fuel system and even to fuel injection equipment component breakdowns. Too high fuel temperature will increase the risk of polymerization, especially in the presence of oxygen.

When operating on straight liquid biofuels, it is utmost important to maintain a proper fuel temperature before fuel injection pumps in order to ensure safe operation of the engine and fuel system. The recommended fuel operating temperature depends on both the liquid biofuel quality and the degree of processing. E.g. many palm oil qualities do require ~ 80 – 90 °C fuel temperature in order to achieve an expected lifetime of fuel injection equipment and to avoid fuel filter clogging. Some refined palm oil qualities are however behaving acceptably also at lower, ~ 70 - 75 °C operating temperature. For other types of straight liquid biofuels the temperature requirement can be slightly different and must be confirmed before the use.

Biodiesel / HVO temperature before fuel injection pumps has to be 45 ±5 °C.

Table 1: Straight liquid biofuel specification

Property	**Unit**	**Limit**	**Test method reference**
Viscosity, max. Injection viscosity, min. Injection viscosity, max.	mm²/s @ 40°C mm²/s mm²/s	100 [1)] 1.8 – 2.8 [2)] 24	ISO 3104
Density, max.	kg/m³ @ 15 °C	991	ISO 3675 or 12185
Ignition properties [3)]			FIA test
Sulphur, max.	% m/m	0.05	ISO 8754
Total sediment existent, max.	% m/m	0.05	ISO 10307-1
Water, max. before engine	% v/v	0.20	ISO 3733
Micro carbon residue, max.	% m/m	0.50	ISO 10370
Ash, max.	% m/m	0.05	ISO 6245 / LP1001
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	15	ISO 10478
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719
Cloud point, max.	°C	[4)]	ISO 3015
Cold filter plugging point, max.	°C	[4)]	IP 309
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	1b	ASTM D130
Steel corrosion (24 / 72 hours @ 20, 60 and 120 °C), max.	Rating	No signs of Corrosion	LP 2902
Acid number, max.	mg KOH/g	15.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664

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Iodine number, max.	g iodine /100 g	120	ISO 3961
Synthetic polymers	% m/m	Report [5)]	LP 2401 ext. and LP 3402

1) *If injection viscosity of max. 24 cSt can not be achieved with an unheated fuel, fuel system has to be equipped with a heater (mm²/s = cSt).*
2) *Min. viscosity limit at engine inlet in running conditions; W20: 1,8 cSt, W32: 2,0 cSt, W46: 2,8 cSt, W34DF: 2,0 cSt, W50DF: 2,0 cSt for pilot fuel and 2,8 cSt for main / back-up fuel (mm²/s = cSt).*
3) *Ignition properties have to be equal to or better than the requirements for fossil fuels, i.e., CN min. 35 for LFO and CCAI max. 870 for HFO.*
4) *Cloud point and cold filter plugging point have to be at least 10 °C below fuel injection temperature.*
5) *Biofuels originating from food industry can contain synthetic polymers, like e.g. styrene, propene and ethylene used in packing material. Such compounds can cause filter clogging and shall thus not be present in biofuels.*

Table 2: Biodiesel specification based on EN 14214:2008 standard

Property	**Unit**	**Limit**	**Test method reference**
Viscosity, min. - max. Injection viscosity, min.	mm²/s @ 40°C mm²/s	3,50 – 5,00 1,8 – 2,8 [1)]	EN ISO 3104
Density, min. - max.	kg/m³ @ 15	860 – 900	EN ISO 3675 / 12185
Cetane number, min.	-	51,0	EN ISO 5165
Sulphur content, max.	mg/kg	10,0	EN ISO 20846 / 20884
Sulphated ash content, max.	% m/m	0,02	ISO 3987
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	500	EN ISO 12937
Carbon residue (on 10% distillation residue), max.	% m/m	0.30	EN ISO 10370
Phosphorus content, max.	mg/kg	4,0	EN 14107
Group I metals (Na+K) content, max.	mg/kg	5,0	EN 14108 / 14109 / 14538
Group II metals (Ca+Mg) content, max.	mg/kg	5,0	EN 14538
Flash point, min.	°C	101	EN ISO 2719A / 3679
Cold filter plugging point, max. (climate dependent requirement)	°C	-44 -> +5 [2)]	EN 116
Oxidation stability @ 110 °C, min.	hrs	6,0	prEN 15751 / EN 14112
Copper strip corrosion (3 hrs @ 50 °C), max.	Rating	Class 1	EN ISO 2160
Acid value, max.	mg KOH/g	0,50	EN 14104
Iodine value, max.	g iodine/100 g	120	EN 14111
FAME content, min.	% m/m	96,5	EN 14103
Linolenic acid methyl ester, max.	% m/m	12,0	EN 14103
Polyunsaturated (≥ 4 double bonds) methyl esters, max.	% m/m	1	Test method under development
Methanol content, max.	% m/m	0,20	EN 14110
Monoglyceride content, max.	% m/m	0,80	EN 14105
Diglyceride content, max.	% m/m	0,20	EN 14105
Triglyceride content, max.	% m/m	0,20	EN 14105

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Free glycerol, max.	% m/m	0,02	EN 14105 / 14106
Total glycerol, max.	% m/m	0,25	EN 14105

1) *Min. limit at engine inlet in running conditions; W20: 1,8 cSt, W32: 2,0 cSt, W46: 2,8 cSt, W34DF: 2,0 cSt, W50DF: 2,0 cSt for pilot fuel & 2,8 cSt for main / back-up fuel (mm²/s = cSt).*
2) *Cold flow properties of renewable biodiesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system.*

02.6 Lubricating oil specification

WÄRTSILÄ	© Wärtsilä Finland Oy Finland	REQUIREMENTS & OIL QUALITY					
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Subtitle	*Product*	*Made*		05.09.97	*PAGE*	*DOCUMENT NO:*	*REV*
Instruction	Wärtsilä 32 Wärtsilä 32GD	*Checked*		05.09.97	*1(4)*	4V92A0645	*p*
		Approved		05.09.97			
Revision Made	23.10.2013	*Revision Checked*	24.10.2013	*Revision Approved*	24.10.2013	*D-MESSAGE NO:* 241033	

1.2.5 REQUIREMENTS AND OIL QUALITY

SYSTEM OIL REQUIREMENTS AND QUALITY FOR WÄRTSILÄ 32 AND WÄRTSILÄ 32GD ENGINES

Viscosity
Viscosity class SAE 40

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	Fuel S content, [% m/m]
A	ASTM D 975-01 BS MA 100: 1996 CIMAC 2003 ISO 8217: 2012(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	10 - 30	< 0,4
B	ASTM D 975-01 BS MA 100: 1996 CIMAC 2003 ISO 8217: 2012(E)	GRADE NO. 1-D, 2-D, 4-D DMX, DMA, DMB DX, DA, DB ISO-F-DMX - DMB	15 - 30	0,4 – 2,0
C	ASTM D 975-01, ASTM D 396-04, BS MA 100: 1996 CIMAC 2003 ISO 8217: 2012(E)	GRADE NO. 4-D GRADE NO. 5-6 DMC, RMA10-RMK55 DC, A30-K700 RMA 10-RMK 700	30 - 55	≤ 4,5
D	CRUDE OIL (CRO)		30 - 55	≤ 4,5
F	LIQUID BIO FUEL (LBF)		10 - 20	≤ 0,05
G	NATURAL GAS *)		10 - 55	~ 0

*) For Wärtsilä 32GD. Required BN depends on pilot / back-up fuel quality.

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.

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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.

In heavy fuel operation BN 30 lubricants are recommended to be used only in special cases, like e.g. 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.

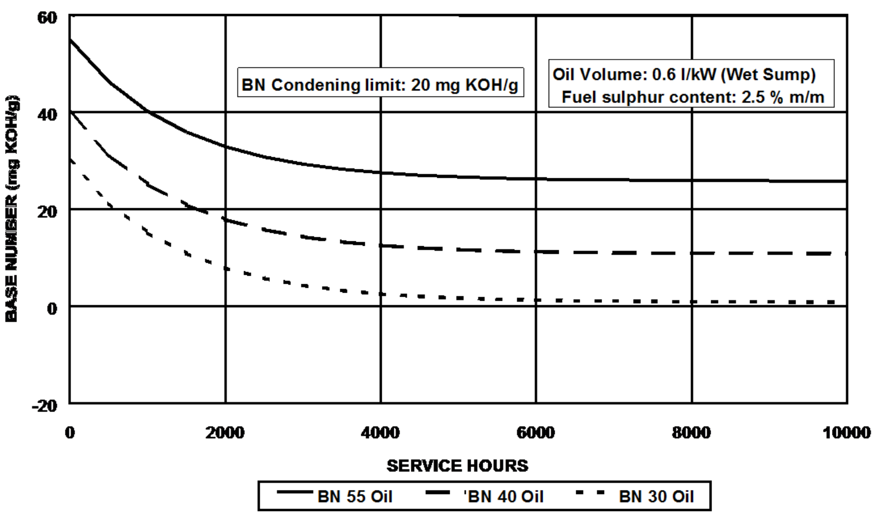
BN 30 oils are also a recommended alternative when operating on crude oil having low sulphur content. Though crude oils many times have low sulphur content, they can contain other acid compounds and thus an adequate alkali reserve is important. With crude oils having higher sulphur content BN 40 – 55 lubricating oils should be used.

If both distillate fuel and residual fuel are used in turn 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.

In the Wärtsilä 32GD engine type lubricating oil BN shall be chosen according to pilot / back-up fuel quality. If only distillate fuel is used as pilot / back-up fuel, lubricating oils with BN of 10 – 20 shall be used. If heavy fuel or crude oil is used as pilot / back-up fuel, lubricating oils with BN of min. 30 shall be used. Optimum BN level depends on engine's lubricating oil consumption, sulphur content of liquid fuels and the lengths of the periods operated on different fuel qualities.

The intervals between lubricating oil changes may be extended by adding oil frequently (even 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.



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Additives
The oils shall 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 shall 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.

CONDEMNING LIMITS FOR USED LUBRICATING OIL

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 or % m/m	max. 0,30	ASTM D 95 or D 6304C
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 Flash Point, COC	°C °C	min. 170 min. 190	ASTM D 93 ASTM D 92

CHANGE OF LUBRICATING OIL BRAND

Top-up with another lubricating oil brand than being filled to the system is not allowed, except if the both two lubricating oils originate from the same manufacturer. E.g. if company A's BN 40 oil is filled into the oil system and top-up with same Company A's BN 50 oil is desired, that can be done provided that both products are based on same base oils and additive technology. Otherwise the lubricating oil system has to be drained and then filled with another brand by following the procedure described here below.

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.

VALIDATED LUBRICATING OIL QUALITIES FOR WÄRTSILÄ 32 AND WÄRTSILÄ 32GD ENGINES

Should a non-validated lubricating oil be used during the engine warranty period, and there exist no agreement with the engine manufacturer about testing, the engine guarantee does not hold.

WÄRTSILÄ 32: OPERATION ON DISTILLATE FUEL OR LIQUID BIO FUEL

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. Lubricating oils having fresh oil BN below 15 can be used only if fuel sulphur content is below 0,4 % m/m. Also BN 30 lubricating oils included in Table 3 can be used on distillate fuel operation, though not preferred in the first place.

WÄRTSILÄ 32GD: OPERATION ON NATURAL GAS OR DISTILLATE FUEL AS MAIN FUEL AND DISTILLATE FUEL AS PILOT FUEL

If distillate fuel is used as pilot / back-up fuel in the Wärtsilä 32GD engine, lubricating oils with BN of 10 – 20 shall be used. Note that the use of liquid bio fuels (LBF) is not released for Wärtsilä 32GD.

Table 1.

Validated system oils - fuel categories A, B, F and G, recommended in the first place when operating on distillate fuel or liquid bio fuel and when distillate fuel in Wärtsilä 32GD is used as a pilot fuel:

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
BP	**Energol HPDX 40**	**SAE 40**	**12**	**A,B,F,G**
	Energol DS3-154	**SAE 40**	**15**	**A,B,F,G**
	Energol IC-HFX 204	**SAE 40**	**20**	**A,B,F,G**
Castrol	**HLX 40**	**SAE 40**	**12**	**A,B,F,G**
	MHP 154	**SAE 40**	**15**	**A,B,F,G**
	Seamax Extra 40	**SAE 40**	**15**	**A,B,F,G**
	TLX Plus 204	**SAE 40**	**20**	**A,B,F,G**

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Chevron (Texaco + Caltex)	**Delo 1000 Marine 40 Taro 12 XD 40 Taro 20 DP 40 Taro 20 DP 40X**	**SAE 40 SAE 40 SAE 40 SAE 40**	**12 12 20 20**	**A,B,F,G A,B,F,G A,B,F,G A,B,F,G**
SUPPLIER	**BRAND NAME**	**VISCOSITY**	**BN**	**FUEL CATEG.**
Conqord Oil	**Q8 Marine D 1000 SAE 40**	**SAE 40**	**12**	**A,B,F,G**
ENI S.p.A.	**Cladium 140 S**	**SAE 40**	**14**	**A,B,F,G**
ExxonMobil	**Delvac 1640 Mobilgard ADL 40 Mobilgard 412 Mobilgard 1 SHC**	**SAE 40 SAE 40 SAE 40 SAE 40**	**12 12 15 15**	**A,B,F,G A,B,F,G A,B,F,G A,B,F,G**
Indian Oil Corporation	**Servo Marine 1040 Servo Marine 2040**	**SAE 40 SAE 40**	**10 20**	**A,B,F,G A,B,F,G**
Petrobras	**Marbrax CCD-415 Marbrax CCD-420**	**SAE 40 SAE 40**	**15 20**	**A,B,F,G A,B,F,G**
Shell	**Gadinia Oil 40**	**SAE 40**	**12**	**A,B,F,G**
Statoil	**MarWay 1040**	**SAE 40**	**10,6**	**A,B,F,G**
Total / Lubmarine	**Disola M 4015 Disola M 4020 Caprano M 40**	**SAE 40 SAE 40 SAE 40**	**14 20 14**	**A,B,F,G A,B,F,G A,B,F,G**

WÄRTSILÄ 32: OPERATION ON HEAVY FUEL OR CRUDE OIL

Modern trunk piston diesel engines are stressing lubricating oil heavily e.g. due to 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 these facts it is essential to use only lubricating oils with modern additive technologies having good compatibility between fuel and lubricating oil.

WÄRTSILÄ 32GD: OPERATION ON NATURAL GAS, HEAVY FUEL OR CRUDE OIL AS MAIN FUEL AND HEAVY FUEL OR CRUDE AS PILOT FUEL

If heavy fuel or crude oil is used as pilot / back-up fuel even only occasionally in the Wärtsilä 32GD engine, lubricating oils with BN of 30 – 55 shall be used.

<u>Table 2.</u>

Validated system oils - fuel categories C, D and G, included in the Table 2 are recommended in the first place when operating Wärtsilä 32 engine on heavy fuel and or 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. The oils included in the Table 2 or 3 shall also be used in the Wärtsilä 32GD engine if heavy fuel or crude oil is used as pilot / back-up fuel.

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
Aegean Lubricants Co.	Alfamar 440 Alfamar 450 Alfamar 455 Alfamar GII 440 Alfamar GII 450 Alfamar GII 455	SAE 40 SAE 40 SAE 40 SAE 40 SAE 40 SAE 40	40 50 55 40 50 55	C,D,G C,D,G C,D,G C,D,G C,D,G C,D,G
BP	Energol IC-HFX 404 Energol IC-HFX 504	SAE 40 SAE 40	40 50	C,D,G C,D,G
SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
Castrol	TLX Plus 404 TLX Plus 504 TLX Plus 554	SAE 40 SAE 40 SAE 40	40 50 55	C,D,G C,D,G C,D,G
Cepsa	Troncoil 4040 PLUS Troncoil 5040 PLUS Larus 4040 Larus 5040	SAE 40 SAE 40 SAE 40 SAE 40	40 50 40 50	C,D,G C,D,G C,D,G C,D,G
Chevron (Texaco + Caltex)	Taro 40 XL 40 Taro 50 XL 40 Taro 40 XL 40X Taro 50 XL 40X	SAE 40 SAE 40 SAE 40 SAE 40	40 50 40 50	C,D,G C,D,G C,D,G C,D,G
Chinese Petroleum Corporation	Marilube Oil W 404 Marilube Oil W 504	SAE 40 SAE 40	40 50	C,D,G C,D,G
ENI S.p.A.	Cladium 400 S SAE 40 Cladium 500 S SAE 40 Cladium 550 S SAE 40	SAE 40 SAE 40 SAE 40	40 50 55	C,D,G C,D,G C,D,G
ENOC	Strata MSD 440 Strata MSD 450 Strata MSD 455 EPPCO Bahri MSD 440 EPPCO Bahri MSD 450 EPPCO Bahri MSD 455	SAE 40 SAE 40 SAE 40 SAE 40 SAE 40 SAE 40	40 50 55 40 50 55	C,D,G C,D,G C,D,G C,D,G C,D,G C,D,G
ExxonMobil	Mobilgard M 440 Mobilgard M50	SAE 40 SAE 40	40 50	C,D,G C,D,G
Fuchs	Titan PSW 40 SAE 40 Titan PSW 55 SAE 40	SAE 40 SAE 40	40 55	C,D,G C,D,G
Gulf Oil International	Gulfgen Supreme 440 Gulfgen Supreme 455	SAE 40 SAE 40	40 55	C,D,G C,D,G
Gulf Oil Marine / Sealub Alliance	GulfSea Power 4040 GulfSea Power 4055	SAE 40 SAE 40	40 55	C,D,G C,D,G
Indian Oil Corporation	Servo Marine K-4040 Servo Marine K-5040 Servo Marine K-5540	SAE 40 SAE 40 SAE 40	40 50 55	C,D,G C,D,G C,D,G
JX Nippon Oil & Energy Corporation	Marine T404 Marine T504	SAE 40 SAE 40	40 50	C,D,G C,D,G

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Lukoil	**Navigo TPEO 40/40** **Navigo TPEO 50/40** **Navigo TPEO 55/40**	**SAE 40** **SAE 40** **SAE 40**	**40** **50** **55**	**C,D,G** **C,D,G** **C,D,G**
Morris Lubricants	**Aquamor 140MD** **Aquamor 150MD**	**SAE 40** **SAE 40**	**40** **50**	**C,D,G** **C,D,G**
Pertamina	**Martron 440** **Martron 450** **Medripal 440** **Medripal 450** **Salyx 440** **Salyx 450**	**SAE 40** **SAE 40** **SAE 40** **SAE 40** **SAE 40** **SAE 40**	**40** **50** **40** **50** **40** **50**	**C,D,G** **C,D,G** **C,D,G** **C,D,G** **C,D,G** **C,D,G**
Petrobras	**Marbrax CCD-440** **Marbrax CCD-450**	**SAE 40** **SAE 40**	**40** **50**	**C,D,G** **C,D,G**
SUPPLIER	**BRAND NAME**	**VISCOSITY**	**BN**	**FUEL CATEG.**
Petron	**Petromar XC 4040** **Petromar XC 5540** **Petromar HF 4040** **Petromar HF 5040** **Petromar HF 5540**	**SAE 40** **SAE 40** **SAE 40** **SAE 40** **SAE 40**	**40** **55** **40** **50** **55**	**C,D,G** **C,D,G** **C,D,G** **C,D,G** **C,D,G**
Petronas International Lubricants	**Disrol 400 SAE 40** **Disrol 500 SAE 40** **MAEO 4040** **MAEO 4050**	**SAE 40** **SAE 40** **SAE 40** **SAE 40**	**40** **50** **40** **50**	**C,D,G** **C,D,G** **C,D,G** **C,D,G**
Repsol YPF	**Neptuno W NT 4000 SAE 40** **Neptuno W NT 5500 SAE 40**	**SAE 40** **SAE 40**	**40** **55**	**C,D,G** **C,D,G**
Saudi Arabian Lubricating Oil Company (Petrolube)	**Petromin Petropower 3-40** **Petromin Petropower 4-40** **Petromin Petroshield 3-40** **Petromin Petroshield 4-40**	**SAE 40** **SAE 40** **SAE 40** **SAE 40**	**40** **55** **40** **55**	**C,D,G** **C,D,G** **C,D,G** **C,D,G**
Shell	**Argina X 40** **Argina XL 40** **Argina XX 40**	**SAE 40** **SAE 40** **SAE 40**	**40** **50** **55**	**C,D,G** **C,D,G** **C,D,G**
Sinopec	**TPEO 4040** **TPEO 4050**	**SAE 40** **SAE 40**	**40** **50**	**C,D,G** **C,D,G**
SK Lubricants	**Supermar 40TP40** **Supermar 50TP40**	**SAE 40** **SAE 40**	**40** **50**	**C,D,G** **C,D,G**
Total / Lubmarine	**Aurelia TI 4040** **Aurelia TI 4055**	**SAE 40** **SAE 40**	**40** **55**	**C,D,G** **C,D,G**

Table 3.

Validated system oils - fuel categories A, B, C, D and G. Lubricating oils with BN 30 included in the Table 3 are designed to be used when operating Wärtsilä 32 engine on crude oil with low sulphur content (<1,0 % m/m). Further, on heavy fuelled installations BN 30 lubricants have eventually a positive influence on cleanliness of the SCR catalyst. However, due to low lubricating oil consumption oil change intervals with BN 30 lubricating oils will be shorter than with higher BN lubricating oils. Lubricating oils included in Table 3 can also be used in the Wärtsilä 32GD engine, if low sulphur heavy fuel or crude oil is used as a pilot / back-up fuel.

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SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
Aegean Lubricants Co.	Alfamar 430 Alfamar GII 430	SAE 40 SAE 40	30 30	A,B,C,D,G A,B,C,D,G
BP	Energol IC-HFX 304	SAE 40	30	A,B,C,D,G
Castrol	TLX Plus 304	SAE 40	30	A,B,C,D,G
Cepsa	Troncoil 3040 PLUS Larus 3040	SAE 40 SAE 40	30 30	A,B,C,D,G A,B,C,D,G
Chevron (Texaco + Caltex)	Taro 30 DP 40 Taro 30 DP 40X	SAE 40 SAE 40	30 30	A,B,C,D,G A,B,C,D,G
Chinese Petroleum Corporation	Marilube Oil W 304	SAE 40	30	A,B,C,D,G
ENI S.p.A.	Cladium 300 S SAE 40	SAE 40	30	A,B,C,D,G
SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
ENOC	Strata MSD 430 EPPCO Bahri MSD 430	SAE 40 SAE 40	30 30	A,B,C,D,G A,B,C,D,G
ExxonMobil	Mobilgard M 430	SAE 40	30	A,B,C,D,G
Fuchs	Titan PSW 30 SAE 40	SAE 40	30	A,B,C,D,G
Gulf Oil International	Gulfgen Supreme 430	SAE 40	30	A,B,C,D,G
Gulf Oil Marine / Sealub Alliance	GulfSea Power 4030	SAE 40	30	A,B,C,D,G
Indian Oil Corporation	Servo Marine K-3040	SAE 40	30	A,B,C,D,G
JX Nippon Oil & Energy Corp.	Marine T304	SAE 40	30	A,B,C,D,G
Lukoil	Navigo TPEO 30/40	SAE 40	30	A,B,C,D,G
Morris Lubricants	Aquamor 130MD	SAE 40	30	A,B,C,D,G
Pertamina	Martron 430 Medripal 430 Salyx 430	SAE 40 SAE 40 SAE 40	30 30 30	A,B,C,D,G A,B,C,D,G A,B,C,D,G
Petrobras	Marbrax CCD-430	SAE 40	30	A,B,C,D,G
Petron	Petromar XC 3040 Petromar HF 3040	SAE 40 SAE 40	30 30	A,B,C,D,G A,B,C,D,G
Petronas International Lubricants	Disrol 300 SAE 40	SAE 40	30	A,B,C,D,G
Saudi Arabian Lubricating Oil Company (Petrolube)	Petromin Petropower 2-40 Petromin Petroshield 2-40	SAE 40 SAE 40	30 30	A,B,C,D,G A,B,C,D,G
Shell	Argina T 40	SAE 40	30	A,B,C,D,G
Sinopec	TPEO 4030	SAE 40	30	A,B,C,D,G
SK Lubricants	Supermar 30TP40	SAE 40	30	A,B,C,D,G
Total / Lubmarine	Aurelia TI 4030	SAE 40	30	A,B,C,D,G

Before using a lubricating oil not listed in Tables 1-3, the engine manufacturer must be contacted. Lubricating oils that are not validated have to be tested according to engine manufacturer's procedures.

Lubricating oil companies listed above along with other possible manufacturers and distributors undertake all responsibility for the performance of their validated lubricating oils in service to the exclusion of any liability of any Wärtsilä company belonging to Wärtsilä group. Further, they shall indemnify, compensate and hold harmless Wärtsilä and companies belonging to Wärtsilä group from and against any claims, damages and losses caused by the lubricating oils in question.

LUBRICATING OILS FOR ENGINE TURNING DEVICE

Based on the turning device manufacturer's instructions EP-gear oils having viscosity of 414 - 506 cSt at 40 °C = ISO VG 460 are normally considered as suitable lubricating oils for turning device. The following products are fulfilling the requirements:

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)	Meropa 460	460	31,2	97
ENI S.p.A.	Blasia 320	300	23,0	95
ExxonMobil	Mobilgear 600 XP 460	460	30,6	96
Fuchs	Renolin CLP 460	460	30,4	95
Shell	Omala S2 G 460	460	30,8	97
Total / Lubmarine	Carter EP 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

02.7 Cooling water specification

WÄRTSILÄ	© Wärtsilä Corporation Finland Technology	RAW WATER QUALITY AND VALIDATED COOLING WATER ADDITIVES AND TREATMENT SYSTEMS					
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Subtitle	Product	Made	09.10.1998		Page	Document No	Rev
Instruction	20, 26, 32, 38, 46, 46F, 64, 34SG, 50SG, 20DF 32DF, 34DF, 50DF	Appd.	12.10.1998		1 (5)	4V92A0765	i
Revised date: 22.05.2012			.		D-message No.: 220019		

RAW WATER QUALITY AND VALIDATED COOLING WATER ADDITIVES AND TREATMENT SYSTEMS

FOR WÄRTSILÄ® VASA 32/32LN, WÄRTSILÄ® 20, WÄRTSILÄ® 26, WÄRTSILÄ® 32, WÄRTSILÄ® 38, WÄRTSILÄ® 46, WÄRTSILÄ® 46F, WÄRTSILÄ® 64, WÄRTSILÄ® 20DF, WÄRTSILÄ® 32DF, WÄRTSILÄ® 34DF, WÄRTSILÄ® 50DF, WÄRTSILÄ® 34SG AND WÄRTSILÄ® 50SG ENGINE TYPES

RAW WATER QUALITY

Raw water quality to be used in the closed cooling water circuits of engines has to meet the following specification.

Property	Unit	Limit	Test method reference
pH [1)]	-	6,5 – 8,5	ASTM D 1287 or D 1293
Hardness	°dH	max. 10	ASTM D 1126
Chlorides [1)]	mg/l	max. 80	ASTM D 512 or D 4327
Sulphates	mg/l	max. 150	ASTM D 516 or D 4327

Use of raw water produced with an evaporator as well as a good quality tap water will normally ensure that an acceptable raw water quality requirement is fulfilled, but e.g. sea water and rain water are unsuitable raw water qualities.

1) If a Reverse Osmosis (RO) process is used, min. limit for pH is 6,0 based on the RO process operational principle. The use of water originating from RO process further presumes that a max. content of 80 mg/l for chloride content is achieved.

VALIDATED COOLING WATER ADDITIVES

Manufacturer	Additive name	Additive type
Alm International S.A. 76 rue du Bourg Voisin 21140 Semur En Auxois France	Diaprosim RD11 (RD11M)	Sodium nitrite
S.A. Arteco N.V. Technologiepark-Zwijnaarde 2 B-9052 Ghent/Zwijnaarde, Belgium	Havoline XLi	Organic Acid Technology

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Manufacturer	Additive name	Additive type
Ashland Specialty Chemical Drew Industrial One Drew Plaza Boonton, NJ 07005 United States	Drewgard 4109	Sodium nitrite + borate
Ashland Specialty Chemical Drew Marine One Drew Plaza Boonton, NJ 07005 United States	DEWT-NC powder Liquidewt Maxigard	Sodium nitrite + borate Sodium nitrite + borate Sodium nitrite + borate
Chevron Global Lubricants 6101 Bollinger Canyon Road San Ramon, CA 94583 United States	Havoline XLi	Organic Acid Technology
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	Sodium nitrite + borate Sodium nitrite + borate
Korves Oy Seenintie 8 40320 Jyväskylä Finland	Pekar J	Organic Acid Technology
Kuwait Petroleum (Danmark) AS Hummetoftveij 49 DK-2830 Virum Denmark	Q8 Corrosion Inhibitor Long-Life	Organic Acid Technology
Marine Care B.V. Mozartlaan 3 3144 NA Maasssluis The Netherlands	Caretreat 2 Diesel	Sodium nitrite + borate
Maritech AB PO Box 143 S-29122 Kristianstad, Sweden	Marisol CW	Sodium nitrite + borate
Nalco Chemical Company One Nalco Centre Naperville, Illinois 60566-1024 United States	Trac 102 (ex-Nalcool 2000)	Sodium nitrite + borate
Suomen KL-Lämpö Oy Keisarinviitta 22 33960, Pirkkala Finland	Korrostop KV	Sodium molybdate

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Manufacturer	Additive name	Additive type
Total Diamant B, 16, rue de la République 92922 Paris La Défense Cedex, France	WT Supra	Organic Acid Technology
Vecom Marine Alliance B.V. Mozartlaan 3 3144 AA Maassluis The Netherlands	Cool Treat NCLT (ex-Vecom CWT Diesel QC-2)	Sodium nitrite + borate
Wilhelmsen Chemicals AS P.O. Box 15 N-3141 Kjøpmannskjær Norway (ex. Unitor & Nalfleet)	Dieselguard NB Rocor NB liquid Cooltreat AL Engine Water Treatment 9-108 Nalcool 2000	Sodium nitrite + borate Sodium nitrite + borate Organic Acid Technology Sodium nitrite + borate Sodium nitrite + borate

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
Diaprosim RD11 (RD11M)	5 kg	1250 ppm as NO_2
Corrshield NT 4293 CorrShield NT 4200	10 litres 10 litres	670 – 1000 ppm as NO_2 670 – 1000 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
Pekar J	20 litres	30 ppm as Mo
Q8 Corrosion Inhibitor Long-Life	50 – 100 litres	1.8 – 3.7 Brix° of active compounds measured with a supplier's refractometer
Caretreat 2 Diesel	6 - 10 litres	1500 – 2500 ppm as NO_2
Maricol CW	6 – 9 litres	1000 – 1500 ppm as NO_2
TRAC102	32 – 48 litres	1000 - 1500 ppm as NO_2
Korrostop KV	20 – 25 litres	120 - 150 ppm as Mo
Havoline XLi	50 - 100 litres	1,8 – 3,7 Brix° of active compounds measured with a supplier's refractometer
WT Supra	50 - 100 litres	1,8 – 3,7 Brix° of active compounds measured with a supplier's refractometer
Dieselguard NB Rocor NB Liquid Cooltreat AL Engine Water Treatment 9-108 Nalcool 2000	2,0 – 4,8 kg 9,5 - 24 litres 50 – 100 litres 2,25 – 3,4 litres 32 - 48 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 refractometer 670 - 1000 ppm as NO_2 1000 - 1500 ppm as NO_2
Cool Treat NCLT (ex-Vecom CWT Diesel QC-2)	6 - 10 litres	1500 – 2500 ppm as NO_2

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Note 1: For many products the recommended minimum and maximum limits are listed in the table above. Since the amount of active corrosion inhibitors, especially nitrites, is decreasing during the service of engines, the engine manufacturer recommends to start the dosage from the upper level of indicated range.

Note 2: 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 3: 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 equals to 1.5 mg/l as $NaNO_2$.

Note 4: Nitrite based cooling water additives are not offering a good protection against corrosion for aluminium and its alloys and thus the use of such products can't recommended for cooling systems containing those construction materials.

VALIDATED COOLING WATER TREATMENT SYSTEMS

ENWAMATIC MWT

As an alternative to the validated cooling water additives, the Enwamatic MWT cooling water treatment system can also be used. The Enwamatic MWT protects the engine from corrosion without any chemicals. It acts as a side stream filtration and water treatment unit and includes the following functions: corrosion protection, scale control, filtration, control of bacterial growth and air separation. The raw water quality requirements are the same as specified when cooling water additives are used. More information can be found from the document DAAF017522.

The Enwamatic MWT can be a sensible alternative for the installations in which environmentally friendly solutions are appreciated.

The installation, operation and maintenance instructions of the manufacturer shall always be followed. The contact information can be found in the table below.

Manufacturer	Treatment system
Enwa AS PO Box 257 Forus N-4066 Stavanger, Norway	Enwamatic MWT

USE OF GLYCOL

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, additionally an approved cooling water additive must always be used. All approved cooling water additives are compatible with glycol.

Ready-to-use mixtures containing both glycol and corrosion inhibitors are not allowed to use, since those are normally designed to be used as strong (30 –) 50% / 50% mixtures. However, in Wärtsilä engines normally a much lower glycol amount is adequate to protect the cooling water system against freezing. But when decreasing the glycol amount, simultaneously also the concentration of corrosion inhibitors will decrease to too low level resulting in an increased risk of corrosion.

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The amount of glycol in closed cooling water system shall always be minimized since heat transfer of water containing glycol has deteriorated significantly. The engine may therefore be subject to additional output derating when using glycol in the cooling water, see document DAAE062266 for more information.

There are commercially available two types glycol qualities, monopropylene glycol (MPG) and monoethyleneglycol (MEG). So called industrial qualities of both glycol types can be used, but MPG is considered to be a more environmental alternative.

03. Start, Stop and Operation

03.1 Turning of crankshaft

v3

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

03.1.1 Electrically-driven turning device

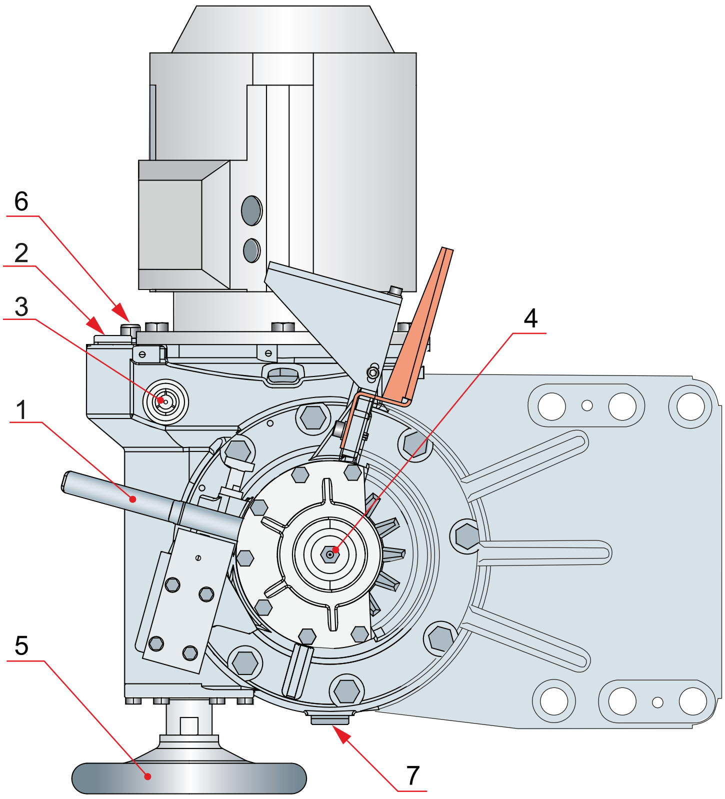
v7

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 of the flywheel is about 0.6 RPM.

The engaging and disengaging of the turning gear is accomplished by means of a lever and locking device. 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 if the turning gear is engaged. For more information see starting air system.

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



1 Lever
2 Filling hole
3 Gauge glass
4 Grease nipple
5 Hand wheel
6 Vent hole
7 Drain hole

Fig 03-1 Electrically-driven turning device

03.2 Start

v3

1. Remote start
2. Local start
3. Emergency start (solenoid valve)
4. Emergency start (starting valve)

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, the LT and HT water circuits, are in running order (correct pressures, circulating water preheated and pre-circulated sufficiently to heat the engine)
- the oil level in the governor is correct
- the starting air pressure exceeds 15 bar
- the starting air system is drained of condensate
- the drain pipe of the air cooler casing is open, no leakage
- stop lever is in work position
- prelubricating oil pump is running and pressure is over 0.3 bar
- turning device is disengaged
- indicator valves are closed
- the automation system indicates ready for start

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

NOTE

Never leave the engine running when covers are removed.

03.2.1 Local start

v5

Procedure

1 **Start the prelubricating oil pump to obtain a lubricating oil pressure over 0.3 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 **It is recommended to rotate the crankshaft two revolutions by using the turning device with the indicator valves open. This eliminates the risk of water locks.**

4 **Disengage the turning gear from the flywheel (yellow ball knob).**

5 **Check start blocking on the LDU.**

Remove blocking and return to the main page.

6 **Check that the automation system indicates ready for start.**

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

8 **Check that the local/remote switch is in local position.**

9 **Push the start button.**

If the engine does not start after the starting sequence, the reason should be checked.

10 **Check that the automation system indicates that the engine is running and that the running parameters are normal.**

NOTE

The starting air supply should be open when the engine is running, otherwise the pneumatic stop may not work.

03.2.2 Remote and automatic start v2

See installation-specific instructions.

03.2.3 Emergency start v3

In emergency situations, the engine can also be start manually by pushing the button on the starting solenoid or main starting valve.

03.3 Stop

03.3.1 Shutting down engine manually v5

Procedure

1 **Idle the engine for a minute before stopping.**

2 **Stop the engine by moving the stop lever into stop position or by pressing the stop button (LCP).**

The slowing-down period offers a good opportunity to detect possible disturbing sounds.

3 **Pre-lubricating oil pump should be operated for 90 minutes. after stop.**

03.3.2 Engine manual stop v4

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. Also make sure that the starting air shut-off valve located before main starting valve is closed and the starting air line drained. 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.

Use of pre-lubricating oil pump on a stopped engine: See installation specific instructions.

Blow the engine through open indicator valves and start the engine at least once in a week to check everything is in order.

03.4 Operation at low load and idling v5

Engine idling

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

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

If the engine has been idling for more than 5 minutes, high load running (minimum 70%) must 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
Low load operation	10–20% of rated power
Maximum time:	30 hours

When the maximum low load time has been accumulated, the engine must be operated at a minimum load of 70% for the duration of 60 minutes to clean up the engine.

03.5 Normal operation supervision v4

When a alarm is activated, all necessary measures must be taken immediately to return the engine to normal operating conditions. Waiting for the engine to shutdown automatically may damage the engine.

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

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 (indicated by 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!

For more information on low load operation and idling, see chapter 03 *03.4*.

03.5.1 Every second day or after every 50 running hours v3

Procedure

1 **Read all temperatures and pressures as well as the load of the engine.**

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

The charge air temperature should, in principle, be as low as possible, but not so low that condensation occurs, see Fig *Fig 03-2*.

2 **Check pressure drop over the lubricating oil filter.**

Too large of a pressure drop indicates clogged candles, which results in reduced oil filtration when the bypass valve is open. Reduced oil filtration results in increased wear. Change the candles.

3 **Check the oil level in the oil sump/oil tank.**

Estimate the appearance and consistency of the oil. A simple measure 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.

4 **Check the ventilation (de-aeration) of the engine cooling water system.**

Check that the leakage from the telltale hole of the HT-water- and the LT-water pump is normal (slight).

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

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

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

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

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

Example

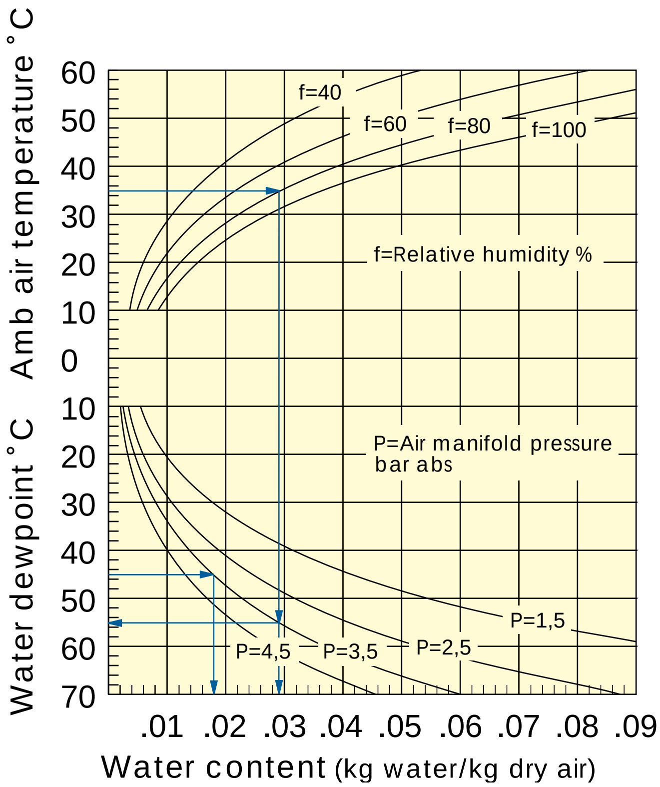


Fig 03-2 Condensation in charge air coolers

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 about 3.5 bar (ambient pressure + air manifold pressure), the dew point will be 55°C (from diagram). If the air temperature in the air manifold is only 45°C, the air can only contain 0.018 kg/kg (from diagram). The difference, 0.011 kg/kg (0.029-0.018), will appear as condensed water.

03.5.2 Other maintenance v2

To avoid malfunction of the engine a regular maintenance must be carried out, see Chapter *04*.

03.5.3 When performing maintenance work v4

Procedure

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 are of limited value ("go - no go" only).
- lubricating oil changes
- cleaning of centrifugal lubricating oil filter, see*section 18.9*
- cleaning or changing of lubricating oil automatic filter candles, see *section 18.8*

- change of parts in connection with maintenance according to Chapter *04*.

03.6 Operating standby engines

v6

In standby mode, the engine is ready to accept load instantly according to the engine loading guidelines.

- **Keep the prelubrication pump running.**
  Lubricating oil temperature must be in accordance with the engine loading guidelines.
- **Circulate the high-temperature (HT) cooling water and keep its temperature in accordance with the engine loading guidelines.**
  Cooling water must flow in a reversed way through the engine for an optimum engine preheating result.
- **Keep the low-temperature (LT) water temperature of the charge air cooler at a minimum of 10°C.**
- **Start the engine once a week to check that everything is in order.**
  Use only light fuel oil (LFO) if the engine is in standby mode for a longer period. If heavy fuel oil (HFO) is used, the engine fuel system must be running.

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

03.7.1 Manual start

v4

Procedure

1 **Check**
- the lubricating oil level
- the cooling water level in the expansion tank
- the 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 there is a 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, check that the starting air distributing pipe is not heated at any cylinder (leakage from the starting valve in the cylinder head).**

03.8 Start after overhaul

v5

Procedure

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

2 **With the speed governor control lever being in max. position and the stop lever in work position, press the stop button in the Local Control Panel (LCP).**

Check that all injection pump racks move to a value less than 2 mm.

3 **If the injection pumps, the adjusting screws in the guide blocks, or the camshaft or its driving mechanism have been touched, check the injection timing.**

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

- the oil cooler
- the charge air cooler

5 **Check/adjust the valve clearances.**

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

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

7 **Start the priming pump.**

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

NOTE

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

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

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

9 **See the instructions in Section *03.2* and *section 03.7.1* when starting.**

03.9 Supervising operation after overhaul v3

Procedure

1 **At the first start, listen carefully for any abnormal sounds.**

CAUTION

If anything is suspected, stop the engine immediately.

2 **Let the engine idle at normal speed for maximum five minutes.**

3 **Check the condition with stopped engine.**

a **Stop the engine.**

b **Measure the temperatures of the main and big end bearings with the laser.**

c **Especially check the temperature of all other bearings which have been opened.**

d **Check the free movement of the connecting rods.**

e **If everything is in order, restart the engine.**

f If required, carry out a program run.

4 **Check for possible leakage (oil, water, air or fuel system).**

NOTE

Check for leakage in the fuel lines, injection pumps and injection valves. Observe the increase of leakage from the clean leak oil line!

NOTE

Check the starting air distribution pipe, that it is not heated at any cylinder. The temperature rise on the distribution lines will indicate, that the exhaust gases can enter the starting air system.

WARNING

Leaking in starting valve may cause an explosion!

5 **Check the condition of the running engine.**

a Check:

- Pressures and temperatures
- Automatic alarm and stop devices
- Pressure drop over the lubricating oil automatic filter
- Drain holes are open in the CAC
- Oil level in the oil sump/oil tank
- Ventilation (de-aerating) of the engine cooling water system
- Quantity of leak fuel
- Holes in the coolers
- Content of additives in the cooling water
- Take full operating data
- Cylinder pressures
- Crankcase pressure.

NOTE

The used oil need to fulfill the specifications.

b Listen for any abnormal sounds.

6 **Vent the fuel filters and water systems.**

03.10 Running-in

v6

Prerequisites

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

Procedure

1 **After changing piston rings, pistons or cylinder liners, and after honing cylinder liners, follow the 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.

CAUTION
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.

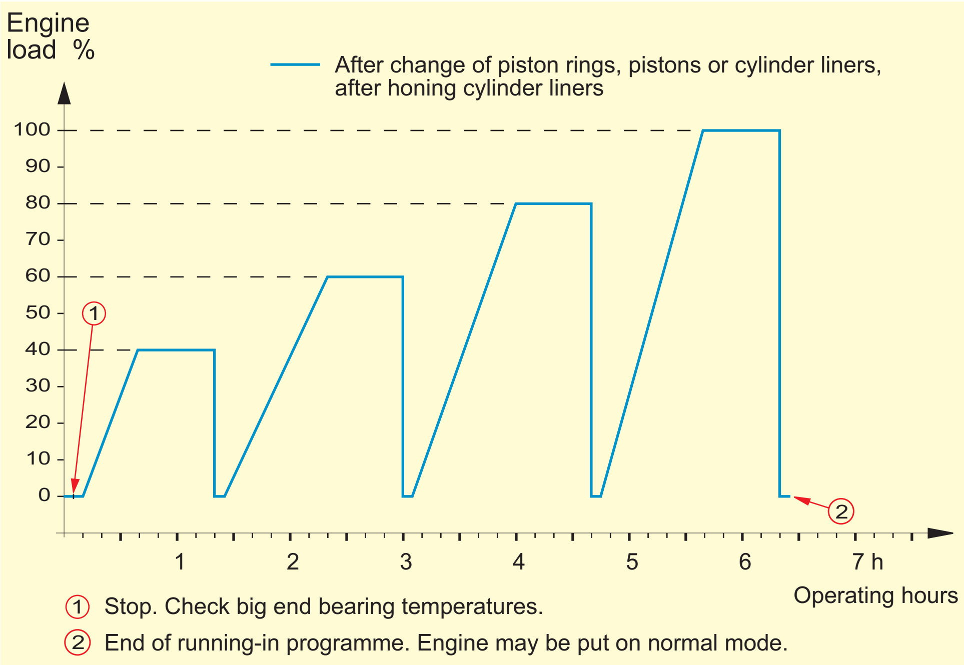


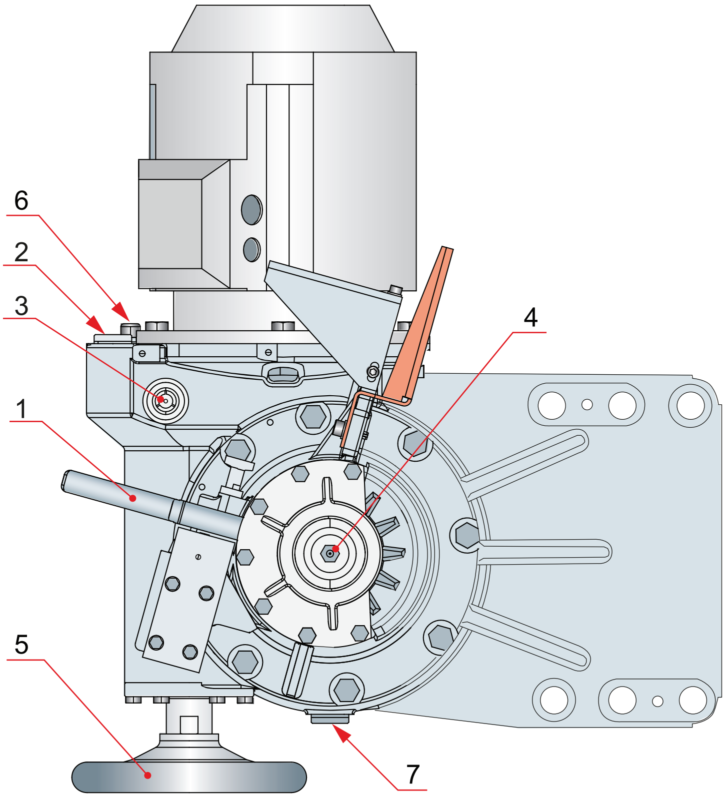
Fig 03-3 Running-in programme

03.11 Maintaining the turning device v6

The turning device maintenance includes changing the gearbox lubricating oil and greasing the drive shaft.

Change the lubricating oil once during the first year of operation. After that, the oil should be changed according to the maintenance schedule.

Grease the drive shaft according to the maintenance schedule. To grease the drive shaft, use the grease nipple in the end of the drive shaft. For a list of lubricating oils for the engine turning device, see the lubricating oil specification in Chapter 02.



1 Lever
2 Filling hole
3 Gauge glass
4 Grease nipple
5 Hand wheel
6 Vent hole
7 Drain hole

Fig 03-4 Electrically-driven turning device

Procedure

1 **Ensure that the vent hole (6) is open.**

2 **Drain the old oil, preferably while warm, through the drain hole (7).**

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

4 **Fill the gear box with oil.**
Fill the oil through the filling hole (2), until the oil level reaches the level gauge glass (3).

> **NOTE**
>
> Keep the working environment clean.

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

6 **Check the oil level and fill if necessary.**

7 **Grease the drive shaft through the grease nipple (4).**

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04. Maintenance schedule

The actual operating conditions, and above all the quality of the fuel used, 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 are for guidance only. However, do not exceed them during the warranty period.

If there are any indications that the maintenance procedure is required in advance of the recommended time period, perform the suggested maintenance. Additionally, if inspection or observation reveals that a part shows wear or use beyond the prescribed tolerances, renew the part immediately.

See the instruction books of the turbocharger and the governor, separate instructions for additional equipment and chapter 03 Start, Stop and Operation.

NOTE

Before performing any maintenance work, carefully read the sections Risk reduction, Welding precautions and Hazardous substances in chapter 00.

- Before starting any procedure, carefully read the corresponding instructions in this manual.
- During all maintenance work, observe the utmost cleanliness and order.
- Before dismantling, check that all systems concerned have been drained or the pressure has been released. After dismantling, immediately cover the 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 provided with an identification mark stating the cylinder number, mark the new part with the same number on the same spot. Enter every exchange in the engine log and state the reason clearly.

CAUTION

Do not mark bearings as it may cause damage.

- Always renew all gaskets, sealing rings and O-rings during maintenance work.

NOTE

Do not lubricate the O-rings in the cooling water system with oil-based lubricants. Use soap or similar.

- After reassembling, check that all screws and nuts have been tightened and, if necessary, locked.

WARNING

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

WARNING
When overhauling the engine, to avoid accidental turning of the crankshaft, make absolutely sure that the generator breaker is secured and the gearbox is not engaged. Accidental turning of the crankshaft may cause engine damage or personal injury.

04.1 Average load and fuel quality

v4

The length of some maintenance intervals depends on the average operating load and the characteristics of the used fuel.

Average operating load and fuel type	
Average operating load	Below 75% of nominal engine output Above 75% of nominal engine output
Fuel type	HFO 1 = heavy fuel oil, normal quality HFO 2 = heavy fuel oil, below normal quality DO = diesel oil or light fuel oil

The fuel types HFO 1 and HFO 2 are defined in the fuel specification in Chapter 02.

04.2 Every second day, irrespective of the engine being in operation or not

v4

Every second day, irrespective of the engine being in operation or not		
Component	**Procedure**	**Section**
Automatic prelubrication	Check the operation on a stopped engine.	*03.2* *18.4*
Crankshaft	Marine engine: If the engine has not been running, turn the crankshaft into a new position.	*03.1*

04.3 Once a week, irrespective of the engine being in operation or not

v4

Once a week, irrespective of the engine being in operation or not		
Component	**Procedure**	**Section**
Start process	Test start (if the engine is on standby).	*03.2*

04.4 Interval: 50 operating hours

v12

Interval: 50 operating hours		
Component	**Procedure**	**Section**
Air coolers	Check the draining of the air coolers. Check that the drain pipe is open and check for any leakage.	15 *03.5.1*
Cooling water system	Check the water level in the cooling system. Check the water level in the expansion tank(s) and the static pressure in the engine cooling circuits.	*19.2*
Connecting rod	Check the tightening of the connecting rod nuts. Check the tightening of the connecting rod nuts after the first 50 operating hours on a new engine and, after overhaul, those nuts that have been loosened. Note! Pump to the stated pressure. Tighten, if possible. Do not loosen!	*11.2.6* *07.3*
Crankshaft	Check the tightening of the counterweight fastening nuts. Check the tightening of the counterweight fastening nuts after the first 50 operating hours on a new engine and, after overhaul, those nuts that have been loosened. Note! Pump to the stated pressure. Tighten, if possible. Do not loosen!	*07.3*
Gauges and indicators	Take readings. Read and record all temperatures and pressures together with the associated engine load. Use form number WV98V091.	*03.5.1*
Governor, actuator	Check the oil level in the governor. Check the oil level, and look for leaks.	*02.2* *22.4*
Fuel filter	Check the pressure drop. Replace the cartridges if the pressure difference indicator shows too high pressure drop. See the manufacturer's instructions.	*18*
Injection and fuel system	Check the fuel leakage quantity. Check the amount of fuel leakage from the injection pumps and nozzles.	*03.5.1* *17*
Injection pipes	Check the tightening of the injection pipe connections. Check the tightening of injection pipe connections on a hot engine after the first 50 operating hours on a new engine and, after overhaul, those connections that have been loosened.	*07.1* *16.3*
Lubricating oil filter	Check the pressure drop. Clean or change the filter candles if a high pressure drop is indicated.	*03.5.1* *18.8*
Lubricating oil sump	Check the oil level in the sump. Check the oil level with the dipstick and compensate for consumption.	*18.1*
Main bearings	Check the tightening of the main bearing nuts. Check the tightening of the main bearing nuts after the first 50 operating hours on a new engine and, after overhaul, those nuts that have been loosened. Note! Pump to the stated pressure. Tighten, if possible. Do not loosen!	*10.2.3* *07.3*
Multiduct	Check the tightening of the multiduct screws. Check the tightening of the multiduct screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. The engine must be at normal operating temperature.	*07.1*
Running-in filter	Remove the running-in filter. After the first 50 operating hours, remove the running-in filter, pump up the hydraulic jack, and tighten and secure the screws of the hydraulic jack. Maximum running hours with running-in filters is 100 hours.	
Turbocharger	Clean the compressor with water. Clean the compressor by injecting water.	15

Continued on next page

Interval: 50 operating hours		
Component	**Procedure**	**Section**
Valve mechanism	**Check the valve clearances.** Check the valve clearances in new and overhauled engines after the first 50 running hours.	*12.5* *06.1*

04.5 Interval: 100 operating hours

v5

Interval: 100 operating hours		
Component	**Procedure**	**Section**
Turbocharger	**Water cleaning of turbine (HFO).** Clean the turbine by injecting water, if the engine is operating on HFO, more often if necessary.	Chapter 15

04.6 Interval: 500 operating hours

v10

Interval: 500 operating hours		
Component	**Procedure**	**Section**
Air cooler(s)	**Clean the charge air cooler(s).** Check the charge air cooler pressure difference.	Chapter 15
Centrifugal filter	**Clean the centrifugal filter.** Clean more often, if necessary. Remember to open the valve before the filter after cleaning.	*18.9.1*
Control mechanism	**Maintain the control mechanism.** Check for free movement, clean and lubricate.	*22.2*
Cooling water	**Check the water quality.** Check the content of additives.	*19.6* *02.3*
Cylinder pressure	**Check the firing pressures.** Record the firing pressures of all cylinders.	*12.8* *03.5.3*
Injection pumps	**Wash the injection pumps running on heavy fuel.** Wash the injection pumps running on heavy fuel with a cleaning device. **Note!** If the injection pumps are dirty, clean them mechanically and open the drain holes before using the cleaning device.	*16.2*
Lubricating oil	**Take an oil sample.** In a new installation and after changing the lubricating oil brand, take oil samples for analysis. To ensure safe engine operation, frequent oil analysis at 500–1000 operating hours intervals (every six month if the engine is running less than 1000 h a year) are recommended also after the first year of operation. Change the 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, change the oil in connection with every piston overhaul or every fourth year (every sixth year if the engine is running less than 1000 h/year), whichever comes first.	*02.2* *18.1*
Turbocharger	**Water cleaning of turbine (LFO).** Clean the turbine by injecting water, if the engine is operating on LFO.	Chapter 15

04.7 Interval: 1000 operating hours

v13

Interval: 1000 operating hours		
Component	**Procedure**	**Section**
Air filter (on-built)	**Clean the turbocharger air filter.** Remove the filter(s), and clean them according to the manufacturer's instructions. Clean more often, if necessary.	15
Electrical fuel feed pump	**Regrease the electrical fuel feed pump.** Regrease the pump under running condition.	
Flexible coupling Geislinger (Oil filled)	**Change or check the coupling oil.** At the first interval, change the coupling oil. At the following (1000 h) intervals, check the oil level. See the manufacturer's instructions.	
Fuel filter	**Check the fuel oil filter.** Clean or replace the filter cartridges, if needed. Clean the wire gauze and filter housing. Replace the filter cartridges if they are broken or damaged. If the differential pressure indicator shows too high pressure drop, clean the filter cartridges (standard filter type) or replace them (paper cartridge type). See the manufacturer's instructions.	
Valves	**Check the valve condition.** Check that the inlet and exhaust valves move freely in their guides after the engine has been out of operation for a couple of hours. Check the valve clearances. Check the cylinder tightness (valves, piston rings) with a pneumatic test.	*12.5* *06.1* *12A*

04.8 Interval: 2000 operating hours

v17

Interval: 2000 operating hours		
Component	**Procedure**	**Section**
Air cooler(s)	**Check the water side of the charge air cooler(s).** During the first check and possible cleaning of the waterside, if the deposits are insignificant and the cooler is in good condition, subsequent intervals may be increased to 4000 running hours.	*15.4*
Automation	**Check the functioning of the safety and alarm system.** Replace faulty sensors. Check the functioning of the automatic stop devices.	*01.2* Chapter 23
Electro-pneumatic overspeed trip device	**Check the electro-pneumatic overspeed trip device.** Check the function and tripping speed.	*22.1* *06.1* Chapter 23
Flexible hoses	**Inspect the flexible hoses visually.** Renew the hoses, if necessary.	
Governor	**Change the oil in the governor.** Change the lubricating oil.	*02.2* *22.4*
Injection valves	**Inspect the injection valves.** Test the opening pressure. Dismantle and clean the 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.	*16.4*

Continued on next page

Interval: 2000 operating hours		
Component	**Procedure**	**Section**
Turning device	Regrease the drive shaft. Regrease the drive shaft when the turning device is connected and the engine stopped.	*03.11*

04.9 Interval: 4000 operating hours

v31

Interval: 4000 operating hours		
Component	**Procedure**	**Section**
Air cooler(s)	Clean the charge air cooler(s). Check the pressure difference over the charge air cooler (air side) by using a U-tube or pressure differential indicator. Clean and pressure test. Look carefully for corrosion. Check for possible leakage. Replace parts, if necessary.	Chapter 15
Automation	Check the connectors and cables. Check the mounting and connections. Verify the presence of contact lubricant and add, if necessary. Check the tightness of the connections. Check the condition of cables, wires and cable glands. Rectify, improve or replace the equipment, if necessary.	Chapter 23
Camshaft	Inspect the contact faces of the camshaft. Check the contact faces of the cams and tappet rollers. Check that the rollers rotate. Rotate the engine with the turning gear.	*14.1.3* *03.1*
Cooling water spaces	Inspect the HT water spaces. Remove the air venting pipe and the adapter plug on the multiduct. Inspect the water side of one duct. If the deposits are thicker than 1 mm, clean all the liners and the engine block water space. Improve the cooling water treatment.	Chapter 02 Chapter 10 Chapter 15 Chapter 19
Control mechanism	Check the control mechanism. Check for wear in all connecting links between the governor and all injection pumps.	*22.2*
Crankshaft	Check the crankshaft alignment. Check the alignment on a warm engine. Use form WV98V036.	*11.1.1*
	Check the thrust bearing clearance. Check the axial clearance.	*11.1.2* *06.2*
Exhaust manifold	Check the exhaust manifold for leaks. Check for leaks once a year. Replace parts, if necessary.	*20*
Flexible coupling Geislinger (Oil filled)	Change the coupling oil. See the manufacturer's instructions.	
Fuel system	Check and adjust the fuel system. Check the adjustment of the fuel system. Check for leakage. Replace parts, if necessary.	*17*
Injectors	Inspect the injection valves. Test the opening pressure. Dismantle and clean the nozzles. Check the effective needle lift. Check the springs. Check and change the push rod, if necessary. Replace the O-rings. Check the nozzle condition in a test pump. HFO: Replace the nozzle at 6000 operating hours. DO (LFO): Replace the nozzle at 8000 operating hours.	*16.4*

Continued on next page

Interval: 4000 operating hours		
Component	**Procedure**	**Section**
Lubricating oil cooler	**Check the lubricating oil cooler.** Check that the lubricating oil temperature before the engine is within normal operating values, see chapter 01. Check for leakage.	*18.6*
Starting fuel limiter	**Check the starting fuel limiter.** Check the function.	*22.1* 23

04.10 Interval: 8000 operating hours

v9

Interval: 8000 operating hours		
Component	**Procedure**	**Section**
Automation	Check the wiring condition inside the cabinets and boxes. Check for insulation wear, loose terminals and loose wires. Check for cable insulation wear, damage, loose cable glands, connectors, holders and loose grounding shields. Check for loose grounding straps and corrosion. Check the sensors, actuators, solenoids etc. for leakages and physical damages. Also check the signal or measurement where applicable. Check the condition of vibration dampers. Replace, if necessary. Verify correct readings on engine displays and meters. Check the electronic modules visually for damages. Rectify, improve or replace the equipment, if necessary. Check the sealing condition on cabinets and boxes.	Chapter 23
Flexible coupling	**Check the flexible coupling.** Check the flexible rubber elements visually according to the manufacturer's instructions. Dismantle, if necessary.	
Lubricating oil automatic filter	**Replace the lubricating oil filter candles.** Drain the filter housing. Clean the wire gauze. Replace the filter candles.	*18.8.1* *18.1*
Lubricating oil coolers	**Clean the lubricating oil cooler.** If the lubricating oil temperature before the engine is within normal operating values, the interval can be prolonged. Avoid opening the cooler unless necessary. Clean the lubricating oil cooler before the alarm limit is reached. Examine carefully for corrosion.	*18.6* *19.6*
Charge air shut-off valve	**Overhaul the charge air shut-off valve.** Replace worn parts. See the manufacturer's instructions.	Chapter 15
Wastegate	**Check the function of the air wastegate valve and actuator.** Replace the positioner pilot valve.	

04.11 Interval: 12,000 operating hours

v8

Interval: 12,000 operating hours		
Component	**Procedure**	**Section**
Flexible hoses	**Renew the hoses if they have not been changed during the last 12,000 operating hours.**	
Fuel system (Only V-engines)	**Replace the fuel feed pipes between the A-bank and B-bank.**	*17*

Continued on next page

Interval: 12,000 operating hours		
Component	**Procedure**	**Section**
Governor driving gear	Inspect the governor driving gear. Replace parts, if necessary.	*22.4* *06.2*
HT water pump	Inspect the HT water pump. Dismantle and check the pump. Replace the bearings, shaft seals and worn parts. Inspect the driving gear. For externally-mounted water pumps, see the supplier's operation and maintenance manual.	*19.7* *19.7.1* *06.2*
HT water thermostatic valve	Clean and inspect the HT water thermostatic valve. For externally-mounted thermostatic valves, see the supplier's operation and maintenance manual. Clean and check the thermostatic element, valve cone-casing and O-rings.	*19.8.1*
LT water pump	Inspect the LT water pump. Dismantle and check the pump. Replace the bearings, shaft seals and worn parts. Inspect the driving gear. For externally-mounted water pumps, see the supplier's operation and maintenance manual.	*19.7* *19.7.1* *06.2*
LT water thermostatic valve	Clean and inspect the LT water thermostatic valve. For externally-mounted thermostatic valves, see the supplier's operation and maintenance manual. Clean and check the thermostatic element, valve cone casing and O-rings.	
Lubricating oil pump	Inspect the lubricating oil pump. Replace parts, if necessary.	*18*
Lubricating oil pump driving gear	Inspect the lubricating oil pump driving gear. Replace parts, if necessary.	*18* *06.2*
Oil thermostatic valve	Clean and inspect the oil thermostatic valve. Clean and check the thermostatic element, valve cone casing and O-rings.	*18*
Prelubricating oil pump	Inspect the prelubricating oil pump. Dismantle and check the pump. Replace the shaft seal and worn parts. Replace the flexible coupling and the roller bearing for the electric motor.	*18*
Turbocharger ABB	Inspect, clean and replace the bearings if necessary. Clean the turbocharger mechanically. Inspect the nozzle ring, turbine diffuser/cover ring and the gas inlet/outlet casings. Replace the parts, if necessary. **Replace the bearings at 36,000 h, at the latest.** See the manufacturer's instructions.	Chapter 15

04.12 Interval: 12,000–16,000 operating hours

v6

Interval: 12,000–16,000 operating hours		
Component	**Procedure**	**Section**
Electro-pneumatic overspeed trip device	Overhaul the overspeed trip device cylinder on the injection pump. Replace worn parts. Replace the sealing and O-ring.	*22.6*
Injection pumps	Overhaul the injection pumps. Clean and inspect the injection pumps. Replace worn parts. Replace the erosion plugs.	*16.2.3*
Injection pump guide block	Overhaul the injection pump guide block. Check the tappets. Replace worn or damaged parts, if necessary.	*16.2*

04.13 Interval 12,000–24,000 operating hours

v9

This overhaul interval depends on the fuel characteristics and the average load level according to the table below.

Fuel	Overhaul interval (standard)	
	Average load > 75 %	Average load < 75 %
HFO 2	12,000	16,000
HFO 1	16,000	20,000
DO	20,000	24,000

Component	Procedure	Section
Connecting rods	Replace the big end bearings. Measure the big end bore. Use form number 3211V017.	*11.2.3* *06.2*
	Replace the connecting rod screws. Replace the connecting rod screws at every second piston overhaul at 12,000–16,000 h intervals and at every piston overhaul at intervals longer than 16,000 h.	*11.2*
	Replace the connecting rod shims. Replace the connecting rod shims at every second piston overhaul at 12,000–16,000 h intervals and at every piston overhaul at intervals longer than 16,000 h.	*11.2*
	Inspect the small end bearings. Inspect the small end bearings. Replace, if necessary.	*11.2.3* *06.2*
Cylinder heads	Overhaul the cylinder head. Dismantle and clean the underside, inlet and exhaust valves and ports. Inspect the cooling spaces and clean them, if necessary. Grind the valves. Inspect the valve rotators. Check the rocker arms. Replace the O-rings in the valve guides. Replace the O-rings at the bottom of the cylinder head screws at every overhaul.	*12.3* *12.2* *12.4* *12.3.1*
Cylinder liners	Inspect the cylinder liners. Measure the bore using form number 3210V018. If the wear limits are exceeded, replace the liner. Hone the liners. Renew the antipolishing ring.	*10.4.1* *06.2*
Lubricating oil	Change the lubricating oil. Change the oil in connection with every piston overhaul or every fourth year (every sixth year if the engine has been running for less than 1000 h/year), whichever comes first. Clean all oil spaces with a high-quality, fibre- and lint-free cloth.	*18.1* *02.2*
Pistons	Inspect the pistons. Dismantle the composite pistons to inspect the mating surfaces between the piston skirt and piston crown. Inspect and clean the oil spaces.	*11.2.3*
Piston, piston rings	Inspect the pistons and piston rings. Pull, inspect and clean. Check the height of the ring grooves (the height clearance of the rings). Use form number 3211V022. Check the support surfaces, use form number 3211V025. Check the retainer rings of the gudgeon pins. Replace the complete set of piston rings. Note the running-in programme.	*11.2.3* *06.2* *11.2* *03.10*
Starting valves	Check the starting valves. Check the starting valves in the cylinder head. Replace parts, if necessary.	*21.3*

04.14 Interval: 16,000 operating hours

v14

Interval: 16,000 operating hours		
Component	**Procedure**	**Section**
Camshaft driving gear	Inspect the intermediate gears. Replace parts, if necessary.	*13.1* *06.2*
Flexible coupling (Oil filled)	Check the flexible coupling. Dismantle and check the flexible coupling according to the manufacturer's recommendations.	
Fuel feed pump	Overhaul the fuel feed pump. Dismantle and check the pump. Replace worn parts. See the manufacturer's instructions.	
Booster servomotor for governor	Overhaul the booster servomotor. Replace worn parts. See the manufacturer's instructions.	
Governor drive	Check the governor drive bearing. Check the governor driving shaft bearing clearance in situ.	*22.4.1* *06.2*
Governor	Overhaul the governor. You can also send it to the engine manufacturer for overhaul.	
Hydraulic jack for main bearing caps	Check the function. Change the O-rings in the hydraulic jack at every second overhaul interval.	*10.2.1*
Turning device	Change the oil in the turning device. Regrease the drive shaft.	*02.2* *03.11*
Vibration damper Viscous type	Take an oil sample from the vibration damper. Take an oil sample for analysis.	*11.1*
Vibration damper Geislinger	Check the vibration damper. Dismantle and check the vibration damper at every 32,000 hours.	*11.1*

04.15 Interval: 16,000–20,000 operating hours

v4

The overhaul interval depends on the average load as follows:

Average load	Overhaul interval
Average load > 75 %	16,000
Average load < 75 %	20,000

Component	Procedure	Section
Camshaft	Inspect the camshaft bearings. Replace, if necessary.	*10.3.1* *06.2*
Crankshaft	Inspect the main bearings. Inspect one main bearing. If it is in bad condition, check all main bearings and change them, if necessary. Note! The type of bearing in use and do the inspection accordingly. Change the main bearings at every second overhaul interval.	*10.2.2* *06.2*
Valve mechanism	Check the valve mechanism parts. Check the tappets.	*14.1.3* *06.2*

04.16 Interval: 24,000 operating hours

v18

Interval: 24,000 operating hours		
Component	**Procedure**	**Section**
Automation and control system	Replace the drive electronics, such as coil drivers, fuel injection controls and actuator controls. Replace the electronics every tenth year, at the latest.	Chapter 23
	Replace the vibration dampers (rubber elements). Replace the rubber elements for components such as connection boxes, control modules, connection rails and main cabinet. Replace the vibration damper every fourth year, at the latest.	
Engine fastening bolts	Check the tightening of the engine fastening bolts. Re-tighten, if necessary.	*07.3.1*
Exhaust manifold	Check the expansion bellows. Replace, if necessary.	*20.1*
Flexible coupling (Oil supply from engine)	Check the flexible coupling. Dismantle and check the flexible coupling according to the manufacturer's recommendations.	
Main starting valve	Overhaul the main starting valve. Replace worn parts.	*21.1*
Starting air distributor	Overhaul the starting air distributor. Replace worn parts.	*21.2.1*

04.17 Interval: 48,000 operating hours

v6

Interval: 48,000 operating hours		
Component	**Procedure**	**Section**
Automation	Replace the measuring electronics. Replace the electronics every tenth year, at the latest.	Chapter 23
Camshaft driving gear	Replace the intermediate gear bearings. Replace other parts, if necessary.	*13.1* *06.2*
Crankshaft	Inspect the crankshaft. Inspect the crankshaft for wear.	*06.2*
Engine foundation	Check the flexible elements of the engine foundation. Replace, if necessary.	
Flexible coupling	Check the flexible coupling. Dismantle and check the flexible coupling according to the manufacturer's instructions. Replace the spring packs/inner star, if necessary.	
Turbocharger	Replace the rotor and rotating parts. The lifetime of the components depends on the operating conditions. See the manufacturer's instructions.	Chapter 15

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05. Maintenance tools

Maintenance of an engine requires some special tools. Some of these tools are supplied with the engine; others are available through our service stations.

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

The list presented in Spare Parts Catalogue has an comprehensive selection of tools for Wärtsilä engines.

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

Regarding maintenance tools for governor and turbocharger, we refer to lists in the special instructions enclosed with Instruction Manual.

05.1 Using of Spare Parts Catalogue v1

Procedure

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

2 **Check with list**
in Spare Parts Catalogue that all the maintenance tools are available.

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

05.2 Ordering maintenance tools v1

Procedure

1 **Find the part(s)**
that interests you in the Spare Parts Catalogue.

2 **Select the tools or parts required;**
note that tools which are part of standard deliveries are mentioned in the installation specific delivery list.

3 **Make notes of the specifications**
and other information as in the list above or in "Inquiry/Order List".

4 **Send the order**
to Wärtsilä Service Office, printed on the Inquiry/Order List. All commercial terms are stated in the Inquiry/Order List.

NOTE
All available tools are listed in the Spare Parts Catalogue; see also the installation specific tool lists. Some of the tools are only useable for certain cylinder numbers and only with certain engine mounting equipment.

Example

In order to make deliveries on time, please state spare parts number and name of part according to Spare Parts Catalogue. Also state engine type, specification- and engine-number, when ordering. These statements are found on the engine name plate.

When ordering special equipment or tool that is not included in Spare Parts Catalogue or Instruction Manual, please give manufacturer's type designation and serial number of the tool. If such indication is missing, describe the tool as clearly as possible and/or a picture should accompany the order.

Name of consignee and purchaser, their exact addresses as well as method of forwarding should be stated. **All orders given by telephone should be confirmed by email or letter.**

The tools required should be ordered directly from Wärtsilä. Adress and telephone numbers are given on title page of this manual.

A complete order of maintenance tools should include the following indications: (example)

Engine type	Wärtsilä 9L20
Specification number	173176
Engine number	PAAE035380
Tool number	832 004
Name of part	Lifting tool for cylinder head
Quantity	1
Consignee	Engineer A. Clipper
	M/S Brigitte
	C/O Seaforwarding
	Sea Port, Hull
Method of forwarding	Express air line
Purchaser	Shipowner Atlanta
	Head Square,
	Birmingham E.C.

06. Adjustments, Clearances and Wear Limits

06.1 Adjustments

v11

Valve timing

The engine is equipped with variable inlet closing (VIC) and has two different timings for inlet valve closing. Otherwise valve timing is fixed and cannot be changed for single cylinders.

Set values

- Valve clearances: inlet valves 0.4 mm, exhaust valves 0.8 mm
- Fuel delivery commencement: see factory test records
- Opening pressure of fuel injection valve: 600 bar

06.2 Clearances and wear limits (at 20°C)

v16

Part, measuring point		Nominal value (mm)	Wear limit (mm)
10	**Main bearing**		
	Main bearing clearance (also flywheel bearing)	0.225-0.346	
	Journal, diameter		339.93
	Journal, out of circularity		0.05
	Main bearing shell thickness, trimetal shells		–[1]
	Main bearing shell thickness, bimetal shells		7.35
	Assembled bearing bore		340.360
	Thrust bearing		
	Thrust bearing, axial clearance	0.37-0.57	0.80
	Thrust washer thickness		14.60
	Camshaft bearing piece (Ø 190 mm)		
	Camshaft bearing clearance	0.150-0.255	
	Assembled bearing bore		190.330
	Camshaft thrust bearing, axial clearance	0.350-0.600	0.9
	Camshaft bearing piece (Ø 230 mm)		
	Camshaft bearing clearance	0.160-0.269	
	Assembled bearing bore		230.350
	Camshaft thrust bearing, axial clearance	0.250-0.700	1.0
	Cylinder liner		
	Cylinder liner, diameter		top: 320.80 bottom: 320.30
	Cylinder liner, out of cylindricity at TDC		0.25

[1] Tri-metal bearings can be used until the overlay is partially worn off. See *Section 10.2.2 a*.

Part, measuring point		Nominal value (mm)	Wear limit (mm)
11	Big end bearing clearance	0.210-0.307	
	Crank pin, out of circularity		0.05
	Crank pin, diameter		309.93
	Big end bearing shell thickness		*Section 11.3.3*
	Big end bore		324.90 (min)
	Big end bore, ovality		0.15
	Small end bearing, see measurement record 3211V017		
	Bore diameter in piston		150.1
	Piston ring gap I (Clamped ø 320)	0.7-1.1	
	Piston ring gap II (Clamped ø 320)	1.3-1.6	
	Oil scraper ring gap (Clamped ø 320)	1.2-1.5	
	Piston ring groove height, groove I		8.50
	Piston ring groove height, groove II		8.50
	Piston ring groove height, groove III		8.30

Part, measuring point		Nominal value (mm)	Wear limit (mm)
12	Valve guide diameter assembled		24.25
	Valve stem diameter		23.90
	Valve stem clearance		00.30
	Valve seat radial deviation in relation to valve guide		0.1 (max)
	Inlet valve		
	Seat face minimum inner diameter “x”		87
	Seat angle	20.00-20.10	
	Edge thickness minimum diameter “Y”	10.6	10.1
	Burn-off maximum diameter “Z”		2.0
	Inlet valve seat ring		
	Seat face minimum outer diameter “x_1”		113
	Seat angle	19.70-19.90	
	Exhaust valve		
	Seat face minimum inner diameter “x”		82
	Seat angle	40.10-40.20	
	Edge thickness minimum diameter “Y”	8.8	7.8
	Burn-off maximum diameter “Z”		2.0
	Exhaust valve seat ring		
	Seat face minimum outer diameter “x_1” (3V12B0351)		110
	Seat face minimum outer diameter “x_1” (DAAF001529)		111
	Seat angle	39.95-40.05	

Part, measuring point		Nominal value (mm)	Wear limit (mm)
13	**Intermediate gear for camshaft drive (bearing diameter Ø 190 mm)**		
	Axial clearance	0.4-0.6	0.9
	Shaft diameter	189.97-190.00	
	Assembled bearing bore		190.30
	Camshaft driving gear backlash		
	Crankshaft gear wheel and large intermediate gear wheel	0.25-0.55	
	Small intermediate gear wheel and camshaft gear wheel	0.25-0.55	
13	**Intermediate gear for camshaft drive (bearing diameter Ø 230 mm)**		
	Axial clearance	0.35-0.55	0.9
	Shaft diameter	229.97-230.00	
	Assembled bearing bore, bi-metal bearing		230.31
	Assembled bearing bore, tri-metal bearing		–[1]
	Camshaft driving gear backlash		
	Crankshaft gear wheel and large intermediate gear wheel	0.33-0.76	
	Small intermediate gear wheel and camshaft gear wheel	0.33-0.66	

[1] Tri-metal bearings can be used until the overlay is partially worn off. See *Section 10.2.2 a*.

Part, measuring point		Nominal value (mm)	Wear limit (mm)
14	Valve tappet, diameter clearance	0.072-0.161	
	Bush diameter, bore		40.09
	Bearing clearance bush-tappet pin	0.059-0.091	
	Rocker arm bore		75.35
	Clearance rocker arm-shaft	0.01-0.075	
	Yoke bore diameter		30.1
	Yoke diameter clearance	0.065-0.103	

Part, measuring point		Nominal value (mm)	Wear limit (mm)
16	Nozzle needle lift, nozzles stamped before 04/99	0.68-0.72	0.77
	Nozzle needle lift, nozzles stamped 04/99 and later	0.83-0.87	0.92
	Injection pump tappet, distance (X) between the adjusting screw and the upper surface of the tappet housing at 6-mm prelift	74±0.05	
	Prelift of the tappet	6	
	Push rod wear		3.5
	Impact bush wear		

Part, measuring point		Nominal value (mm)	Wear limit (mm)
17	Fuel feed pump, backlash for driving gear, L32	0.26-0.61	
	Fuel feed pump, backlash for flexible coupling, L32	2	
	Base tangent length over three teeth, spanned, L32	62.027-61.939	

Part, measuring point		Nominal value (mm)	Wear limit (mm)
18	Main lubricating oil pump of screw type		
	Driving spindle, difference between spindle and housing diameter		0.40
	Idle spindle, difference between spindle and housing diameter		0.30
	Backlash for driving gear	0.30-0.60	
18	Main lubricating oil pump of gear type		
	Bearing clearance, L32	0.05-0.13	0.20
	Bearing clearance, V32	0.09-0.21	0.30
	Assembled bearing bush diameter, L32	54.95-55.01	
	Assembled bearing bush diameter, V32	89.97-90.06	
	Axial clearance, L32	0.20-0.40	
	Axial clearance, V32	0.35-0.55	
	Backlash for pump driving gear, L32	0.24-0.62	
	Backlash for pump driving gear, V32	0.27-0.75	
18	Prelubricating oil pump		
	Bearing clearance, L32	0.3-0.124	
	Bearing clearance, V32	0.02-0.17	
	Axial clearance, L32	0.07-0.15	
	Axial clearance, V32	0.10-0.30	
18	Centrifugal filter		
	Difference between bottom spindle and bearing diameter	0.039-0.071	0.28
	Bottom bearing nominal diameter	28.000-28.021	
	Rotor top spindle diameter	19.967-19.980	
	Rotor bottom spindle diameter	27.950-27.961	

Part, measuring point		Nominal value (mm)	Wear limit (mm)
19	Water pump		
	Backlash for driving gear, L32	0.35-0.72	
	Backlash for driving gear, V32	0.30-0.63	

Part, measuring point		Nominal value (mm)	Wear limit (mm)
22	Bearing clearance for governor driving shaft	0.08-0.121	00.15
	Axial clearance	0.2-0.5	
	Backlash for driving gear	0.10-0.40	
	Control shaft bearing clearance	0.010-0.126	0.25

07. Tightening Torques and Use of Hydraulic Tools

07.1 Tightening torques for screws and nuts

v5

NOTE

See section *07.3* 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 the torque stated in the tables. A loose screw connection might cause serious damages/personal 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.

CAUTION

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

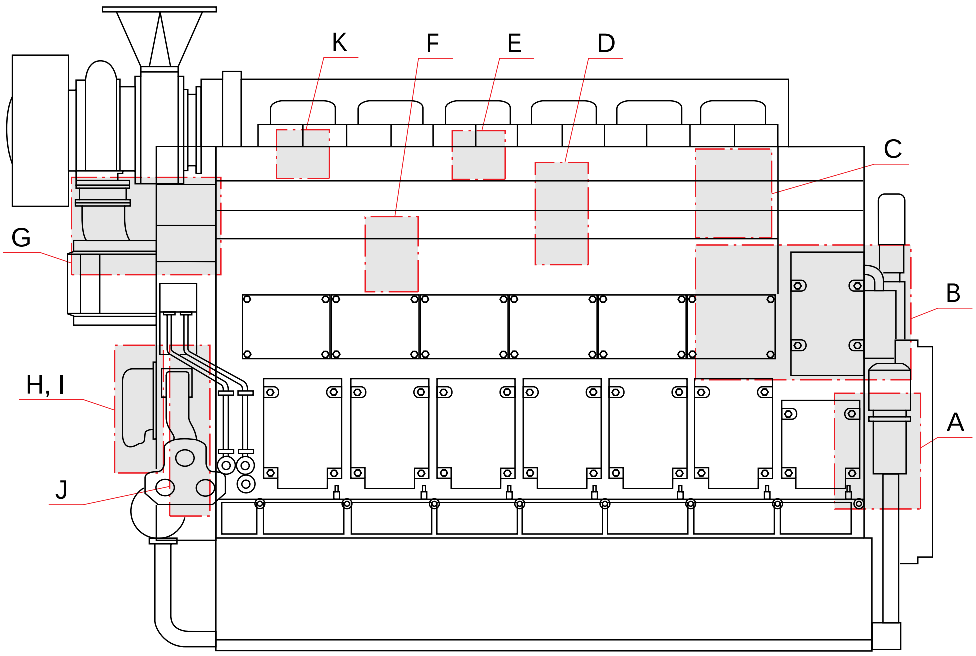


Fig 07-1 Tightening torques

The use of torque measuring tools is recommended also when tightening other screws and nuts. The following torques apply to screws of the strength class 8.8, 10.9 and 12.9 treated with lubricating oil or Loctite.

Table 07-1 Tightening torques (strength classes 8.8, 10.9 and 12.9)

Screw dimension	Width across flats of hexagon screws (mm)	Key width of hexagon socket head screws (mm)	Torque	
			(Nm)	(kpm)
Strength class 8.8				
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
Strength class 10.9				
M8	13	6	37	3.8
M10	17	8	75	7.7
M12	19	10	130	13.3
M16	24	14	310	31.6
M20	30	17	620	63.2
M24	36	19	1060	108
Strength class 12.9				
M8	13	6	43	4.4
M10	17	8	87	8.9
M12	19	10	150	15.3
M16	24	14	370	37.7
M20	30	17	720	73.4
M24	36	19	1240	126.5

07.1.1 A: Crankshaft and flywheel

v4

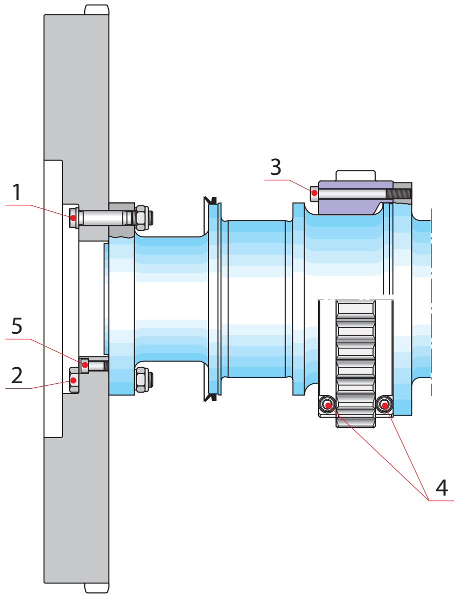
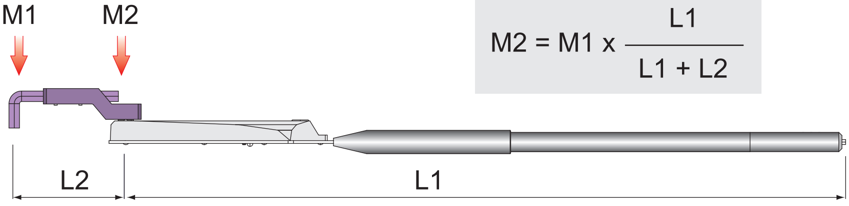


Fig 07-2

Pos.	Screw connection	Torque (Nm)
1.	Flywheel bolts, fitted bolts, M30	600±30
2.	Flywheel elongation bolts, M30	1200±60
3.	Split gear on crankshaft, M20*190, 10.9 screws(M_2)	550±20
	Lubricate threads with engine lubricating oil.	
4.	Split gear on crankshaft, M20*120, 12.9 screws (M_2).	600±30
	Torque wrench setting (M_1) with tool combination.	532
	Lubricate threads with engine lubricating oil.	
5.	Flywheel mounting bolts, M20	390±20

NOTE

Torque wrench settings must be recalculated if any other tool combination than *Fig 07-3* is used for the split gear wheel screws.



$$M2 = M1 \times \frac{L1}{L1 + L2}$$

Fig 07-3 Torque calculation

07.1.2 B: Intermediate gear and camshaft

v6

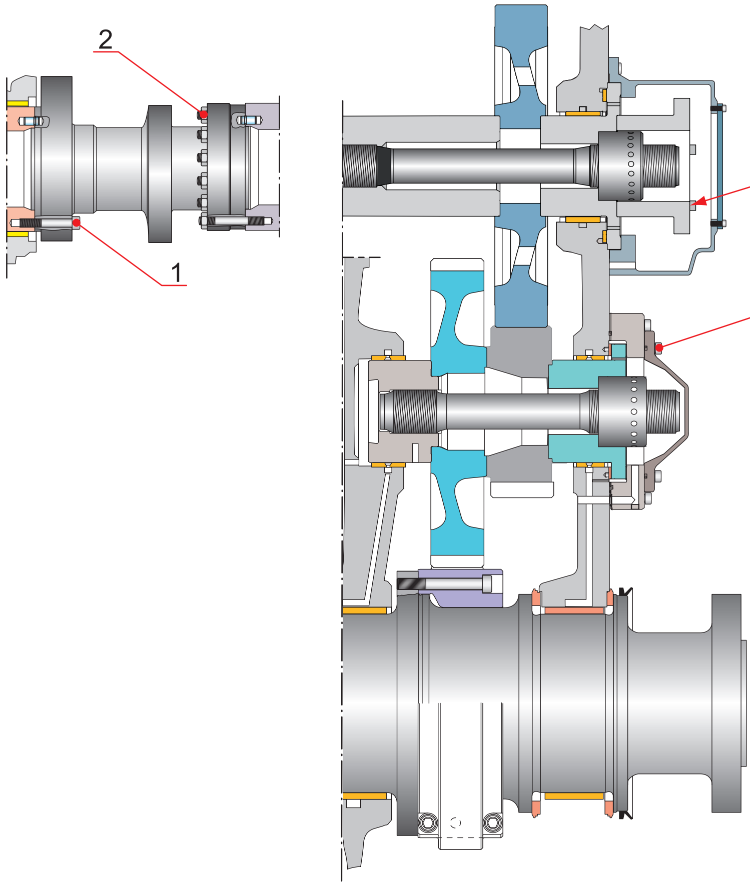


Fig 07-4 Camshaft driving gear

Pos.	Screw connection	Torque (Nm)
1.	Camshaft flange connection screws. Apply Loctite 243 on the threads.	290±10
2.	Camshaft flange connection nuts.	290±10
3.	Camshaft hexagon screws Apply Loctite 243 on the threads.	108 ±10
4.	Flange fastening screws.	80±5

NOTE

See chapter 13 Camshaft Driving Gear.

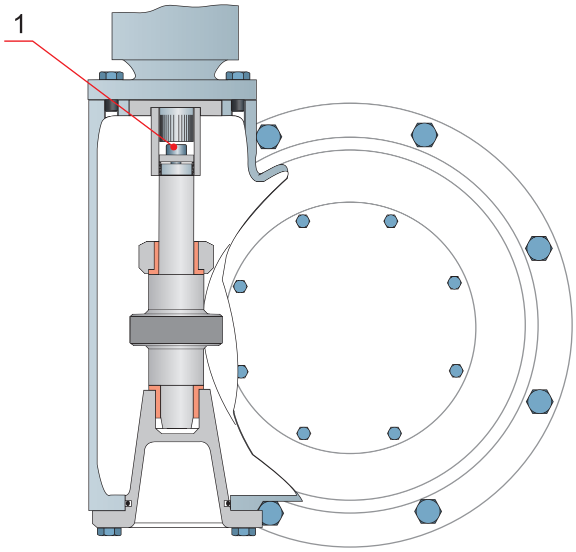


Fig 07-5 B: Governor drive

Pos.	Screw connection	Torque (Nm)
1.	Governor drive shaft screw Apply Loctite 2701 on the threads.	80±5

07.1.3 C: Cylinder head

v7

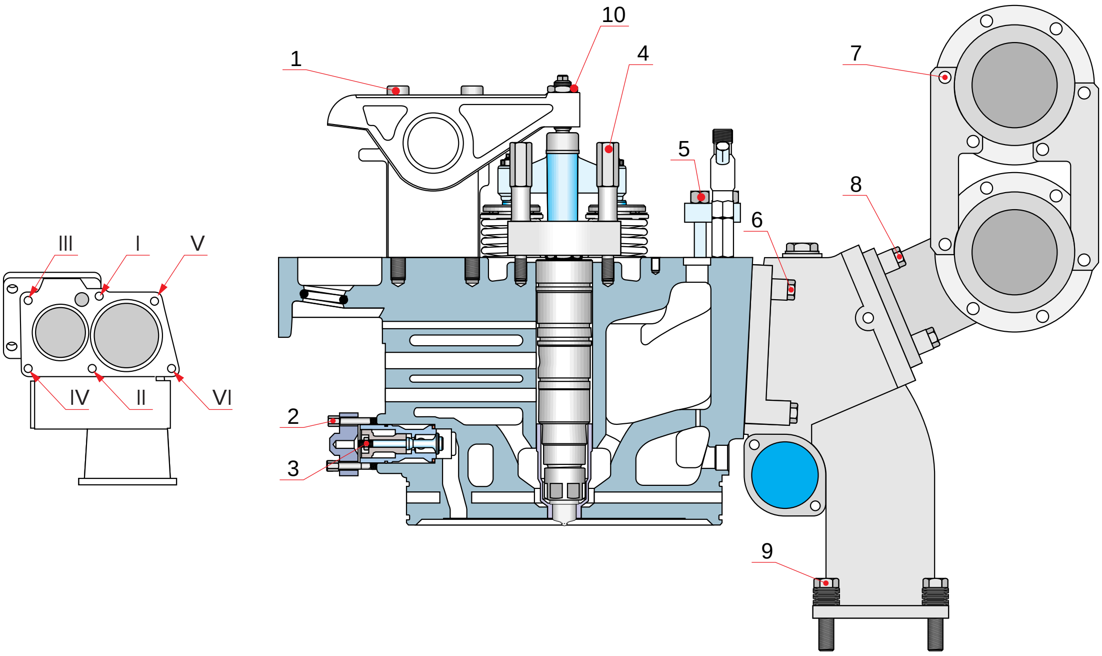


Fig 07-6 Cylinder head

Pos.	Screw connection	Torque (Nm)
1.	Rocker arm console, fastening screws	400±20
2.	Starting valve fastening screws	55±5
3.	Nut for starting valve spindle	35±5
4.	Nuts for injection valve	125±10
5.	Safety valve in cylinder head, fastening nuts	85±5
6.	Fastening screws for cylinder head/multiduct Note the tightening order. Re-check the screws' tightening torque. Apply Nova lube or similar heat resistant grease to threads.	195±10
7.	Fastening screws for flange connections	79±5
8.	Fastening screws for multiduct/exhaust manifold	195±10
9.	Fastening screws for multiduct/engine block	195±10
10.	Fastening screws for rocker arms	300

07.1.4 D: Injection pump

v7

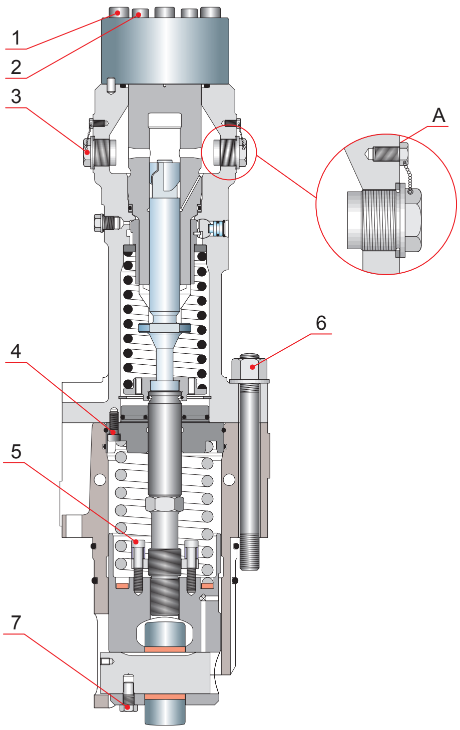
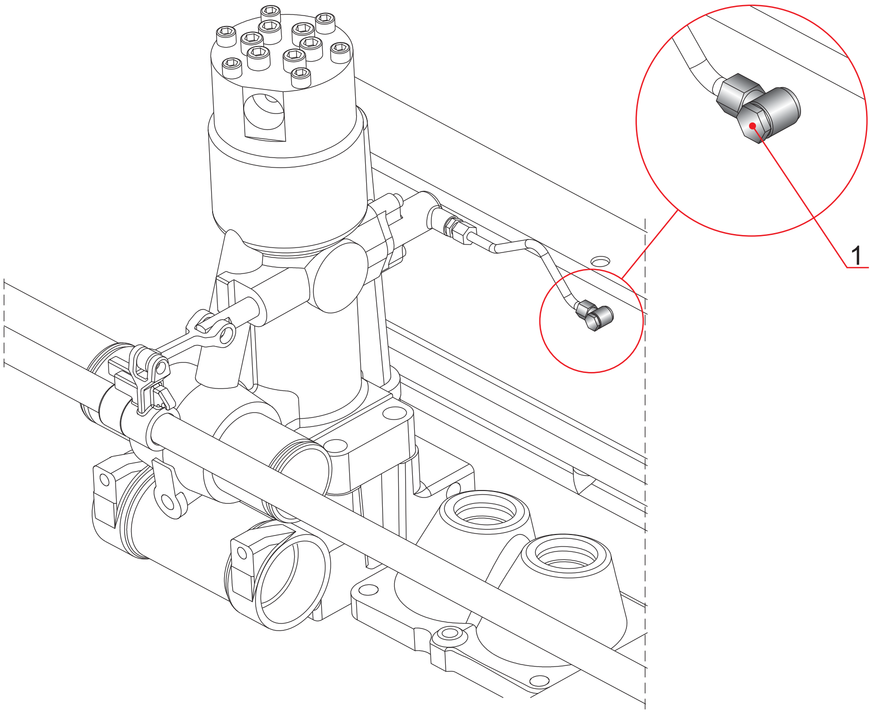


Fig 07-7

Pos.	Screw connection	Torque (Nm)
		L'Orange
1.	Fastening screws for head piece, M14	160±10
2.	Fastening screws for head piece, M12	120±10
3.	Erosion plugs	200±10

Continued on next page

Pos.	Screw connection	Torque (Nm)
		L'Orange
4.	Flange fastening screws	30±5
5.	Locking screws for injection pump adjusting screw	50±5
6.	Fastening nuts for injection pump	400±20
	Lubricate threads and contact surfaces with engine oil.	
7.	Locking screw for roller pin	80±5
	Apply Loctite 2701 to threads, see section *07.2*.	



Pos.	Screw connection	Torque (Nm)
1.	Hollow bolt for pipe element	40±5

Fig 07-8 D: Overspeed trip device

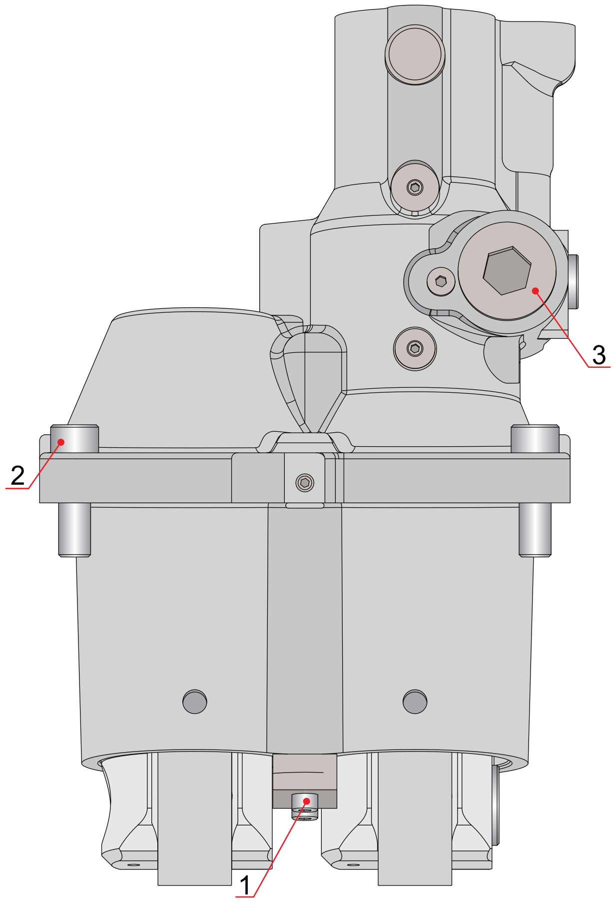


Fig 07-9 Valve tappet housing

Pos.	Screw connection	Torque (Nm)
1.	Guide plate fastening screw	25±3
2.	Valve tappet housing fastening screw	200±10
3.	Plug	300±15

07.1.5 E: Fuel injection valve

v12

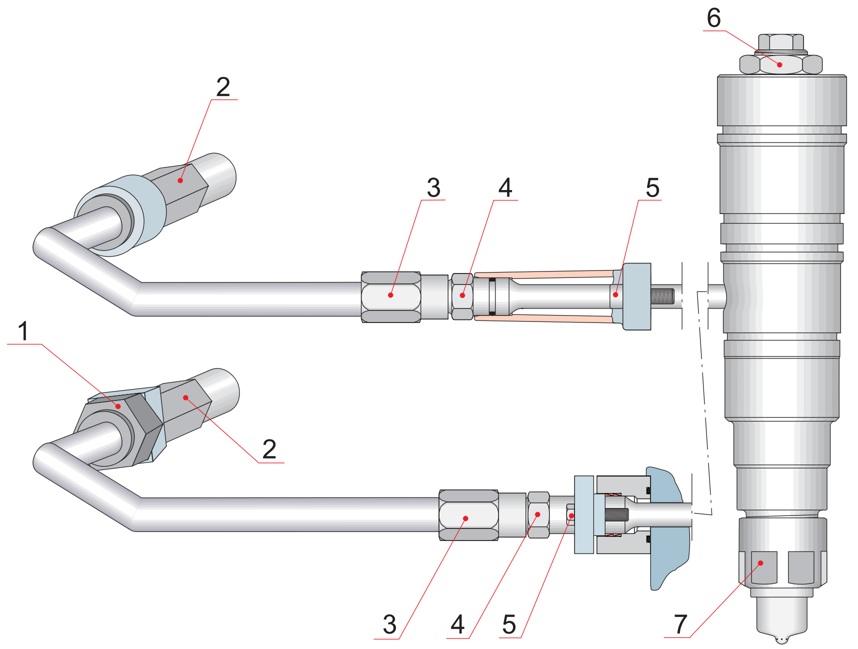


Fig 07-10 Injection valve

Pos.	Connection	Torque (Nm)
2.	Injection pipe cap nut to injection pump	140±10
3.	Injection pipe cap nut to connection piece	90±10
4.	Connection piece to nozzle holder	160±10
5.	Screws for protecting sleeve	80±5
6.	Injection valve counter nut	150±20
7.	Injection nozzle cap nut (L'Orange) Injection nozzle cap nut (Woodward)	450±20 678±40

Fuel injection pipe of friction ring type		
Pos.	**Connection**	**Torque (Nm)**
1.	Nut for leak fuel connection	200±10
2.	Injection pipe cap nut to injection pump	370±5
3.	Injection pipe cap nut to connection piece	265±5
4.	Connection piece to nozzle holder	160±10
5.	Screws for flange	80±5
6.	Injection valve counter nut	150±20
7.	Injection nozzle cap nut (L'Orange) Injection nozzle cap nut (Woodward)	450±20 678±40

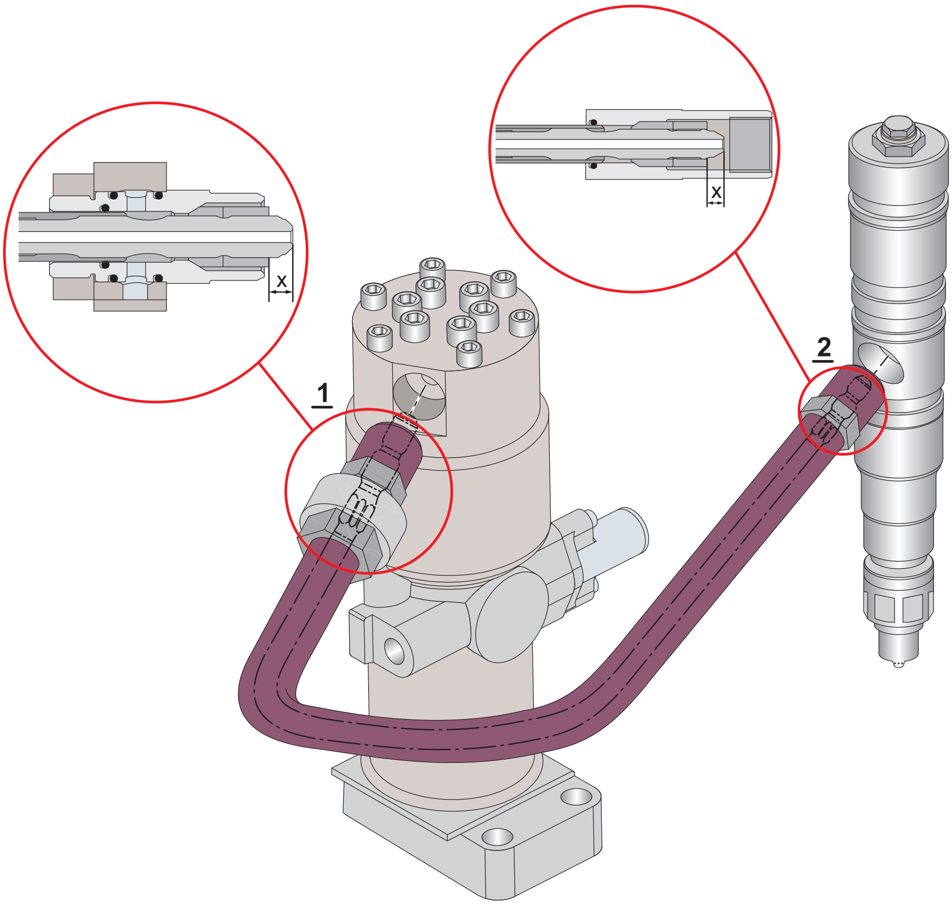


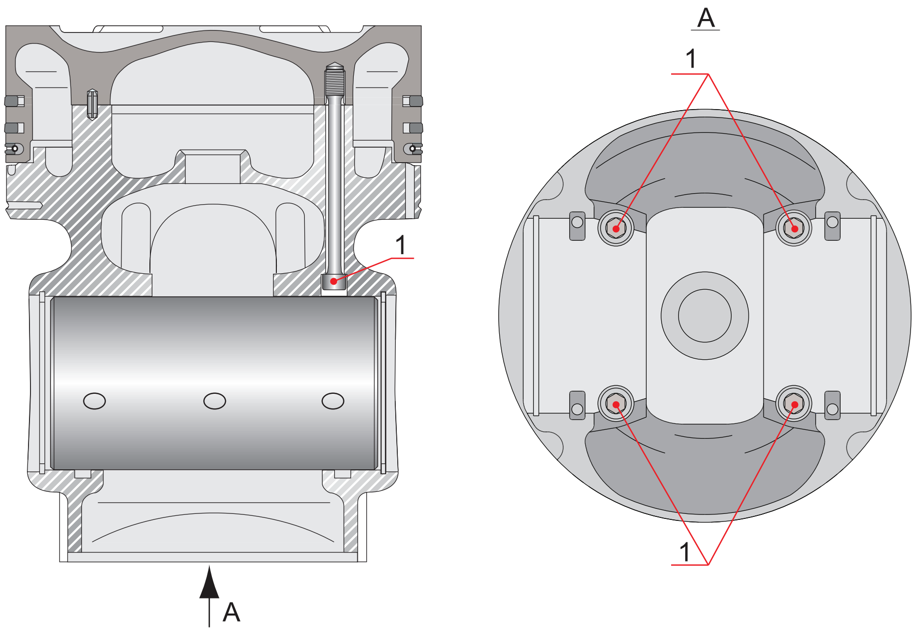
Fig 07-11 E: High pressure pipe, conventional

Pos.	Connection	Distance X (mm)
1.	Distance (X) Pipe end - Power Sleeve (PS) [1]	10.8±0.3
2.	Distance (X) Pipe end - Power Sleeve (PS)	10.2±0.3

[1] Apply loctite 270 to threads for power sleeve.

07.1.6 F: Piston

v3



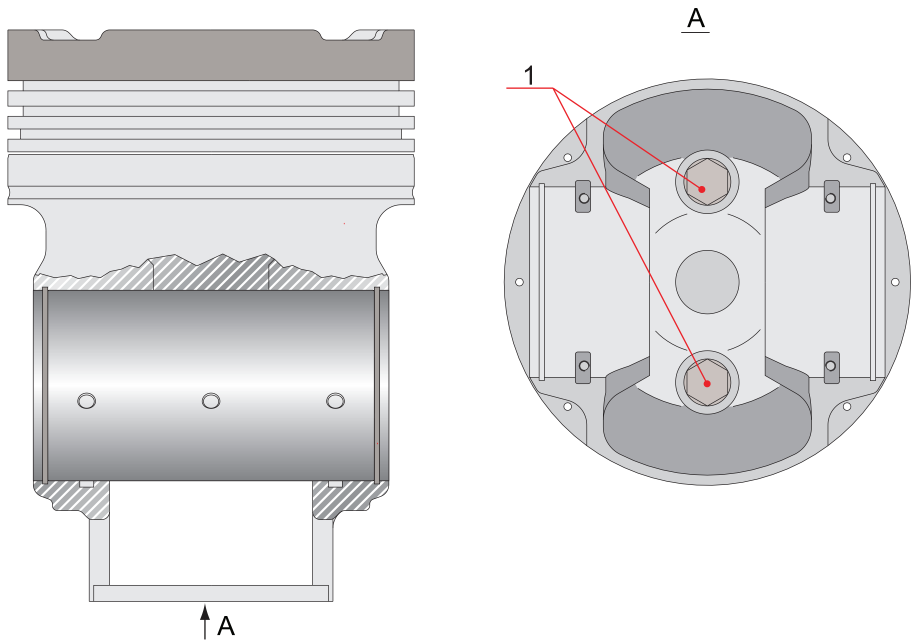
1 Piston crown connection screw

Fig 07-12 F: Piston

Piston type 1 (piston with 4 screws)		
Screw connection		Torque (Nm) Angle (º)
Piston crown connection screws:		
1.	Lubricate threads and contact surfaces with engine oil.	
2.	Tighten the screws crosswise.	155 Nm
3.	Loosen the screws.	
4.	Pre-tighten the screws crosswise.	40 Nm
5.	Tighten the screws crosswise further with an angle of	80°±5°
6.	Test for the correct tightness. The screw should not move when tightening with 125 Nm torque.	

NOTE

Check the length of screws when the piston is opened or piston top is changed. Renew the screws if its length exceeds 169.5 mm.



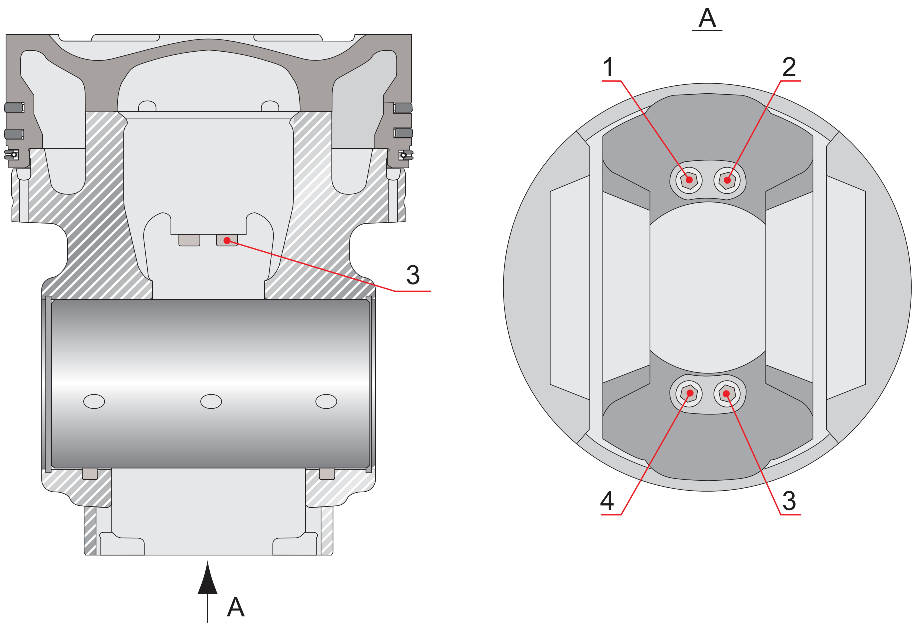
1 Piston crown connection screw

Fig 07-13 F: Piston

Piston type 2 (piston with 2 screws)		
Screw connection		Torque (Nm) Angle (º)
Piston crown connection screws:		
1.	Lubricate threads and contact surfaces with engine oil.	
2.	Pre-tighten the screws crosswise.	250Nm
3.	Loosen the screws.	
4.	Pre-tighten the screws crosswise.	80 Nm
5.	Tighten the screws further with an angle of	90°(+0°/-10°)
6.	Test for the correct tightness. The screw should not move when tightening with 250 Nm torque.	

NOTE

Check the length of screws when the piston is opened or piston top is changed. Renew the screws if its length exceeds 131.4 mm.



1-4: Piston crown connection screws

NOTE

Always tighten the screws in the order 1, 3, 2 and 4.

Fig 07-14 F: Piston

Piston type 3 (piston with 4 screws)		
Screw connection		Torque (Nm) Angle (º)
Piston crown connection screws:		
1.	Lubricate threads and contact surfaces with engine oil.	
2.	Tighten all screws.	30±1 Nm
3.	Turn all the screws to an angle of	96° (+5°/-0°)
4.	Loosen the screws 1 and 3.	
5.	Tighten the screws 1 and 3.	30±1 Nm
6.	Turn the screws 1 and 3 to an angle of	81° (+5°/-0°)
7.	Loosen the screws 2 and 4.	
8.	Tighten the screws 2 and 4.	30±1 Nm
9.	Turn the screws 2 and 4 to an angle of	81° (+5°/-0°)
10.	Test for the correct tightness. The screw should not move when tightening with 165 Nm torque.	

NOTE

Renew the screws at every piston overhaul.

07.1.7 G: Turbocharger fastening screws

v7

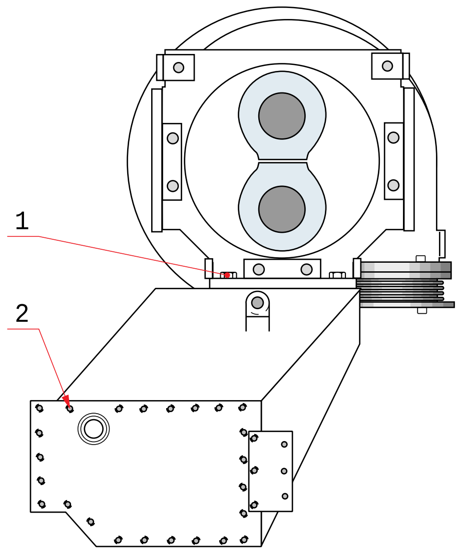


Fig 07-15 Turbocharger fastening screws

Position	Screw connection	Size	Torque (Nm)
1.	Fastening screws for turbocharger		
	TPL61, TPL65	M20	560±20
	TPL67-C	M24	800
	TPL69	M24	920±40
	NA295, NA297, NA307	M20	560±30
	NA355	M24	650±30
	NA357	M24	800
2.	Fastening screws for turbocharger bracket		
	L32	M16	195±10
	V32	M24	650±30

07.1.8 H, I: Engine-driven pumps and centrifugal filter v11

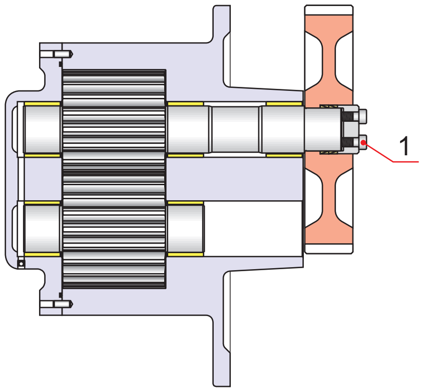


Fig 07-16 Engine-driven lubricating oil pump

Pos.	Screw connection	Torque (Nm)
1.	Driving gear of engine-driven lube oil pumps	
	Tighten the screws crosswise	
	Lubricating oil pump L32 [1]	75±5

[1] The screws are treated with a locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.

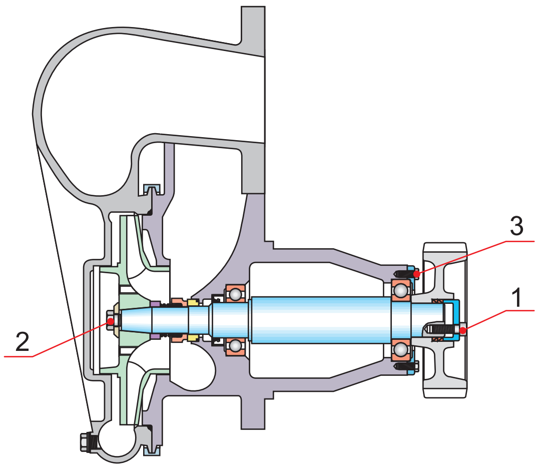


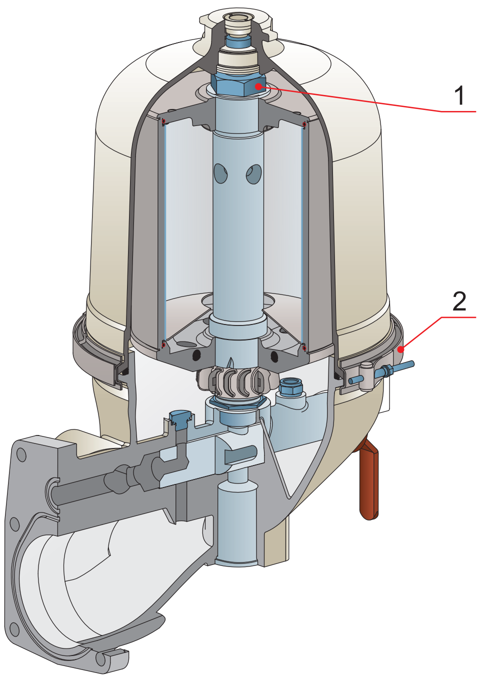
Fig 07-17 Engine-driven cooling water pump

Pos.	Screw connection	Torque (Nm)
1.	Driving gear of engine-driven pumps	
	Water pump L32 [1]	32±2
	Water pump V32 [1]	50±2
	Tighten the screws crosswise in three steps (0-20-40-50 Nm)	
2.	Impeller screw for HT and LT water pump	
	Pump type WD-90/91/120	85±5
	Pump type WD-121	110±5
	Apply locking compound 387 020 to threads, see *section 07.2*	
3.	Screws for bearing retainer	10±3
	Apply locking compound 387 020 to threads, see *section 07.2*	

[1] The screws are treated with a locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.

NOTE

To avoid damaging the threads (Pos. 2 and 3), heat up the screws before removing.



1 Rotor cover nut
2 Cover clamp

Fig 07-18 Centrifugal filter

Pos.	Screw connection	Torque (Nm)
1.	Rotor cover nut	60
2.	Cover clamp	8±1

07.1.9 J: Free end of crankshaft

v4

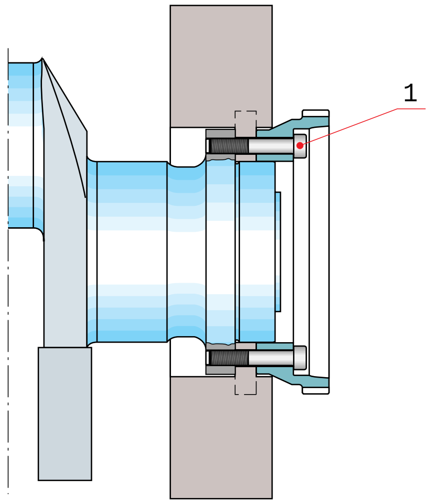


Fig 07-19

Pos.	Screw connection	Torque (Nm)
1.	Screws of pump driving gear at free end of crankshaft. Lubricate threads with engine lubricating oil.	1800±25

07.2 Use of locking fluid

v3

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

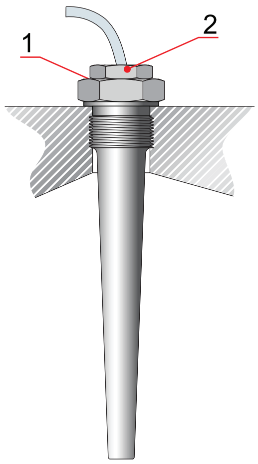


Fig 07-20 **K: Sensors for HT-water**

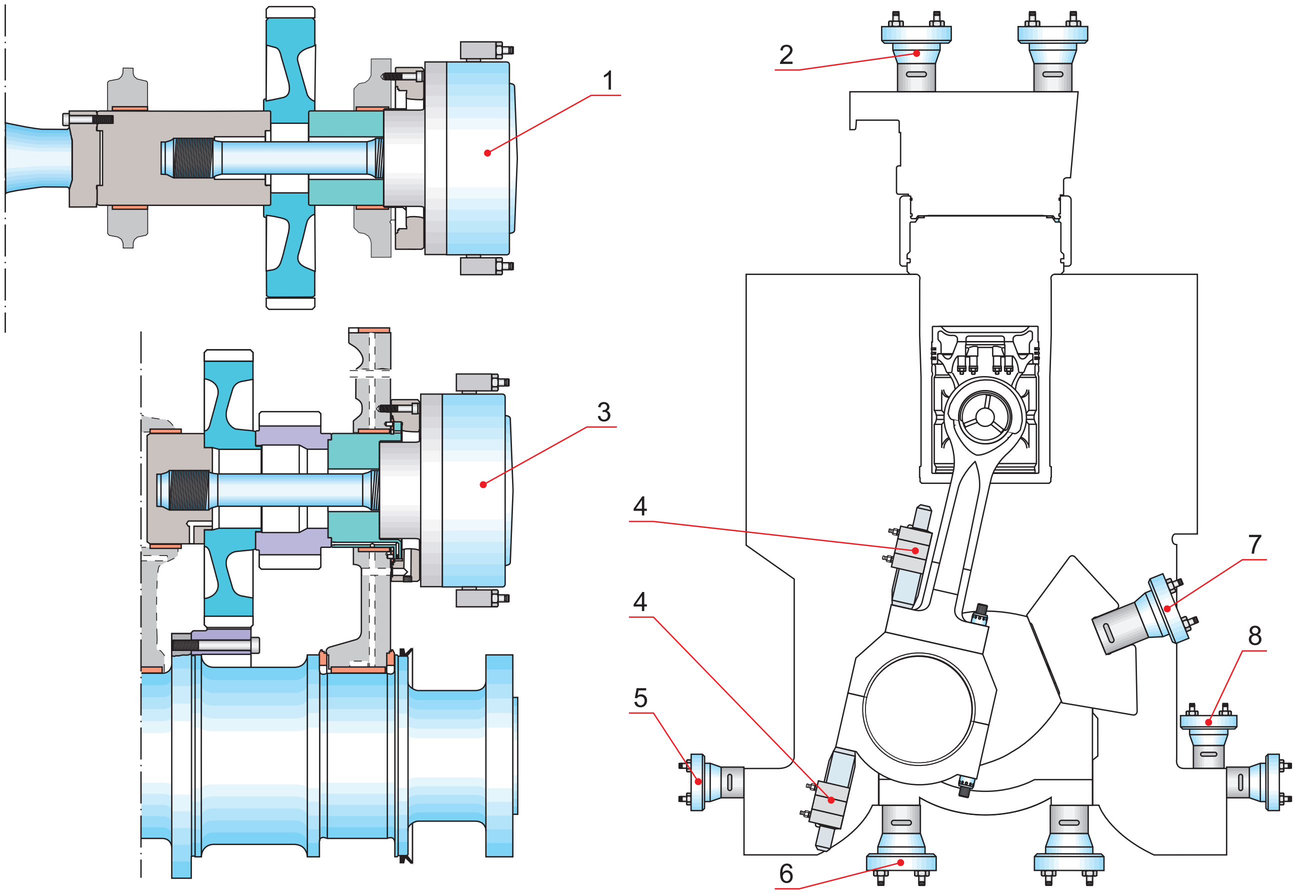
Pos.	Screw connection	Torque (Nm)
1.	Temperature sensor pocket	40±5

Continued on next page

Pos.	Screw connection	Torque (Nm)
2.	Sensor	1.2

07.3 Hydraulically tightened connections
v2

07.3.1 Tightening pressures
v14



1 Camshaft driving gear
2 Cylinder head screw
3 Intermediate gear
4 Connecting rod screw
5 Main bearing, lateral screw
6 Main bearing screw
7 Counterweight screw
8 Engine fastening screw

Fig 07-21 Hydraulically tightened connections

<table>
<tr><th colspan="6">Screw connections</th></tr>
<tr><th colspan="2" rowspan="2">Component</th><th rowspan="2">Tightening procedure</th><th colspan="2">Max. hydraulic pressure (bar)</th><th>Hydraulic cylinder</th></tr>
<tr><th>Tightening</th><th>Loosening</th><th>Spare part number</th></tr>
<tr><td rowspan="2">1.</td><td rowspan="2">Camshaft driving gear M80</td><td>first step</td><td>760</td><td></td><td rowspan="2">800112</td></tr>
<tr><td>second step</td><td>760</td><td>780</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Cylinder head screw M56</td><td>first step</td><td>520</td><td></td><td rowspan="2">800047</td></tr>
<tr><td>second step</td><td>520</td><td>550</td></tr>
<tr><td rowspan="2">3.</td><td rowspan="2">Intermediate gear M80</td><td>first step</td><td>760</td><td></td><td rowspan="2">800112</td></tr>
<tr><td>second step</td><td>760</td><td>780</td></tr>
<tr><td rowspan="2">4.</td><td rowspan="2">Connecting rod screw M27</td><td>first step</td><td>400</td><td></td><td rowspan="2">800020</td></tr>
<tr><td>second step</td><td>800</td><td>820</td></tr>
<tr><td rowspan="2">5.</td><td rowspan="2">Main bearing, lateral screw M42</td><td>first step</td><td>250</td><td></td><td rowspan="2">800041</td></tr>
<tr><td>second step</td><td>700</td><td>720</td></tr>
<tr><td rowspan="4">6.</td><td rowspan="2">Main bearing screw M56</td><td>first step</td><td>250</td><td></td><td rowspan="2">800046 (cylinder marked 3V86B0218 and sleeve marked 3V86B0333)</td></tr>
<tr><td>second step</td><td>615</td><td>635</td></tr>
<tr><td rowspan="2">Main bearing screw M56</td><td>first step</td><td>250</td><td></td><td rowspan="2">800046 (cylinder marked DAAF021078 and sleeve marked DAAF021035)</td></tr>
<tr><td>second step</td><td>700</td><td>720</td></tr>
</table>

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Screw connections					
Component		Tightening procedure	Max. hydraulic pressure (bar)		Hydraulic cylinder
			Tightening	Loosening	Spare part number
7.	Counterweight screw M42 V-engine				800041
	Screw stamped 1022 or stem diameter 30 mm	first step	300		
		second step	700	720	
	Screw stamped 3038 or stem diameter 32 mm	first step	800		
		second step	800	820	
	Counterweight screw M42 In-line engine				800041
	Screw stamped: 940 or stem diameter 30 mm	first step	300		
		second step	700	720	
	Screw stamped 1569 or stem diameter 32 mm	first step	400		
		second step	800	820	
8.	Engine fastening screws	first step	x)		
		second step			

*) See installation instructions.

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

Screw dimension	Tightening torque (Nm)
Cylinder head M56/M60	400±20
Main bearing M56/M60	300±10
All M27 studs on connecting rod	100±10
M42 and M48 x 3	200±10
Intermediate gear M80	200±10

NOTE

Tightening torques in a table do not apply to stud bolts in position 5 and 8.

For tightening stud bolt in position 5, see chapter 10, section “Assembling the main bearing”.

CAUTION

If the stated hydraulic pressure is exceeded, the screws are overloaded and you need to replace them.

07.3.2 Hydraulic Tool Safety Instructions v4

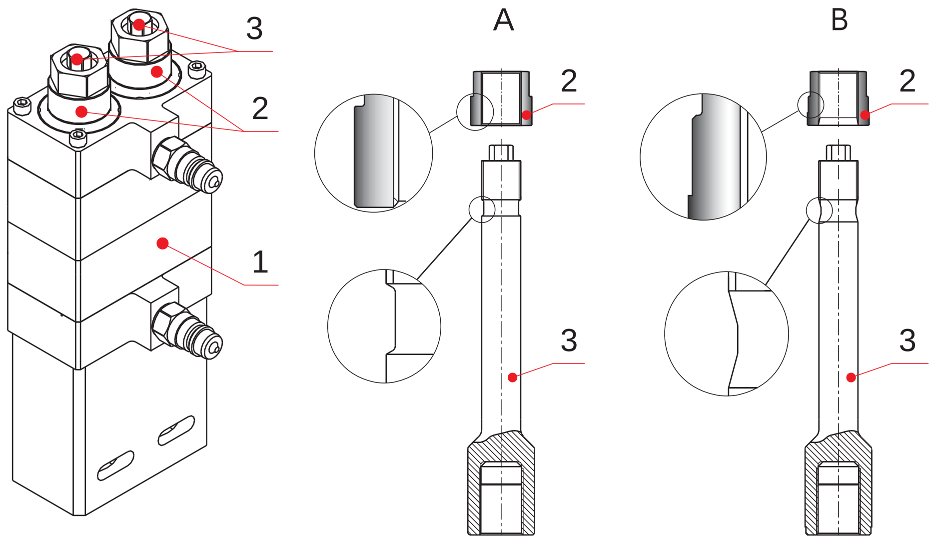
Since the hydraulic tools operate under high pressure and produce great force, proper safety precautions must be taken to reduce the risk of injury to persons and damage to material during work on the engine and in the workshop.

Hydraulic tool service life	
Tool	Load cycles (approx.)
Piston in cylindrical hydraulic tools (see *Fig 07-23*)	1 000
Screws in "twin cylinder" hydraulic tool (see *Fig 07-22*)	1 000
Hydraulic hoses and couplings	10 000

There are two types of hydraulic tools for the connecting rod shank screws, see *Fig 07-22*. The screws and nuts in the tool of **new design** (introduced in 2001) should be replaced before reaching **1000** loading cycles, i.e. raising the pressure to nominal value 1000 times).

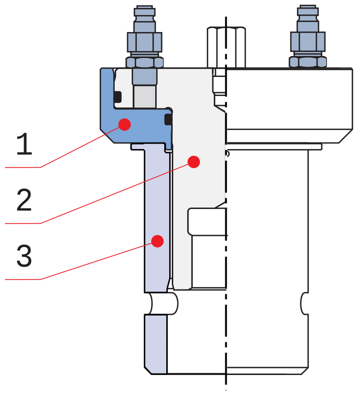
The screws and nuts of **the previous design**, see*Fig 07-22*, should be replaced before reaching **250** loading cycles.

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



A. *Previous design* B. *New design* 1. *Hydraulic tightening tool* 2. *Nut* 3. *Screw*

Fig 07-22 Hydraulic tightening tool for connecting rod shank screw



1. *Cylinder* 2. *Piston* 3. *Sleeve*

Fig 07-23 Cylindrical hydraulic tool

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

v3

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 ensuring that every cylinder is supplied 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 become worn the coupling must be replaced because of the risk of blocking.

- In the high pressure hydraulic tool set the recommendation is to use a special hydraulic oil or in any case an oil with a viscosity of about 12cSt at 20°C.
- During the filling of the container for the high pressure pump it is recommendable to couple the set according to scheme B, *Fig 07-24*. Before filling, open the release valve (2) and empty the cylinders (4) by pressing the piston and cylinder together. After which, the container can be filled through the filling plug (1).
- After filling, vent the system by pressing in, with a finger, the centre pin of the female part of the last quick-coupling, the coupling is disconnected from the pressure gauge. Keep on pumping until oil free from air emerges from the coupling.
- Check the pressure gauge of the hydraulic tool set regularly. A comparison pressure gauge is supplied for this purpose. This pressure gauge can be connected to the plug hole (7), the outlet hose of the pump is connected direct to the pressure gauges.

07.3.3.1 Instructions for high pressure hydraulic tools

v3

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

- When the hoses are pressurised, do not perform any maintenance, adjustments or repairs. Do not even tighten the connections.
- Before raising the pressure in the high pressure tool, vent all hydraulic parts (pump, pipes, hoses, regulating units).

- Do not exceed the maximum allowed pressure for the weakest part.
- Keep a logbook or similar of the hydraulic tools.

07.3.4 Dismantling hydraulically tightened screw connections v4

Prerequisites

WARNING

Do not stand next to a pressurised hydraulic tool.

Procedure

1 **Attach distance sleeves and hydraulic cylinders.**
See*Fig 07-24*A.

2 **Tighten cylinders by hand.**

3 **Connect the hoses to the pump and cylinders.**
See the scheme *Fig 07-24*B.

4 **Open the release valve (2) and tighten cylinders in clockwise direction to expel any oil.**

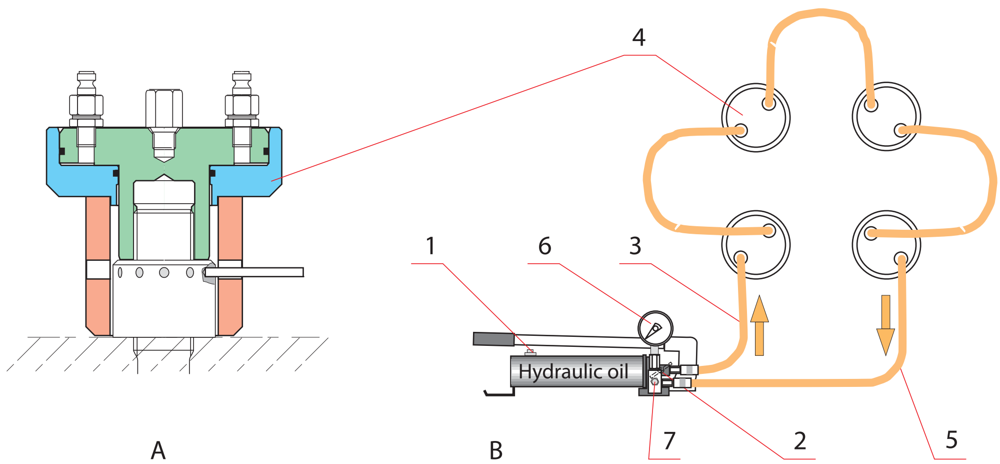
5 **Turn the cylinders in anticlockwise direction approximately half a revolution (180°).**
Otherwise the nut is locked by the cylinder and impossible to loosen.

6 **Close the release valve and raise the pressure to the stated value.**

7 **Tighten the nut in anticlockwise direction approximately half a revolution with the pin.**

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

9 **Remove the nuts by hand.**



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

Fig 07-24 Hydraulic cylinder

07.3.5 Reassembling hydraulically tightened screw connections

v5

Prerequisites

Check that the threads and contact surfaces are clean.

Procedure

1. **Tighten the nuts and attach distance sleeves.**
2. **Tighten cylinders by hand.**
3. **Connect the hoses to the pump and cylinders.**
   Check that the release valve is open and tighten the cylinders in a clockwise direction to expel any oil.
4. **Close the release valve and apply pressure to the stated value.**
5. **Tighten the nuts in a clockwise direction until it is 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. Maintain the pressure constant at the stated value.
6. **Open the release valve and remove the hydraulic tool set.**
   Ensure that the nut is tightened properly by following the given steps:
   a **Raise the pressure according to *section 07.3.1* and tighten the nut in clockwise direction until it is in close contact with the face.**
   b **Increase the pressure further to the stated pressure and screw the nut until it is in close contact with the face again. Now the nut must move just a limited angle, but approximately the same angle for all nuts of the same type.**

NOTE
Before the engine is started, ensure that all screw connections that have been removed are properly tightened and locked.

07.4 Use of hydraulic extractor cylinder

v3

A hydraulic extractor cylinder 800063 is used for some power demanding operations. In connection with this cylinder, the hydraulic high pressure hand pump is utilised, coupling scheme acc. to *Fig 07-25*.

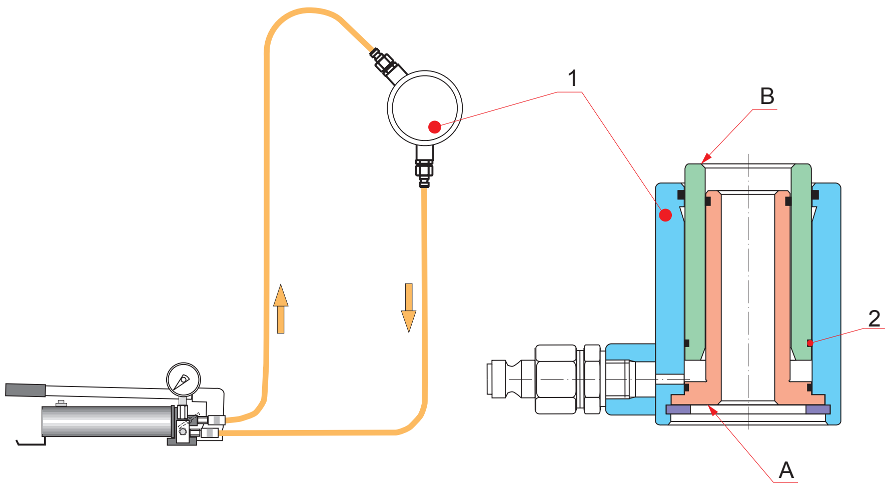


Fig 07-25 Hydraulic extractor cylinder

Due 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 that care is taken when operating at the end of the stroke.

The effective area of the piston is 32.2 cm^2 which gives the following relation between pressure and force (using tool 2V83E0186), see *Fig 07-26*,(1)

In the previous tool (marked with 3V83E0061) the effective area of the piston is 14.42 cm^2. The relation between pressure and force is shown in *Fig 07-26*,(2).

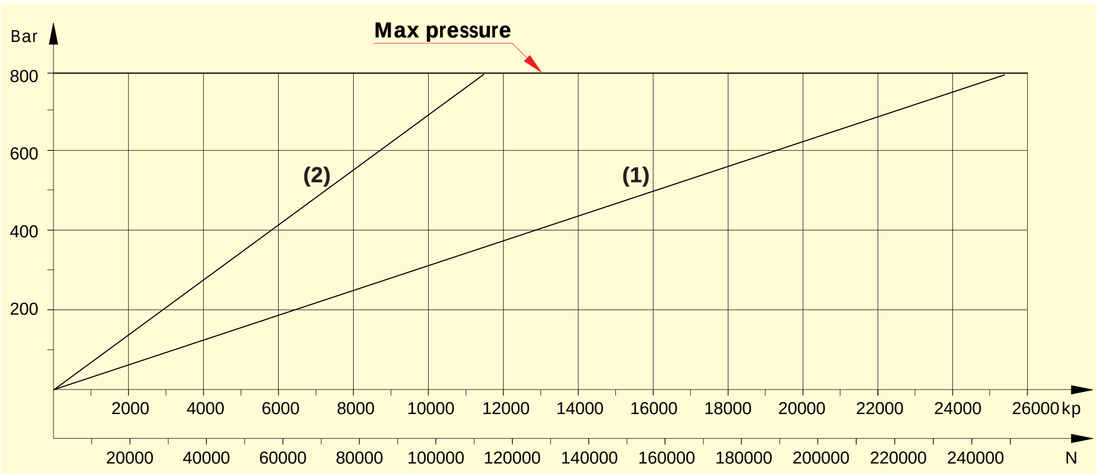


Fig 07-26 Relation between pressure and force

07.5 Low pressure pump for lifting purposes in the crankcase

v3

A special low pressure pump (150 bar) 800 059 is supplied for lifting tools used in the crankcase. Normal engine oil, which is used in the engine lubricating system (sump) must be used in this pump because the drain oil from the tools is led to the sump of the engine.

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08. Operating Troubles, Emergency Operation

08.1 Troubleshooting

v35

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

	Trouble Possible reason	See chapter, section
1.	Crankshaft does not rotate at starting attempt	
a)	Turning device is connected.	*03.1.1*, *21*
	NOTE! Engine cannot be started when turning device is connected. However, before starting, always check that turning device is disconnected.	
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)	Jamming of blocking valve on turning device	*21*
f)	Starting air solenoid valve faulty	*21.1*
g)	Inlet or exhaust valve jamming when open. "Negative" valve clearance (strong blowing noise).	*12*
h)	Engine external automation system faulty	*03.2 23.1*
i)	Charge air shut-off valve released	

2.	Crankshaft rotates but engine fails to fire	
a)	Speed too low (1b),	
b)	Automatic shutdown device is not in start position	*23.5.2*
c)	Load limit of the control shaft or the governor is set at too low a value	*22.3.2*
d)	Starting fuel limiter wrongly adjusted	*23.4.1.3*
e)	Some part of fuel control mechanism jamming and prevents fuel admission	*22.1*
f)	Fuel and injection system not vented, pipe connections between injection pumps and valves not tightened	*16.3*, *17*
g)	Fuel filter outside the engine clogged	
h)	Three-way cock for fuel filter incorrectly set, valve in fuel inlet pipe closed, fuel day tank empty, fuel feed pump not started or faulty	
i)	Stop lever in stop position	
j)	Very low air and engine temperatures (preheat circulating water!) in connection with fuel of low ignition quality	*02.1*
k)	Fuel insufficiently preheated or precirculated (HFO) or fuel oil temperature too high (LFO)	*02.1.2.1*

Continued on next page

2.	Crankshaft rotates but engine fails to fire	
l)	Compression pressure too low (1f)	
m)	Speed pick-up too far away from flywheel	
n)	Worn injection pumps	

3.	Engine fires irregularly, some cylinders do not fire at all	
a)	See points 1f, 2f, g, h, k, l, 4d	
b)	Injection pump control rack incorrectly adjusted	
c)	Injection pump control sleeve does not mesh properly with rack (may cause overspeed if set in direction towards increased fuel quantity or the control sleeve is damaged)	*22.3.1*
d)	Injection pump faulty (plunger or tappet sticking; delivery valve spring broken, delivery valve sticking, constant pressure relief valve leaking)	*16.1*
e)	Injection valve faulty; nozzle holes clogged	*16.1*
f)	Piston rings ruined; compression pressure too low	*11.2.2*
g)	8...18-cylinder engines. It may be problematic 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 for longer periods, 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 made in small steps and the difference between rack positions of various cylinders should not exceed 0.5 mm.	
h)	Connection piece faulty	

4.	Engine speed not stable	
a)	Governor adjustment faulty (normally compensation too low)	*22.4*
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*

5.	Knocks or detonations occur in engine (if the reason cannot be found immediately, stop the engine!)	
a)	Big end bearing clearance too large (loose screws!)	*06.2* pos. 11, *07.3*, *11.2.3*
b)	Valve springs or injection pump tappet spring broken	*12*, *16.1*
c)	Inlet or exhaust valve jamming when open	
d)	Valve clearances too large	*06.1*, *12.6*
e)	One or more cylinders badly overloaded (3b, c)	
f)	Injection pump or valve tappet guide block loose	*16.3*, *14.1*, *07.1*
g)	Initial phase of piston seizure or piston top fastening bolts are loose	
h)	Insufficient preheating of engine in combination with fuel of low ignition quality	

Continued on next page

5.	Knocks or detonations occur in engine (if the reason cannot be found immediately, stop the engine!)	
i)	Fuel injection timing incorrect. See point 9c.	

6.	Dark exhaust gases	
a)	Late injection (wrongly set camshaft drive)	*06.1*, *16.2*, *13.1*
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

7.	Engine exhaust gases blue-whitish or grey-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*, *11.2.2*
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)	Grey-whitish exhaust gases due to water leakage from exhaust boiler, turbocharger/ water in fuel	

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 - leaking nozzle	Test Rec, *01.2* *01.3* *01.3* *16.1*
d)	Excessive deposits in cylinder head inlet or exhaust ports	*15.3*
e)	Exhaust pipe pressure after turbine high	

9.	Exhaust gas temperature of one cylinder above normal	
a)	Faulty exhaust gas temperature measurement	Test Records *23.6 03.5.1*

Continued on next page

9.	Exhaust gas temperature of one cylinder above normal	
b)	Exhaust valve - jamming when open - "negative" valve clearance - sealing surface blown by (burned)	
c)	Faulty injection valve - opening pressure much too low - sticking of nozzle needle when open - broken spring - nozzle cracked	*06.1*, *16*
d)	Late injection	*06.1*, *13.1*
e)	Fuel supply insufficient (filter clogged)	*17.2*
f)	Injection pump faulty, fuel rack sticking in high position	*16.1*
g)	Screw in injection pump lifter loose, check the height of screw	*16.2*

10.	Exhaust gas temperature of one cylinder below normal	
a)	Faulty exhaust gas temperature measurement	*03.5.1*
b)	See points 2f, h, 3b, c, d, e, f	
c)	Leaky injection pipe or pipe fittings	*16.3*
d)	When idling, see point 3g	*03.5.1*

11.	Exhaust gas temperatures very unequal	
a)	See points 9a, c, e	
b)	Fuel feed pressure too low; flow through injection pumps too small. (see points 2h, i). May cause great load differences between cylinders although injection pump rack positions are the same. **Danger!** 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 between two cylinders is normally higher.	

12.	Lubricating oil pressure lacking or too low	*01.2*
a)	Faulty pressure sensor	*23.6*
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)	Leakage in lubricating oil suction pipe connections	*18*
e)	Lubricating oil badly diluted with diesel oil, viscosity of oil too low	*02.2*
f)	Lubricating oil pipes inside engine loose or broken	*18*
g)	Lubricating oil filter clogged	*18*

13.	Lubricating oil pressure too high	
a)	See points 12a and c	

14.	Lubricating oil temperature too high	*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 or dirty cooler	*19.3* *01.3*
c)	Oil cooler clogged, deposits on tubes	*18.6*
d)	Faulty thermostat valve	*18.7*

15.	Abnormally high cooling water outlet temperature, difference between cooling water inlet and outlet temperatures too large	*01.2*
a)	One of the temperature sensors is 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* *03.5.1*
d)	Thermostat valve faulty	*19.8*

16.	Water in lubricating oil	*02.2*, *03.5.1*
a)	Leaky oil cooler	*18.6*
b)	Faulty lubricating oil separator. See separator instruction book!	*02.2*

17.	Water in charge air receiver (escapes through drain pipe in air cooler housing)	
a)	Leaky air coolers	15
b)	Condensation (charge air cooling water temperature too low)	*01.2*

18.	Engine loses speed at constant or increased load	
a)	Engine overloaded, a further increase of fuel supply is prevented by the mechanical load limiter	*22.1*
b)	See points 2c, f, g, h, i	
c)	See points 4c, d, 5g	

19.	Engine stops	
a)	Shortage of fuel, see points 2h, i	
b)	Automatic stop device has tripped	*23.3.1.3*
c)	Faulty governor or governor drive	*22.4*
d)	Faulty power supply to automation system	*23.3.4*
e)	Charge air shut-off valve released manually	

20.	Engine does not stop although stop lever is set in stop position or remote stop signal is given. Note! If engine is loaded do not open the breaker or reduce the load	
a)	Injection pump control rack incorrectly set (3b, c). 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 the engine: - with the stop lever - by releasing the charge air shut-off valve(s) manually - by cutting off the fuel oil supply	*03.3.1*
c)	The engine is driven by the generator or propeller or by another engine connected to same reduction gear	

21.	Engine overspeeds and does not stop although overspeed trip device trips Note! If the engine is loaded, do not open the breaker or reduce the load.	
a)	Injection pump control rack incorrectly 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):	*22.3.1*
	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 check should always be made when the control mechanism or the injection pumps have been handled.	
c)	Charge air shut-off valve. Faulty wiring. The feedback signal from the external instrument air system must be connected to the ships/plants alarm system for alarm and blocking the start.	15

08.2 Emergency operation with defective engine

08.2.1 Operation with defective air coolers

v5

If the air cooler water pipes 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 the water is condensate, reduce the cooling. See *Fig 03-2*, *Chapter 03 Start, stop and operation*.
- If the water is raw water, stop the engine as soon as possible, and fit a spare cooler.

If no spare cooler is available, shut down or remove the air cooler, or operate with a partially plugged air cooler. Limit the engine output so that the normal full load exhaust temperatures are not exceeded. The turbocharger may surge before the admissible exhaust temperatures are reached. In that case, reduce the engine load further to avoid continuous surging.

08.2.2 Operation with defective turbocharger(s) v3

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.). See chapter 15.

08.2.3 Operation with defective cams v6

If the camshaft piece with damaged cams cannot be removed and replaced with a new one, you can keep the engine running by means of the following measures.

NOTE

Concerning torsional vibration and other vibration, see section *08.2.5*

1 Injection pump cams:

Lock the injection pump tappet in upper position using a locking plate 800066 included in the tool set.

When operating with a shut-off injection pump over a long period, the valve push rods of the inlet and outlet valves must be removed, and the indicator valve on the respective cylinder must 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.

2 Valve cams:

Stop fuel injection to the cylinder concerned, see chapter *16.1*. Remove the valve push rods and hang up the tappet in the upper position by locking pins 800067 included in the tool set. Mount the tubes covering the push rods.

CAUTION

If the tappet is locked in the upper position, the push rods should be removed. Otherwise the piston interferes with the valves.

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

08.2.4 Operating with removed piston and connecting rod v6

Prerequisites

If damage to piston, connecting rod or big end bearing cannot be repaired, proceed as follows to allow emergency operation:

Procedure

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

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

3 **Fit the completely assembled cylinder head but leave out the valve push rods.**

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

5 **Hang up the injection pump tappet and valve tappets as described in section *8.2.3*.**

NOTE
Concerning torsional vibration and other vibration, see section *08.2.5*

With one cylinder out of operation, reduce load to prevent the 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 piston and connecting rod removed, from one or more cylinders, should be performed only in an absolute emergency when there are no other means of proceeding under own power.

08.2.5 Torsional vibration

v3

When running the engine with one or more cylinders out of operation, the balance of the engine is disturbed and severe or even dangerous vibration may occur. The vibration conditions are, in practice, dependent on the type of installation.

As general advice, when there are cylinders out of order:

- Reduce the load as much as possible.
- Keep the speed in a favourable range (completely depending on the type of installation).
- If one or several pistons have been removed, use the lowest possible speed.

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.

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10. Engine Block with Bearings, Oil Sump and Cylinder liner

The engine block is cast in one piece. The main water and lubricating oil distributing channels and the charge air receiver are integrated in the engine block. The main bearing caps that support the underslung crankshaft are clamped by hydraulically tensioned screws, two from below and two horizontally.

The thrust bearing is located at the driving end. The four thrust washers guide the crankshaft axially.

The camshaft bearing bushes are fitted directly into the engine block.

The cylinder liners are made of alloy cast iron. To eliminate the risk of bore polishing, the liners are provided with an anti-polishing ring at the upper part.

The crankcase covers and other covers are sealed against the engine block with rubber sealings. On one side of the engine, the crankcase covers are equipped with safety valves that relieve the over pressure to avoid crankcase explosion.

10.1 Oil sump

v4

The oil sump is bolted to the engine block. Suction pipes to the lube oil pump and the separator, if used, as well as for the main lubricating oil distributing pipe for crankshaft bearings are incorporated in the oil sump.

From the main distributing pipe, the lubricating oil is led up to the main bearing through a hydraulic jack. when inspecting the bearings the hydraulic jack is used to lower and lift the bearing cap.

An oil dipstick is located in the engine block. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level near the maximum mark and never allow the level to go below the minimum mark. The limits apply to the oil level in a running engine. One side of the dipstick is graduated in centimeters. Use this scale when checking the lubricating oil consumption.

NOTE

In marine installations, always check the oil level when the ship has the same trim.

10.2 Main bearings

10.2.1 Dismantling the main bearing

v6

Procedure

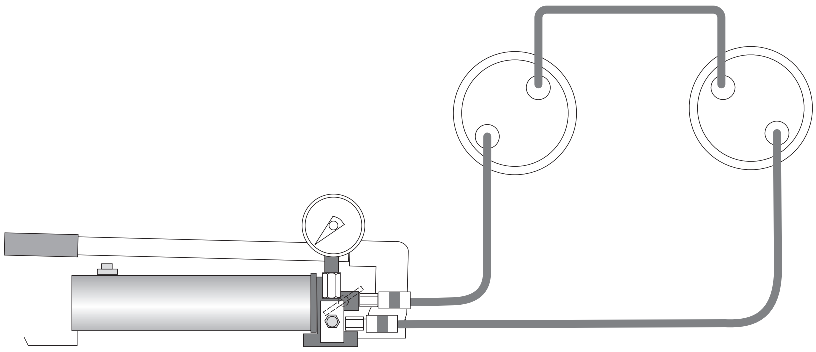
1 **Remove the crankcase covers from each side of the bearing, on both sides of the engine.**

2 **Remove the main bearing temperature sensor and cable with clamps.**

3 **Mount the distance sleeve 800042 and the hydraulic tool 800041 into position on the side screw (A). See** *Fig 10-3*.

One or two nuts can be loosened simultaneously.

4 **Open the nuts of the side screws as described in *Fig 10-1*.**



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 Dismantling with hydraulic tools

5 **Turn the crankshaft of the adjacent cylinder to BDC.**

6 **Mount the distance sleeve 800095 into position on the main bearing screw (B_1), and insert the pin 800049 to keep the sleeve in position. See *Fig 10-3*.**

7 **Mount the hydraulic tool 800046 on the same main bearing screw using the tool 800051.**

8 **Fit the sleeve and hydraulic cylinder onto main bearing screw (B_2) by the same procedure.**

9 **Open the nuts of the main bearing screws as described in the *Fig 10-1*.**

Loosen both nuts at the same time.

10 **Remove the hydraulic tools.**

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

12 **Connect the hose from the hydraulic pump 800059 to the side marked DOWN on the hydraulic jack. See *Fig 10-2*.**

13 **Unscrew the side screws of the main bearing cap to be lowered.**

Use the stud tool 800044.

14 **Lower the main bearing cap by pumping oil to the hydraulic jack with the hydraulic pump.**

15 **Remove the lower bearing shell.**

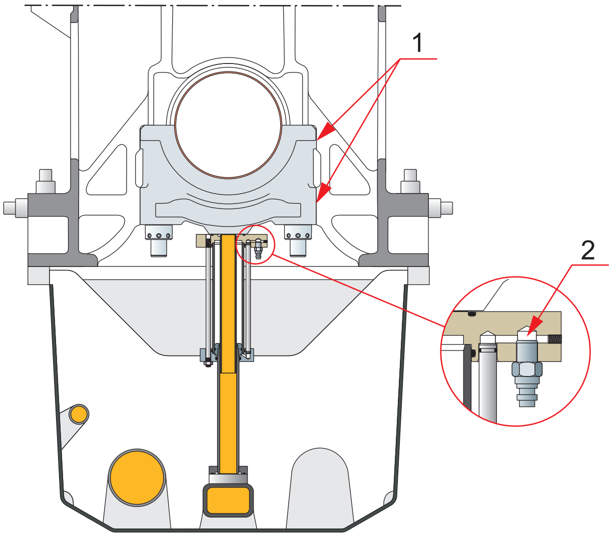
16 **Insert the turning tool 800004 into the main bearing journal radial oil hole.**

17 **Turn the crankshaft carefully until the upper bearing shell has turned 180°.**

Remove the turning tool.

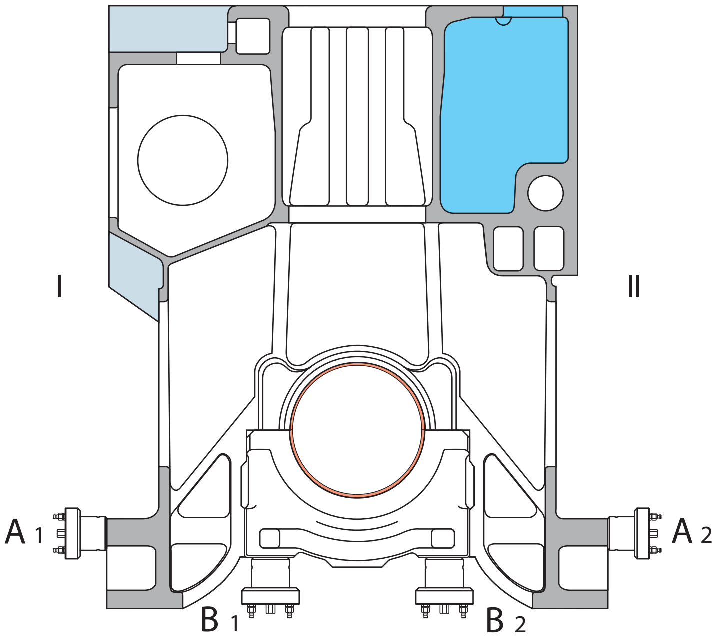
CAUTION

At least every third main bearing must always remain mounted to support the crankshaft.



1 Straight side of main bearing cap
2 Connection for hydraulic pump

Fig 10-2 Hydraulic jack



I *Operating side* II *Rear side*

Fig 10-3 Use of hydraulic cylinders

Hydraulic cylinder combination		
Screw	A1 A2	B1 B2

Continued on next page

Hydraulic cylinder combination				
Hydraulic tool	Main bearing side screws and thrust bearing screws		Main bearing screws	
	Spare part number	Drawing number	Spare part number	Drawing number
Cylinder	800041	3V86B0078	800046	3V86B0218 or DAAF021078
Sleeve	800042	3V86B0046	800095	3V86B0333 or DAAF021035
Pin	800043	4V86B0011	800049	4V86B0002

Hydraulic cylinder combination				
Action/Screw		**Comments**	**Hydraulic pressure**	**Spare part number**
Loosening	A1 A2	One or two at a time	700...720 bar	800041
	B1 B2	Always loosened simultaneously	615...635 bar (when using cylinder marked 3V86B0218 and sleeve marked 3V86B0333)	800046
			700...720 bar (when using cylinder marked DAAF021078 and sleeve marked DAAF021035)	
Tightening	B1 B2	Tighten simultaneously with pin 800049		
	A2	A2 bolt tensioned first with 100 bar hydraulic pressure and the nut turned with pin 800043 to contact	100 bar	
	B1 B2	1. Tighten simultaneously with 250 bar hydraulic pressure	250 bar	
		2. Release the pressure	0 bar	
		3. Tighten simultaneously with 615 or 700 bar hydraulic pressure	615 bar (when using cylinder marked 3V86B0218 and sleeve marked 3V86B0333)	800046
			700 bar (when using cylinder marked DAAF021078 and sleeve marked DAAF021035)	
	A2	Tighten one or two nuts simultaneously on the same side, **first step with 250 bar** hydraulic pressure	250 bar	
	A1	Tighten one or two nuts simultaneously on the same side, **first step with 250 bar** hydraulic pressure	250 bar	
	A2	Tighten one or two nuts simultaneously on the same side, **second step with 700 bar** hydraulic pressure	700 bar	800041
	A1	Tighten one or two nuts simultaneously on the same side, **second step with 700 bar** hydraulic pressure	700 bar	800041

10.2.2 Inspecting the main bearings and journals v8

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

a) Tri-metal bearings can be used until the overlay is partially worn off. When the underlaying nickel-barrier or the lining material is exposed in any area, replace the bearing.

CAUTION

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

b) Bi-metal bearings. Check the wear by measuring the thickness of the lower bearing shells. For this purpose, use a ball anvil micrometer. Follow the wear limits in section Clearances and Wear Limits. If the thickness of lower bearing shells has not reached the wear limit and the difference in thickness of all lower bearing shells is 0.03 mm (maximum), the shells can be used again.

Inspect the main bearing journals. Polish damaged journals that have rough surface, scratches, or shock marks. If considerably uneven wear appears (see section Clearances and Wear Limits), or the crankshaft is damaged it can be ground and thicker bearing shells fitted. (see Spare Parts Catalogue).

10.2.3 Assembling the main bearing v7

Procedure

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

2 **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.**

CAUTION

Lubricate the bearing shell carefully. Otherwise it may be deformed during assembly.

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. Push it by hand as far as possible (recommended 2/3 of its length).**

5 **Insert the turning tool 800004 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

Do not force a bearing shell into its place.

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 **Fit the hydraulic hose from the pump to the connection marked "UP" in the hydraulic jack.**

9 **Lift the main bearing cap by pumping oil to the hydraulic jack with the hydraulic pump. Mount the main bearing nuts by hand. Remove the hose from the hydraulic jack.**

10 **Mount the side screws into the main bearing cap.**

Lubricate the threads that go into the bearing cap.

NOTE

Replace the O-rings on the side screws.

11 **Tighten the side screws to the bottom using the stud tool.**

12 **Mount the distance sleeves 800042 and the hydraulic tool 800041 into position on the side screw (A_2) on the rear side on an inline engine and B-bank on a V-engine, that is, the straight side of the bearing cap, see *Fig 10-2*.**

One or two nuts can be tightened simultaneously on the same side, see *Fig 10-3*.

13 **Rise the hydraulic pressure in the tool to 100 bar and turn the nut to contact with the pin 800043.**

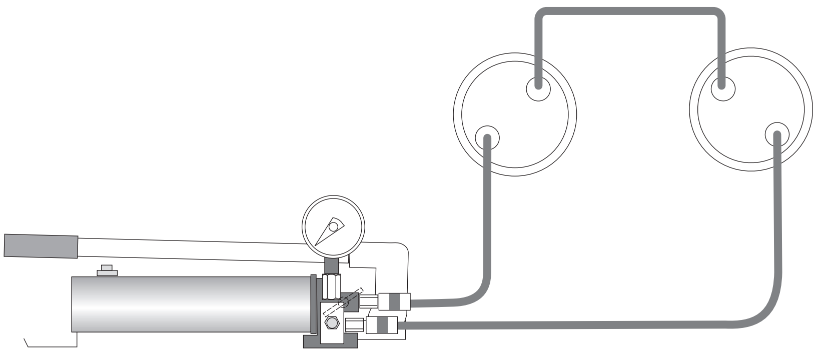
14 **Mount the distance sleeve 800095 into position on the main bearing screw (B_1), and insert the pin 800049 to keep the sleeve in place, see *Fig 10-3*.**

15 **Mount the hydraulic tool 800046 on the same main bearing screw using the tool 800051.**

16 **Mount the sleeve and hydraulic cylinder onto the main bearing screw (B_2) following the same procedure.**

17 **Tighten the nuts of the main bearing screws as described in *Fig 10-4*.**

Tighten both screws at the same time and in two steps. Turn the nuts with the pin 800049.



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 Reassembly with hydraulic tools

NOTE

The hydraulic pressure in the tool must be stable when tightening the nuts.

18 **Connect the hydraulic pump and hose to the tool on the already pretightened side screw (A_2), see *Fig 10-3*.**

19 **Raise the hydraulic pressure in the tool to 250 bar and turn the nut to come in contact with the pin 800043.**

20 **Mount the distance sleeve 800042 and the hydraulic tool 800041 into position on the opposite side screw (A_1).**

21 **Raise the hydraulic pressure in the tool to 250 bar, and turn the nut (A_1) to contact.**

22 **Tighten the side screw (A2) to full stated pressure.**

23 **Tighten the side screw (A1) to full stated pressure.**

24 **Remove the tools, and mount the main bearing temperature sensor, the cable clamps, and the crankcase covers.**

10.3 Flywheel/thrust bearing

10.3.1 Dismantling the flywheel/thrust bearing v6

Procedure

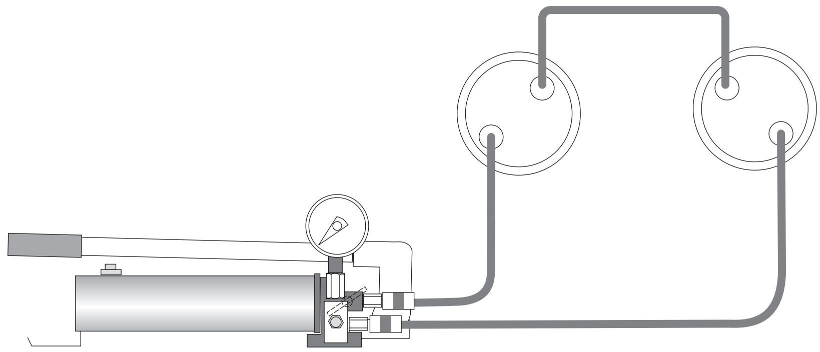
1 **Remove the crankcase covers next to the flywheel end on both sides of the engine.**

2 **Remove the main bearing temperature sensor.**

3 **Mount the distance sleeve 800042 and the hydraulic tool 800041 into position on the side screw (A), see *Fig 10-3*.**

One or two nuts can be loosened simultaneously.

4 **Open the nut of the side screw as described in *Fig 10-5*.**



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 Dismantling with hydraulic tools

5 **Mount the distance sleeve 800095 into position on the main bearing screw (B_1), and insert the pin 800049 to keep the sleeve in position. See *Fig 10-3*.**

6 **Mount the hydraulic tool 800046 on the main bearing screw using the tool 800051.**

7 **Fit the sleeve and hydraulic cylinder onto main bearing screw (B_2) following the same procedure.**

8 **Open the nuts of the main bearing screws as described in the adjacent figure.**

Loosen both nuts at the same time.

9 **Remove the hydraulic tools.**

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

11 **Connect the hoses to the hydraulic pump 800059 and to the side marked DOWN on the hydraulic jack. See *Fig 10-2*.**

12 **Unscrew the side screws of the flywheel/thrust bearing cap.**

Use the stud tool 800044.

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

14 **Remove the lower bearing shell and the lower thrust washers.**

15 **Insert the turning tool 800005 into the bearing journal radial oil hole.**

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

Remove the turning tool.

17 **Remove the thrust washers.**

To remove the thrust washer next to the driving end, fit an M6 screw to each end of the washer. See *Fig 10-6*.

18 **Check the bearing. See *section 10.2.2*.**

Change the thrust washers on the same side in pairs.

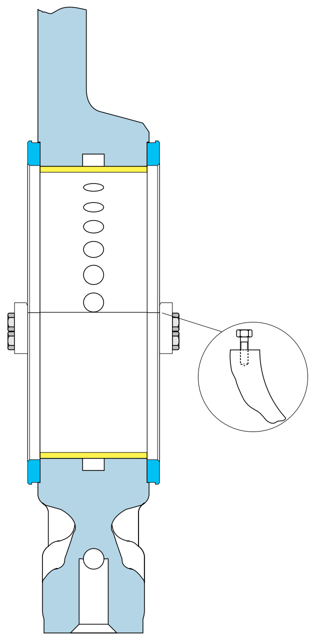


Fig 10-6 Thrust bearing

10.3.2 Assembling the flywheel/thrust bearing v5

Procedure

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

2 **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.**

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

5 **Insert the turning tool 800005 into the bearing journal radial oil hole, and turn the crankshaft carefully until the bearing shell has turned into position.**

CAUTION

Do not force the bearing shell into its place.

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.**

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

10 **Fit the hydraulic hose from the pump to the connection marked "UP" in the hydraulic jack.**

11 **Lift the main bearing cap by pumping oil to the hydraulic jack with the hydraulic pump. Mount the main bearing nuts by hand. Remove the hoses from the hydraulic jack.**

12 **Mount the side screws into the main bearing cap.**

Lubricate the threads that go into the bearing cap.

NOTE

Replace the O-rings on the side screws.

13 **Tighten the side screws using the stud tool 800044 and mount the nuts by hand.**

14 **Mount the distance sleeves 800042 and the hydraulic tool 800041 in position on the side screws (A_2) on the rear side on an in-line engine, or B-bank on a V-engine, that is, the straight side of the bearing cap, see *Fig 10-2*.**

One or two side screws (A_2) can be tightened simultaneously on the same side. See *Fig 10-3*.

15 **Raise the pressure in the hydraulic tool to 100 bar, and turn the nut to come in contact with the pin 800043.**

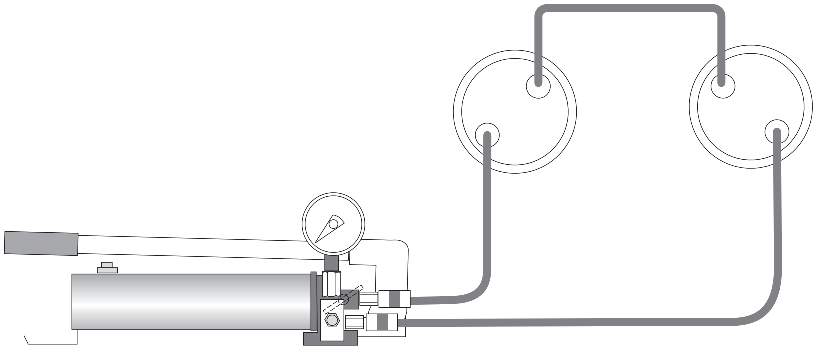
16 **Mount the distance sleeve 800095 into position on the main bearing screw (B_1), and insert the pin 800049, see** *Fig 10-3*.

17 **Mount the hydraulic tool 800046 on the same main bearing screw using the tool 800051.**

18 **Apply the sleeve and hydraulic cylinder onto main bearing screw (B_2) following the same procedure.**

19 **Tighten the nuts of the main bearing screws as described in** *Fig 10-7*.

Tighten both screws at the same time and in two steps. See *Fig 10-3*. Turn the nuts using the pin 800049.



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 Reassembly with hydraulic tools

NOTE

The hydraulic pressure in the tool must stay stable when tightening the nuts.

20 **Connect the hydraulic pump and hose to the tool on the already pre-tightened side screw (A_2), see** *Fig 10-3*.

21 **Raise the pressure in the hydraulic tool to 250 bar, and turn the nut to contact with the pin 800043.**

22 **Mount the distance sleeve 800042 and the hydraulic tool 800041 in position on the opposite side screw (A_1), see** *Fig 10-3*.

23 **Raise the pressure in the hydraulic tool to 250 bar, and turn the nut (A1) to contact.**

24 **Tighten the side screw (A2) to the full stated pressure.**

25 **Tighten the side screw (A1) to the full stated pressure.**

26 **Remove the tools, and mount the main bearing temperature sensor, the cable clamps, and the crankcase covers.**

10.4 Cylinder liner

10.4.1 Maintenance of the cylinder liner

v4

1 **Honing the cylinder liner.** Always hone the cylinder liner when new piston rings are mounted. Normally, light honing is sufficient. When honing with the cylinder liner fitted in the engine block, cover the crankshaft under the cylinder liner concerned with plastic sheet. Prevent the honing debris and oil from falling into the engine oil sump.

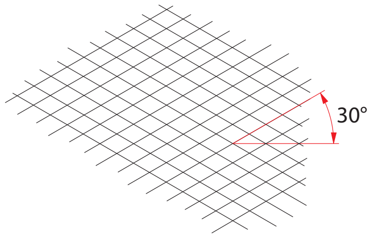


Fig 10-8 Honing pitch angle

- Only use ceramic hones with a coarseness of 80 and 400. Use hones with a coarseness of 80 for about 20 strokes or until the polished areas in the cylinder liner are removed. Use hones with a coarseness of 400 for about 30 strokes to give the correct surface finish (plateau honing).
- The pitch angle of the honing lines in the cross hatch pattern should be about 30°. To achieve this, combine for example 40 strokes per minute with a rotational speed of 100 RPM.
- As a coolant, use honing oil. Light fuel oil 2-15 cSt can also be used.
- After honing, carefully clean the liner bore using a suitable brush, water (preferably hot), and soap or cleaning fluid. Alternatively, light fuel oil can be used. Then dry with a cloth and lubricate with engine oil for corrosion protection.

Table 10-1 Surface parameters according to EN-ISO-13565-2:1997

Rpk [µm]	Rk [µm]	Rvk [µm]	Mr1 [%]	Mr2 [%]
0.7 max.	1.0–2.5	2.0–4.2	10 max.	70–90

The honing equipment 800008 is delivered with the engine.

2 **Check the inner diameter of the cylinder liner.**

3 **Clean the cylinder liner cooling bores.** Clean the cooling bores in the collar by boring with a suitable drill bit (ø 9.5-10 mm).

10.4.2 Removing the cylinder liner

v10

Procedure

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

See chapter 12 Cylinder Head with Valves and chapter 11 Crank Mechanism Crankshaft, Connecting Rod and Piston.

2 **Remove the protecting cover and assemble the lifting tool. See *Fig 10-9*.**

CAUTION
Before lifting the cylinder liner, make sure that the fastening tool for cylinder liner (3) has been removed.

3 **Unscrew the fixing screws from the water jacket.**

4 **Lift the cylinder liner with water jacket 15-20 cm to enable removal of the sensor.**

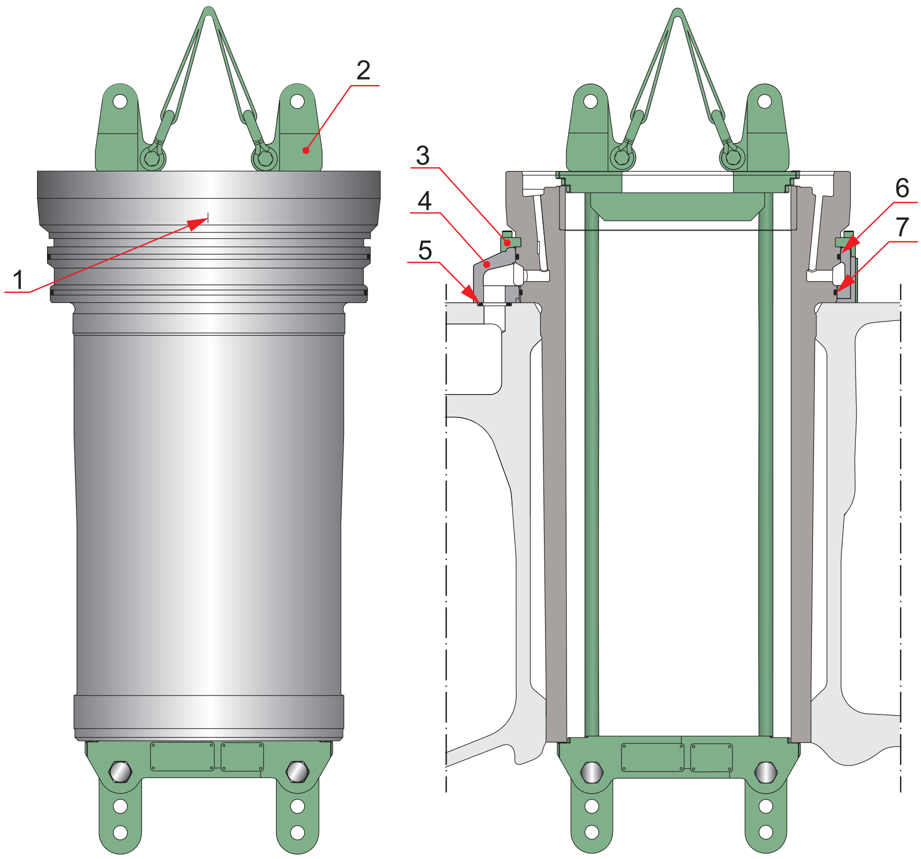
5 **Remove the temperature sensor.**

6 **Lower the liner carefully back into the bore of the engine block.**

7 **Tighten the fixing screws by hand.**

8 **Lift out the cylinder liner.**

9 **Remove the water jacket (4).**



1 Distinct mark
2 Lifting tool for cylinder liner
3 Fastening tool for cylinder liner
4 Water jacket
5 O-ring
6 O-ring
7 O-ring

Fig 10-9 Removing the cylinder liner

10.4.3 Mounting the cylinder liner

v13

Procedure

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

Use a fine grinding stone or emery cloth for cleaning, if needed.

2 **Check that the O-ring groove for the cooling water channel on the engine block is clean.**

Insert a new O-ring.

3 **Mount the water jacket (4), and tighten the fixing screws by hand.**

4 **Lubricate the guiding faces with grease, and assemble the lifting tool.**

See *Fig 10-9*.

5 **Check that the O-ring grooves of the cylinder liner are clean.**

Insert new O-rings. Lubricate the O-rings with soap or similar.

NOTE

Do not lubricate the O-rings in the cooling water spaces with oil based lubricants.

6 **Lower the liner carefully into the bore of the engine block.**

When the lower part of the liner touches the engine block, align the liner so that the distinct mark on the liner is directed towards the driving end of the engine. On the V-engine B-bank, align it so that the distinct mark on the liner is directed towards the free end of the engine. See *Fig 10-9*.

NOTE

Do not lower the cylinder liner completely yet, to ease the mounting of the temperature sensor.

7 **Lift the cylinder liner**

with water jacket 15-20 cm to enable assembling of the sensor (only in alternative design).

8 **Assemble the temperature sensor.**

9 **Lower the liner into the bore and remove the lifting tool.**

10 **Tighten the water jacket fixing screws to the stated torque.**

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

12 **Mount the piston with the connecting rod upper part, anti polishing ring, and cylinder head.**

See chapter 12 Cylinder Head with Valves and chapter 11 Crank Mechanism Crankshaft, Connecting Rod and Piston. Refill the cooling water.

13 **Check the O-ring seals in the water jacket while circulating cooling water.**

If there is an engine-driven cooling water pump, apply a 3-bar static pressure.

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11. Crank Mechanism: Crankshaft, Connecting Rod, Piston

11.1 Crankshaft

v4

The crankshaft is forged in one piece and provided with counter-weights 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. Separate instructions for the vibration damper are provided.

The crankshaft can be turned by a electrical turning device operating the flywheel.

11.1.1 Checking the crankshaft alignment

v7

Prerequisites

Checking the crankshaft alignment is always done on a thoroughly warm engine, immediately after the engine is stopped. The check should be carried out rapidly but carefully. Only the crankcase cover for the cylinder being measured should be opened and it should be closed immediately after measuring. It is recommended to switch off any forced ventilation close to the engine.

If you use a deflection indicator tool **800065**, fit between the crankshaft web centre marks.

Procedure

1 **Combine extensions with the transducer to the required length.**

2 **Connect cable on the measuring unit.**

3 **Turn on the measuring unit by pressing the Power button.**

Push "Light" if needed.

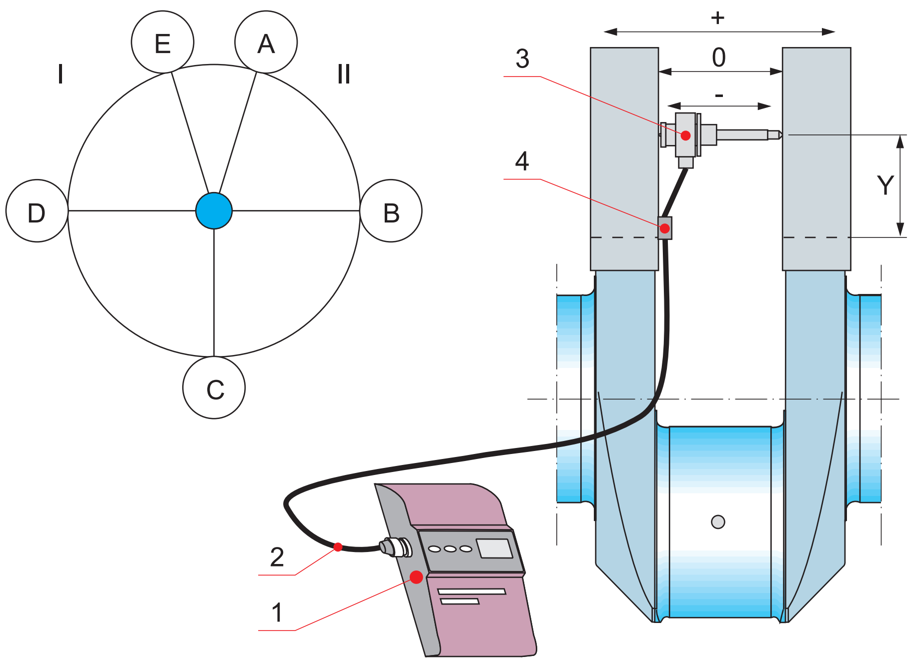
4 **Reset the measuring unit by pressing the Reset button.**

5 **Turn crank of the first cylinder near BDC (bottom dead centre) and fit the transducer, to the centre marks (marked with yellow paint mark) between two crank webs.**

Y indicates the distance between centre mark and contact surface of the counter weight and crank web which is 145 mm, see *Fig 11-1*.

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 11-1*

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



1 Electronic deflection indicator
2 Cable
3 Transducer
4 Cable holder

I Operating side, II Rear side (as seen from flywheel end)

5 Y : Distance between centre mark and contact surface of the counter weight and crank web

Fig 11-1 Transducer position and crankshaft alignment

7 **Read deflections while turning the crank in the marked positions according to** *Fig 11-1*.

The starting point for clockwise rotating engine is measuring point "A" and 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

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

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

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

For evaluating the vertical alignment the difference between C and it's opposite reading, i.e. the mean value E and A should be used.

a) on the same crank, the difference between two diametrically opposed readings must not exceed 0.08 mm after installing or re-aligning. Re-alignment is necessary if this limit is exceeded by more than 0.04 mm. Except the cranks in the both ends.

b) on two adjacent cranks, the difference between two corresponding readings must not exceed 0.06 mm, for crank No.1 to No.2 0.08 mm if flex. coupling and 0.06 mm if fixed coupling. Re-alignment is necessary if these limits are exceeded by more than 0.02 mm.

c) when the crank pin for cylinder 1 is at TDC, the reading should be negative, max. -0.12 mm (-0.13 mm if flex. coupling).

d) when the last crank pin in the free end is at TDC in case of PTO with support bearing, should the reading be positive max. 0.13 mm.

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

NOTE

In an engine having a normal ambient temperature (cold engine), the values must be based on experiences from the particular installation.

11.1.2 Measuring of thrust bearing axial clearance v4

Procedure

1 **Lubricate the bearings by running the prelubricating pump for a few minutes.**

2 **Apply a dial indicator, for instance, against the plane end surface of the flywheel.**

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

4 **Set the dial indicator to zero.**

5 **Move the crankshaft in the opposite direction, and read the axial clearance from the dial indicator.**

NOTE

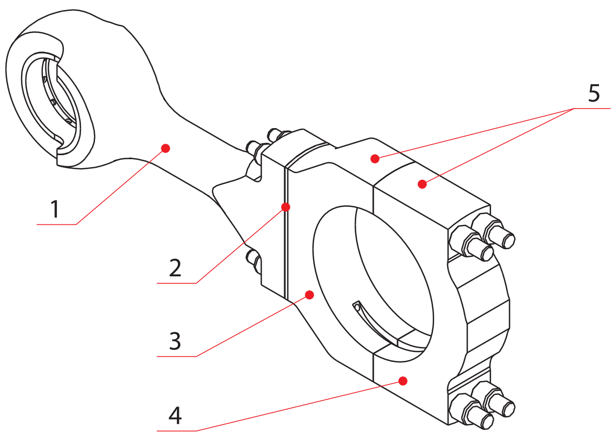
Repeat the movement of crankshaft to ensure that correct clearance is measured.

11.2 Connecting rod and piston v4

Connecting rod

The connecting rod is of a three-piece design. The combustion forces are distributed over a maximum bearing area. The relative movement between mating surface is minimized.

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



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

Fig 11-2 Connecting rod parts

Piston

The piston is of the composite type with an nodular cast iron skirt and a forged steel crown. 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 bores in the crankshaft, to the big end bearing, and further through bores in the connecting rod, gudgeon pin and piston skirt, up to the cooling space, and from there back to the oil sump.

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

11.2.1 Removing the piston and upper part of connecting rod v8

Procedure

1 **Remove the cylinder head according to Chapter 12, section: Removing the cylinder head.**

2 **Mount the fastening tool for cylinder liner 800123, see Chapter 10: Removing the cylinder liner .**

3 **Remove the anti-polishing ring.**

Insert the tool 800009 into the cylinder, by cranking the engine; the piston pushes the anti-polishing ring out, see *Fig 11-4*.

4 **Clean the threaded hole(s) in the piston crown and fasten the lifting tool 800012 using the hexagon screws M12X40 (3).**

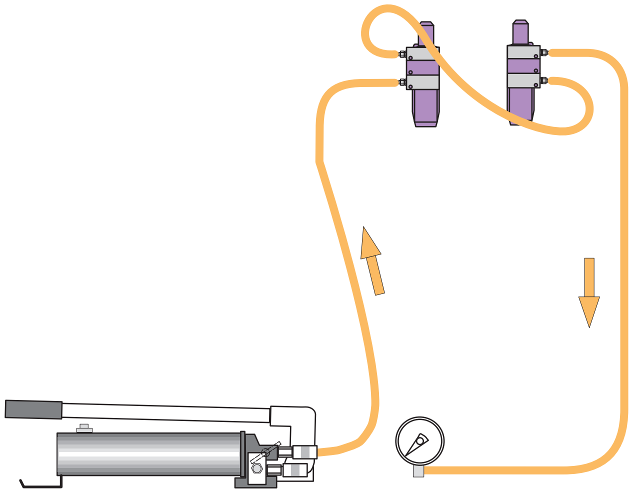
5 **Remove crankcase covers adjacent to the connecting rod on both sides of engine.**

6 **Turn the crankshaft to the BDC of the cylinder concerned.**

7 **Open the upper connection by lifting the distance sleeves into position on the connecting rod, see *Fig 11-4*.**

8 **Lift the hydraulic cylinder and screws as one package to position on the connecting rod, see *Fig 11-4*.**

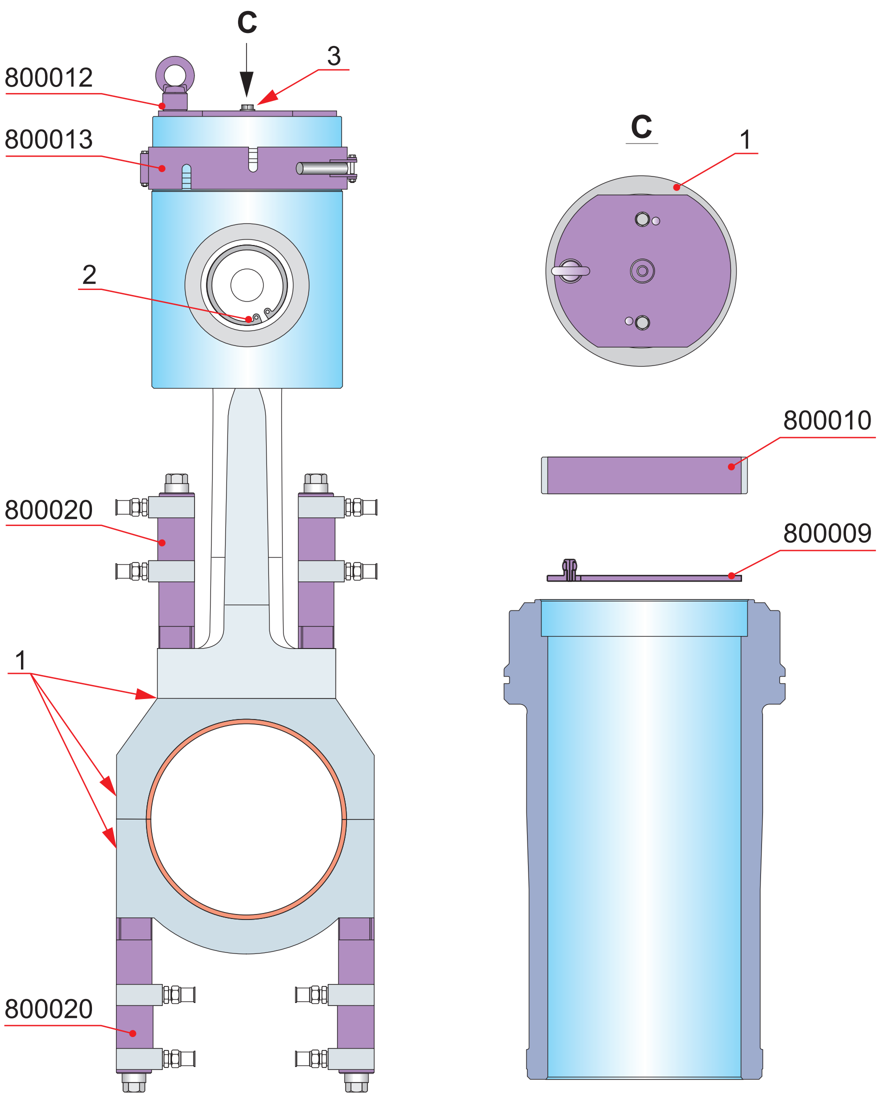
9 **Connect the hoses of the hydraulic pump 800053 and open the valve on the pump, see** *Fig 11-3***.**



1. *Lift the distance sleeve into position on the connecting rod.* 2. *Lift the hydraulic cylinder and screws as one package to position.* 3. *Connect hoses of the hydraulic pump 800053 and open valve on the pump.* 4. *Tighten the tool assembly, until the piston and cylinder is on the same level and open the nuts by 180°.* 5. *Close the valve and pump to required pressure. Open the nuts about half a turn.* 6. *Open the valve slowly to release the pressure and disconnect the hoses. Remove the hydraulic tool as one unit.*

Fig 11-3 Dismantling with hydraulic tools

10 **Tighten the tool assembly, until the piston and cylinder is on the same level and open the nuts by 180°.**



1 Cylinder number stamped
2 Securing ring
3 Screw

800009: *Dismounting tool for anti-polishing ring* 800010: *Assembly tool for piston* 800012: *Lifting tool for piston* 800013: *Clamp device for piston rings* 800020: *Hydraulic tightening tool for connecting rod nuts*

Fig 11-4 Piston and connecting rod assembly

CAUTION
The screws are overloaded if the maximum hydraulic pressure is exceeded. It is recommended to change the screws if the maximum hydraulic pressure is exceeded for any reason.

11 **Close the valve and pump to required pressure, see Chapter 07: Tightening Torques and Use of Hydraulic Tools.**

Open the nuts about half a turn. Open the valve slowly to release the pressure and disconnect the hoses. Remove the hydraulic tool as one unit.

12 **Remove the nuts.**

13 **Turn the crank pin of the cylinder to TDC.**

14 **Separate the upper part (1) from the big end (5) by lifting the piston, see *Fig 11-2*.**

> **CAUTION**
>
> Support the upper part of the connecting rod to avoid damaging the cylinder liner.

> **CAUTION**
>
> Separate the upper part (1) and the big end (5) in a straight line so that the guiding pins and screws are not damaged.

15 **Remove the shim (2), see *Fig 11-2*.**

> **NOTE**
>
> Do not mix the shim (2) with other connecting rod shims.

16 **Mount the guiding plug 800017 in the screw hole on the upper part of the connecting rod, see *Fig 11-13*.**

17 **Lift out the piston and the upper part of the connecting rod.**

18 **Repeat the above steps for the other connecting rod on the same crank pin on a V-engine.**

11.2.2 Changing the big end bearings v6

Procedure

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

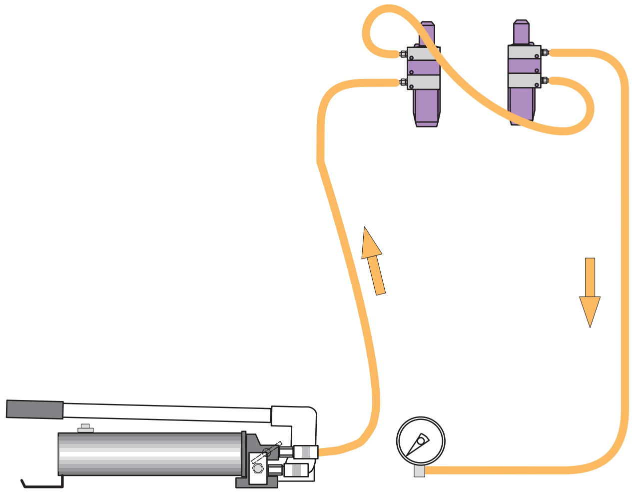
Open the indicator valve.

2 **Turn the crankshaft to BDC of the cylinder concerned.**

3 **Open the upper connection by lifting the distance sleeves into position on the connecting rod, see *Fig 11-4*.**

4 **Lift the hydraulic cylinder and screws as one package to position on the connecting rod, see *Fig 11-4*.**

5 **Connect the hoses of the hydraulic pump 800053 and open the valve, see *Fig 11-5*.**



1. *Lift the distance sleeve into position on the connecting rod.* 2. *Lift the hydraulic cylinder and screws as one package to position.* 3. *Connect hoses hydraulic pump 800053 and open valve on the pump.* 4. *Tighten the tool assembly, until the piston and cylinder is on the same level and open the nuts by 180°.* 5. *Close the valve and pump to required pressure. Open the nuts about half a turn.* 6. *Open the valve slowly to release the pressure and disconnect the hoses. Remove the hydraulic tool as one unit.*

Fig 11-5 Dismantling with hydraulic tools

6 **Tighten the tool assembly, until the piston and cylinder is on the same level, and open the nuts by 180°.**

> **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.

7 **Close the valve and pump to required pressure, see 07 Tightening Torques and Use of Hydraulic Tools.**

Open the nuts about half a turn. Open the valve slowly to release the pressure and disconnect the hoses. Remove the hydraulic tool as one unit.

8 **Remove the nuts.**

9 **Turn the crank pin of the cylinder concerned to TDC.**

10 **Mount the limiter 800018 in the lower part of cylinder liner and tighten the screw, see** *Fig 11-13*.

11 **Separate upper part and big end (5) by turning the crankshaft towards BDC.**

> **CAUTION**
>
> Support the upper part of the connecting rod to avoid damaging the cylinder liner.

> **CAUTION**
>
> To avoid damaging the guiding pins, the separation of the upper part (1) and the big end (5) should be done aligned.

12 **Remove the shim (2), see *Fig 11-2*.**

NOTE

Do not mix the shim (2) with other connecting rod shims.

CAUTION

Extreme care is required when using the turning device with the flute and/or limiter mounted in the crankcase.

13 **Turn the crankshaft towards the operating side to the position 55° from TDC by using the turning device.**

14 **Mount the mounting support 800102 on the upper stud of the crank case cover, see *Fig 11-13*.**

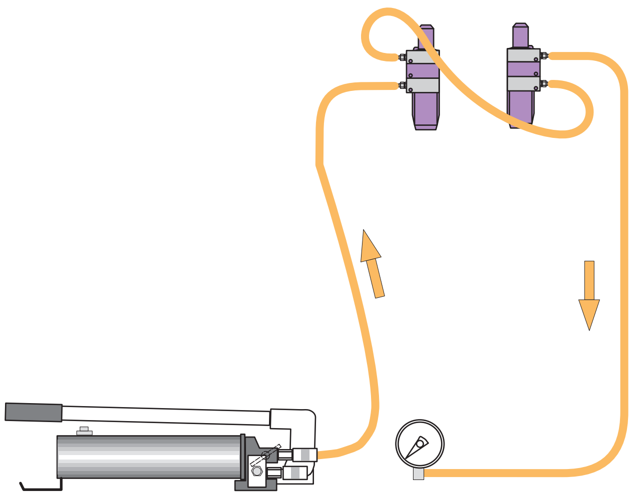
Tighten the nut.

15 **Lift the hydraulic tools 800020 into position.**

16 **Open the lower connection by lifting the distance sleeves into position on the connecting rod, see *Fig 11-4*.**

17 **Lift the hydraulic cylinder and screws as one package to position on the connecting rod, see *Fig 11-4***

18 **Connect the hoses of the hydraulic pump 800053 and open the valve, *Fig 11-6*.**



1. *Lift the distance sleeve into position on the connecting rod.* 2. *Lift the hydraulic cylinder and screws as one package to position.* 3. *Connect hoses hydraulic pump 800053 and open valve on the pump.* 4. *Tighten the tool assembly, until the piston and cylinder is on the same level and open the nuts by 180°.* 5. *Close the valve and pump to required pressure. Open the nuts about half a turn.* 6. *Open the valve slowly to release the pressure and disconnect the hoses. Remove the hydraulic tool as one unit.*

Fig 11-6 Dismantling with hydraulic tools

19 **Tighten the tool assembly, until the piston and cylinder is on the same level, and open the nuts by 180°.**

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.

20 **Close the valve and pump to required pressure, see 07 Tightening Torques and Use of Hydraulic Tools.**

Open the nuts about half a turn. Open the valve slowly to release the pressure and disconnect the hoses. Remove the hydraulic tool as one unit.

21 **Mount the mounting flute through the crank case openings on the lower crank case cover studs and tighten the nuts.**

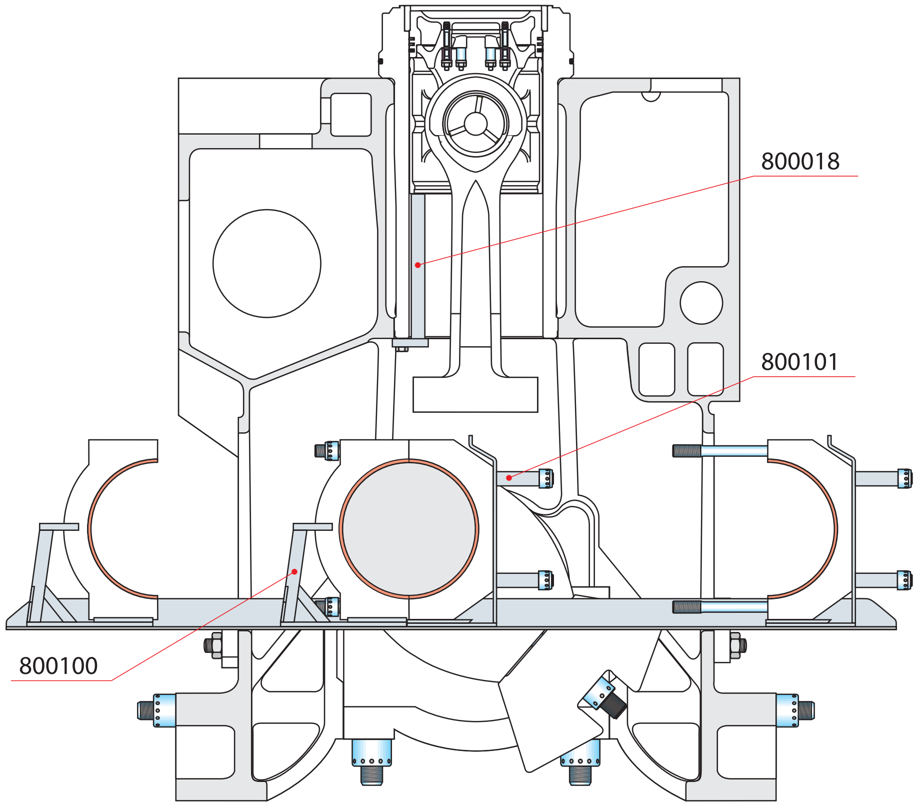
22 **Mount the supporting plate 800099 on the rear side of the engine on the lower crank case cover studs and tighten the nuts, see *Fig 11-13*.**

23 **Remove the nuts holding the big end halves together.**

24 **Mount the sledge 800100 in the mounting flute 800098 according to *Fig 11-7*.**

25 **Remove the mounting support 800102.**

26 **Mount the sledge 800101 on the studs and secure with the nuts, see *Fig 11-7*.**



800018: *Limiter for piston* 800101: *Mounting sledge* 800100: *Mounting sledge*

Fig 11-7 Removing and mounting the big end halves

27 **Pull lower part of the big end out of the crankcase, by using the sledge.**

Take care not to damage the crank pin. Support the lower part sideways and do not drop it.

28 **Pull the upper part of the big end out of the crankcase rear side of the engine by using the sledge.**

Support the upper part sideways and do not drop it.

CAUTION

Take care not to damage the crank pin or the threads of the studs.

29 **Remove the mounting flute.**

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

31 **For mounting, see section *11.2.6*.**

11.2.3 Removing the gudgeon pin and piston rings

v6

Procedure

1 **Remove the securing ring (2) *Fig 11-4* from the gudgeon pin hole in the piston, on the side where the gudgeon pin drawing number is located by using the pliers 800002.**

NOTE

Do not compress the securing ring more than required, to remove it from the groove.

2 **Drive out the gudgeon pin from the opposite side.**

For easy removal heat the piston to about 30°C.

3 **Remove the piston rings by using the piston ring pliers 800001.**

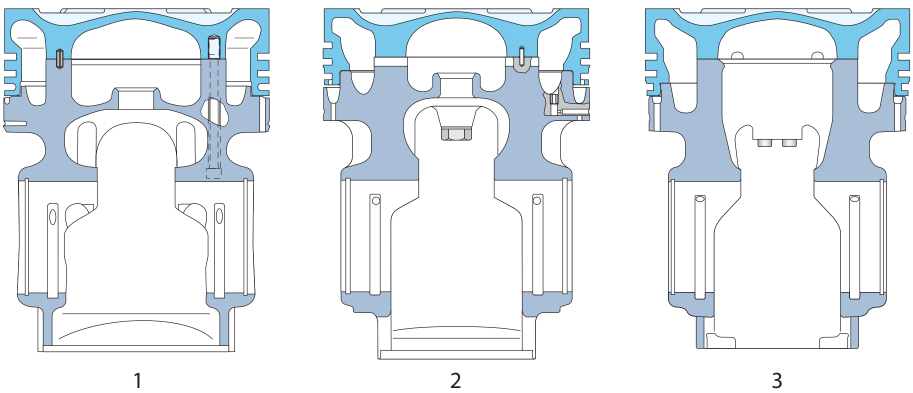
The design of the pliers prevents overstressing of the rings.

CAUTION

Using any other tool to remove the piston ring may overstress the ring.

11.2.4 Maintaining the piston

v4



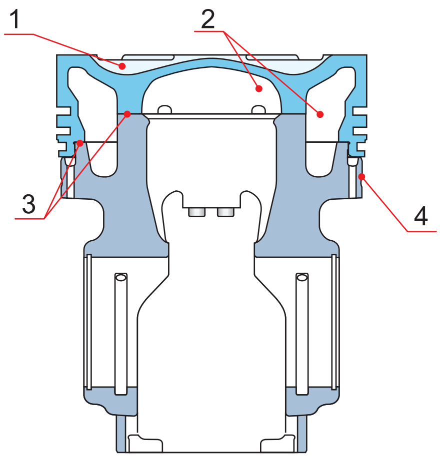
1. *Type 1 piston* 2. *Type 2 piston* 3. *Type 3 piston*

Fig 11-8 Pistons

Piston type	Fastening screws for the crown
Type 1	Four (4) M16 screws
Type 2	Two (2) M22 screws
Type 3	Four (4) M14 screws

The piston assembly must be dismantled:

- to inspect the mating surfaces between piston skirt and piston crown.
- to inspect and clean the cooling oil spaces.



1 Combustion space
2 Cooling oil space
3 Support surfaces
4 Running surface

Fig 11-9

NOTE

Clean all the parts carefully. An efficient carbon solvent should preferably be used to facilitate cleaning of the piston crown.

NOTE

Special care should be taken not to damage the piston surface/material.

CAUTION

Never use emery cloth on the piston skirt nor clean the piston skirt with chemical cleaning agents because the phosphate/graphite overlay may be damaged

11.2.4.1 Piston crown

Visual inspection

The combustion space (1) must be checked for corrosion and/or burning marks.

- If marks deeper than 2 mm are found, the piston crown should be replaced.
- If fretting is found on the support surfaces (3), remove high spots carefully using a very fine oil stone or scraper.

Deposits in the cooling oil space (2) thicker than 0.5 mm is an indication of contaminated lubricating oil. Such deposit layers can cause overheating of the piston crown. Clean the oil space carefully.

NOTE

Do not use sharp tools.

Crack detection test

Perform crack detection test on all surfaces by magnetic particle inspection (MPI) method. Use liquid dye penetrant if MPI equipment is not available.

NOTE

Cracks are not allowed.

CAUTION

Repair welding is not allowed.

Reconditioning

Please contact Wärtsilä for reconditioning of piston crowns.

11.2.4.2 Piston skirt

Visual inspection

Running surface

The running surface (4) of the skirt is coated with a graphite-phosphate layer.

CAUTION

Cleaning with an emery cloth or other abrasive is not allowed.

- Excessive wear marks and/or scoring/seizure marks on the running surface (4) may require replacing of the skirt.

Support surfaces

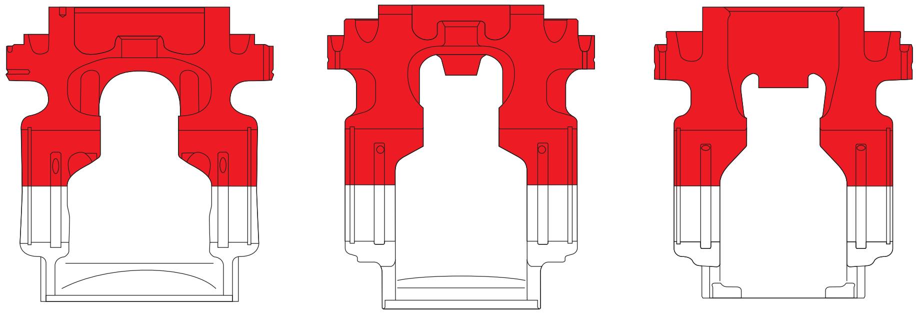
- If fretting or corrosion is found on the support surfaces (3), remove high spots carefully using a very fine oil stone or scraper.

Crack detection test

Perform a crack detection test of the entire piston skirt using a liquid dye penetrant.

Special attention must be given to :

- the upper part of the piston skirt
- the gudgeon pin bore with its supports to the upper part
- the circumferential part of the skirt.



1 2 3

1. *Type 1 piston* 2. *Type 2 piston* 3. *Type 3 piston*

Fig 11-10 Piston skirt

As piston skirts are cast pieces a crack detection test may also give indications for surface irregularities which are normal in castings. Indications exceeding 5 mm in length should be examined in detail. If a crack is confirmed, the piston skirt must be replaced.

11.2.4.3 Measurements

v2

Piston ring groove

The piston ring groove height must be measured for example with an inside micrometer according to the Measurement record.

Table 11-1 Measurement record for piston ring groove height

Engine type	Measurement record
W32	3211V022
W34SG	3411V023
W32DF	3211V031
32LN	3211V021

Support surfaces

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

Use tool set 848062 for the measurement.

NOTE

Not valid for the W32 Piston type 1 as it has only an inner support surface.

11.2.4.4 Assembling of pistons (All types)

v6

If the results of the inspection show that the piston can be reused, assemble the same pair of crown and skirt together again.

NOTE

Do not mix partly worn but reusable crowns and skirts, as the wear on contact surfaces will be different. A new or reconditioned crown or skirt can be assembled together with a used skirt or crown in good condition.

For more information on assembling a piston crown to a piston skirt, see chapter 07, Tightening Torques and use of hydraulic tools.

NOTE

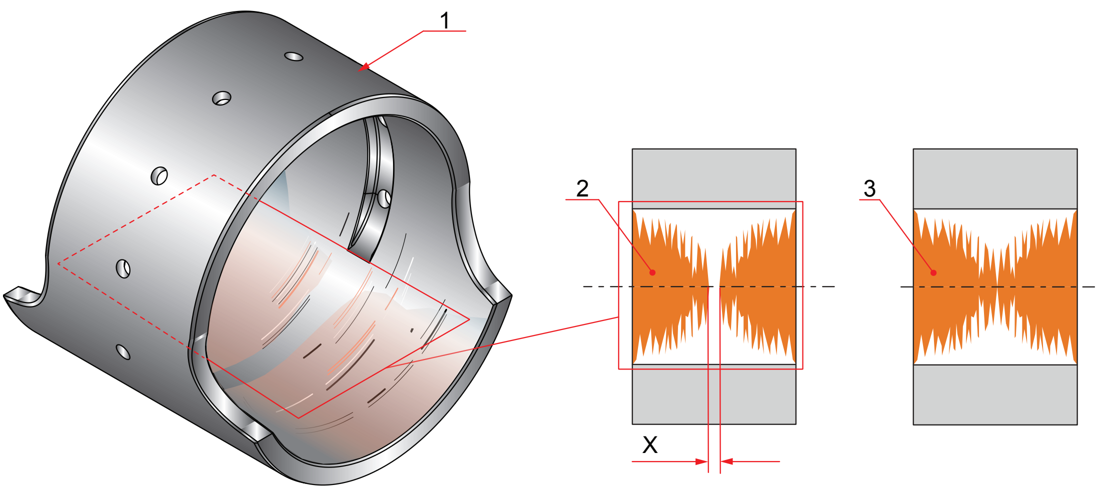
When mounting a new cylinder liner or honing the old liner, all piston rings must be replaced by new ones.

11.2.5 Maintaining the connecting rod

v3

Procedure

1 **Inspect the small end bearing bush visually at every piston overhaul for wear and damage.**



1 Bearing bush
2 Acceptable wear when some overlay metal is visible in gap X
3 Unacceptable wear

Fig 11-11 Wear pattern

NOTE

Replace the bearing bush, if the wear area extends across the bearing bush.

2 **Measure the connecting rod big end bore, according to the measurement record 3211V017.**

CAUTION

When measuring the big end bearing bore, tighten all the connecting rod screws (upper and lower) to the stated torque.

3 **Inspect the connecting rod visually and check for damages.**

Check the shank carefully marked with red in the figure.

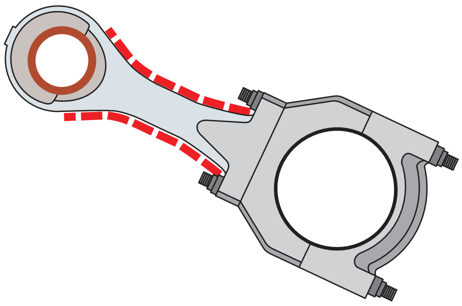


Fig 11-12 Connecting rod

WARNING

Do not use damaged connecting rods as it may put the operators and engine at risk. Surface damage (dents and scratches) on the connecting rod may lead to stress concentrations and eventually cause failure.

WARNING

- Do not dent or scratch any surface of the connecting rods when handling during overhauls or transport.
- For further advice contact Wärtsilä services.

4 **Replace bearing shells according to the maintenance schedule or whenever the bearing housing is split after more than 1000 hours since bearing change.**

Mark new bearings with the cylinder number.

CAUTION

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

11.2.6 Assembling and mounting the piston and connecting rod

v7

Procedure

1 **Lubricate the gudgeon pin, and mount it from the same side from which 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, see Fig 11-4. 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 (2).**

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 with a new one.

3 **Remove the protecting material from the crank pin and lubricate the crank pin with clean engine oil.**

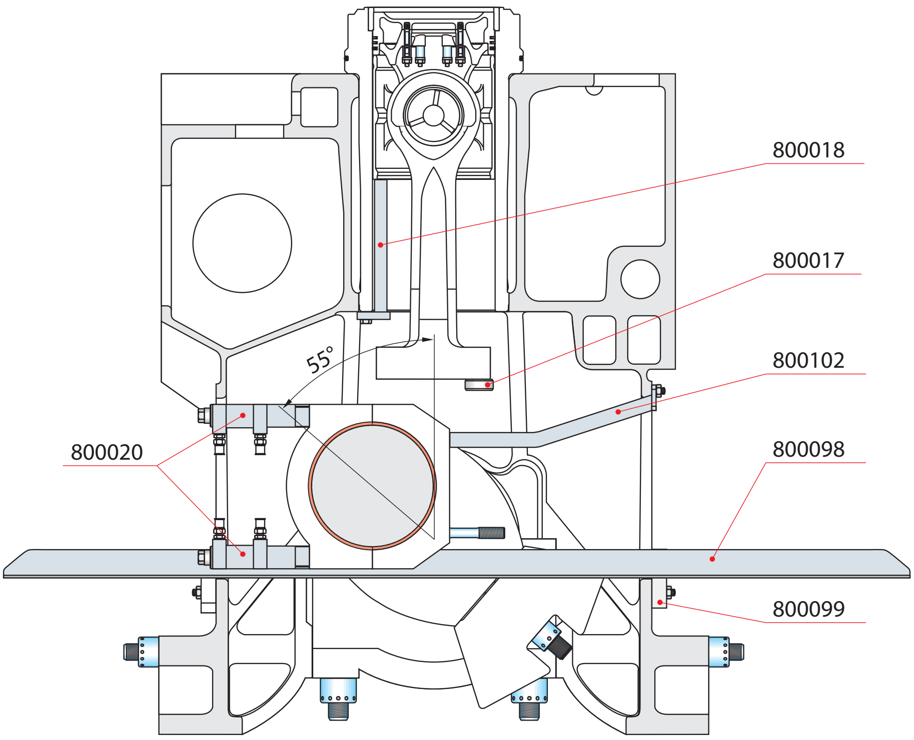
CAUTION

Extreme care is required when using the turning device with the flute and/or limiter mounted in the crankcase.

4 **Turn the crankpin of the cylinder to 55° before TDC.**

Before assembling the big end halves, fine turning with the handwheel may be required.

5 **Mount the mounting flute through the crank case openings on the crankcase cover lower studs and tighten the nuts, see *Fig 11-13*.**



800017: *Guiding plug* 800018: *Limiter for piston* 800020: *Hydraulic tool* 800098: *Mounting flute* 800099: *Supporting plate* 800102: *Mounting support*

Fig 11-13 Mounting tools for connecting rod

NOTE

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

6 **Clean the big end upper half carefully.**

Lubricate the bearing surface and back side of the bearing shell with oil. Mount the shell so that the lug guides in its groove.

CAUTION

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

7 **Lift the upper big end half with the sledge in the mounting flute.**

8 **Push the upper big end half carefully against the crankshaft, taking care not to damage the crank pin or bearing.**

9 **Clean the big end lower half carefully.**

Lubricate the bearing surface and back side of the bearing shell with oil. Mount the shell so that the lug guides in its groove.

CAUTION

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

10 **Lift the big end lower half onto the sledge.**

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

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

13 **Remove the sledge from the operating side of the engine.**

14 **Remove the sledge from the rear side of the engine.**

15 **Fit the mounting support 800102 on the upper crank case stud, see *Fig 11-13*.**

Tighten the nut.

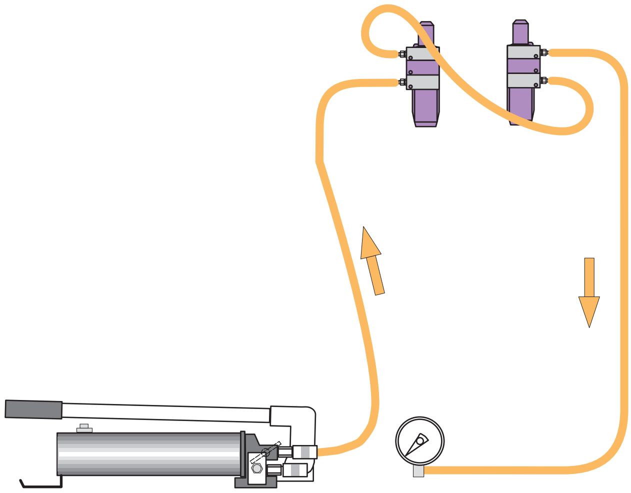
16 **Remove the mounting flute and supporting plate.**

17 **Lift the hydraulic tools 800020 into position.**

Lift the distance sleeves into position on the connecting rod, see *Fig 11-4*.

18 **Lift the hydraulic cylinder and screws as one package to position on the connecting rod, see *Fig 11-4***

19 **Connect the hoses of the hydraulic pump, 800053 and open the valve, see*Fig 11-14*.**



1. *Lift the distance sleeve into position on the connecting rod.* 2. *Lift the hydraulic cylinder and screws as one package to position.* 3. *Connect hoses of the hydraulic pump 800053 and open valve on the pump.* 4. *Tighten the tool assembly, until the piston and cylinder is on the same level.* 5. *Close the valve, tighten the tool and pump to required pressure. Tighten the nuts and release the pressure slowly.* 6. *Repeat steps 4 and 5.* 7. *Open the valve slowly and remove the hydraulic tool.*

Fig 11-14 Reassembling with hydraulic tools

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 any reason.

20 **Tighten the tool assembly, until the piston and cylinder is on the same level.**

21 **Close the valve and pump to required pressure, see Chapter 07: Tightening Torques and Use of Hydraulic Tools.**

Tighten the nuts and open the valve slowly to release the pressure.

22 **Repeat the steps 20 and 21.**

Disconnect the hoses and remove the hydraulic tool as one unit.

23 **Fasten the lifting tool 800012 to the piston crown, see** *Fig 11-4*.

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

25 **Mount the piston rings by using the pliers 800001.**

The rings should be placed with gaps located 120° in relation to each other. The marking "TOP" should be upwards.

Piston ring locations	
Groove #	Marking near the ring gap
I	"TOP GROOVE I"
II	"TOP C99 GROOVE II"
III	(oil scraper ring)

26 **Lubricate the piston and place the clamp device for piston rings, 800013, around the piston, checking that the piston rings slide into their grooves.**

27 **Mount the guiding plug 800017 in the screw hole on the upper part of the connecting rod, see *Fig 11-13*.**

28 **Mount the limiter for piston 800018 inside the cylinder liner.**

29 **Turn the crank pin of the cylinder to the BDC by using the turning device.**

CAUTION

Extreme care is required when cranking the engine while upper part of the connecting rod and big end are disconnected.

30 **Place the mounting tool 800103 into the cylinder liner.**

31 **Lower the piston/connecting rod upper part carefully into the cylinder liner.**

32 **Turn the lower part of the connecting rod straight upwards.**

Mount the shim (2), see *Fig 11-2*.

33 **Turn the crank pin of the cylinder to the TDC.**

NOTE

Check that guiding pins are in the right position.

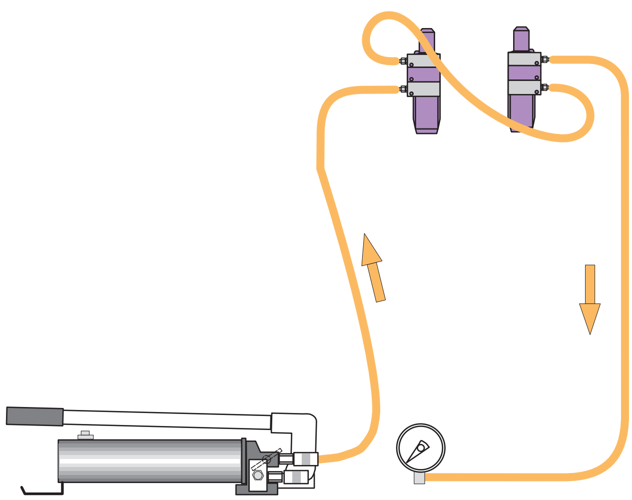
34 **Connect the upper part of the connecting rod and the big end, taking care not to damage the studs and threads.**

Remove the limiter.

35 **Turn the crankshaft counter-clockwise until the nuts can be mounted.**

Remove the mounting tools.

36 **Lift the distance sleeves into position on the connecting rod, see *Fig 11-15*.**



1. *Lift the distance sleeve into position on the connecting rod.* 2. *Lift the hydraulic cylinder and screws as one package to position.* 3. *Connect hoses of the hydraulic pump 800053 and open valve on the pump.* 4. *Tighten the tool assembly, until the piston and cylinder is on the same level.* 5. *Close the valve, tighten the tool and pump to required pressure. Tighten the nuts and release the pressure slowly.* 6. *Repeat steps 4 and 5.* 7. *Open the valve slowly and remove the hydraulic tool.*

Fig 11-15 Reassembling with hydraulic tools

37 **Lift the hydraulic cylinder and screws as one package to position on the connecting rod.**

38 **Connect the hoses of the hydraulic pump 800053 and open the valve, see *Fig 11-15*.**

39 **Tighten the tool assembly, until the piston and cylinder is on the same level.**

40 **Close the valve and pump to required pressure, see 07 Tightening Torques and Use of Hydraulic Tools.**

Tighten the nuts and open the valve slowly to release the pressure.

41 **Repeat the steps 39 and 40.**

Disconnect the hoses and remove the hydraulic tool as one unit.

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

NOTE

Check that the connecting rod can be moved axially after tightening.

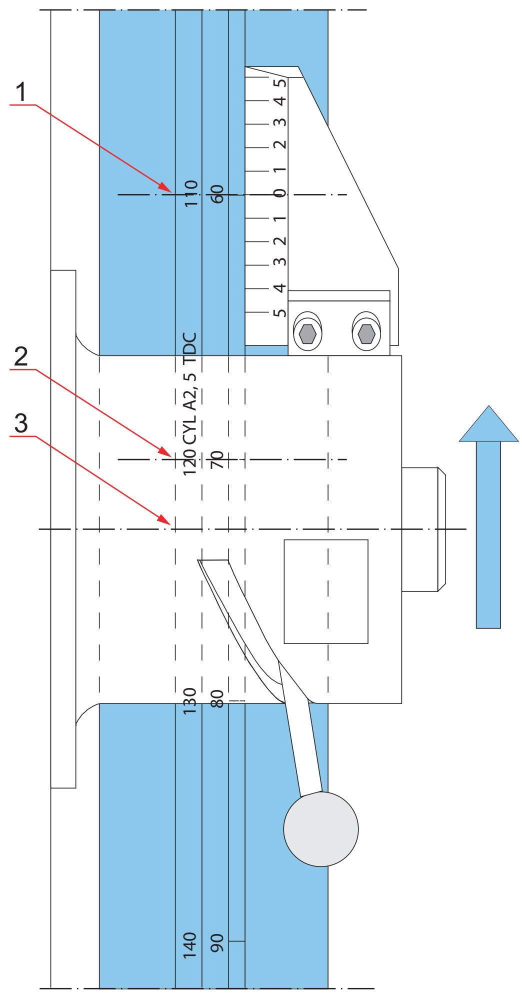
11.3 Markings on the flywheel

v15

The flywheel is provided with a 360° scale, starting from **TDC** for cylinder 1. TDC 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 and the other is at TDC at scavenging. See also firing order in chapter 01.

Firing intervals of an inline 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** for cylinder A1. TDC 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.



1 10°
2 Cylinder A2 TDC
3 Clockwise rotating engine

Fig 11-16 Markings on the flywheel

Example:*In this example of a clockwise rotating V engine, the fuel timing is read to 10° for cylinder A2 when the flywheel is in position shown in the figure above.*

12. Cylinder Head with Valves

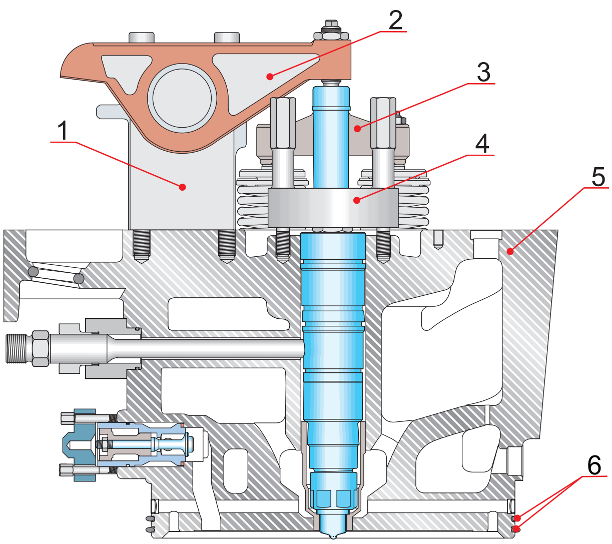
The cylinder heads are cast of nodular cast iron. Each cylinder head includes:

- Two inlet valves
- Two exhaust valves
- Safety valve
- Indicator valve
- Injection valve (see chapter 16 injection system)
- Starting valve (see chapter 21 starting air system)

The cylinder heads are individually tightened to the cylinder liner with four studs and hydraulically tightened nuts. A metallic gasket is sealing between the cylinder liner and the cylinder head. The combustion air, exhaust gas and water channels are connected to a common multiduct, which is connected to the cylinder head by six screws.

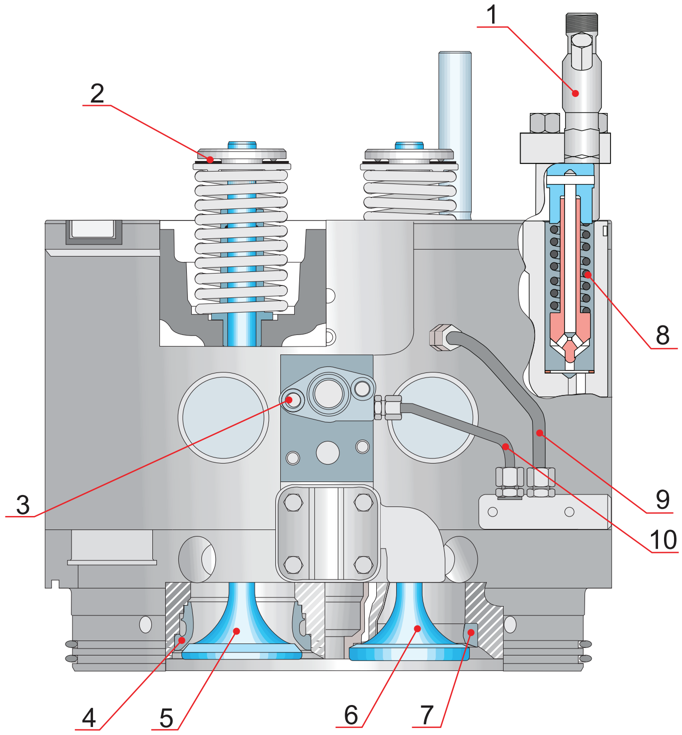
The four-screw and box-cone design is a traditional and well-proven design for cylinder heads. The benefit of four screws is not only the ease of maintenance but it also allows the design of large and correctly designed channels for combustion air and exhaust gases. In a heavy fuel engine the correct material temperatures are a crucial factor in ensuring the long lifetime of the components that are in contact with combustion gases.

Efficient cooling and a rigid design is best achieved with the double deck design in which the flame plate is relatively thin and the mechanical load is transferred to the strong intermediate deck. The most sensitive areas of the cylinder head are cooled by drilled cooling channels optimized to distribute the water flow evenly around the valves, exhaust seats and injection valve.



1 Bearing bracket
2 Rocker arm
3 Yoke
4 Locking piece
5 Cylinder head
6 O-rings

Fig 12-1 Cylinder head assembly



1 Indicator valve
2 Valve rotator
3 Screws for the connection piece fastening flange
4 Exhaust valve seat
5 Exhaust valve
6 Inlet valve
7 Inlet valve seat
8 Safety valve
9 Oil supply to the cylinder head
10 Clean leak fuel oil from the connection piece

Fig 12-2 Cylinder head assembly

12.1 Functional description of cylinder head with valves v4

The flame plate of the cylinder head is a part of the combustion chamber. During the combustion, the flame plate is exposed to high pressures and high temperatures. Combustion air is led from the air receiver through the multiduct and the cylinder head inlet channel into the cylinder. The air flow is governed by two inlet valves in the flame plate. In a similar way, the exhaust gas is led from the cylinder through the cylinder head exhaust channel and the multiduct to the exhaust manifold. The gas flow is governed by two exhaust valves.

The injection valve, as well as injection valve sleeve, is centrally mounted in the cylinder head. The injection valve sleeve holds the injection valve in position and separates the injection valve from the cooling water.

Each cylinder head is individually cooled by a water flow entering the cylinder head from the liner. The water flow to the liner comes from the engine block through one single bore. There are drilled cooling passages to the exhaust valve seats. The cooling water is collected to a single flow after passing the flame plate and the seat rings. The cooling water flows out from the cylinder head direct to the multiduct. Any possible air or gas in the cooling water is vented from the top of the multiduct.

The oil supply to the cylinder head comes through the pipe which is connected from the valve tappet housing. The oil is lead through the bearing bracket, rocker arm and adjusting screw to the yoke. The yoke is equipped with a drilling through which the oil sprays to the valve rotators and valves. The oil flows back to the oil sump trough the push rod protection pipes.

The injection pipe is also protected against hazardous leaks.

12.2 Removing the cylinder head

v7

Procedure

1 **Drain the cooling water.**

2 **Open the indicator valves.**

3 **Remove the side covers.**

4 **Remove the cylinder head covers.**

5 **Turn the engine until both the inlet and exhaust valves are closed and the piston is in TDC in this particular cylinder and remove the valve rocker arm bracket and the push rods.**

6 **Remove the fastening screws of the multiduct.**

7 **Remove the injection pipe, see chapter 16 Injection System.**

Protect all openings and pipe connections.

8 **Mount the cylinder liner fastening tool 800 123.**

9 **Assemble the hydraulic tools and the lifting device.**

Put the distance sleeves 800 096 and hydraulic cylinders 800 047 together and mount the set to the lifting tool DAAF008100.

10 **Lift the jacks to the cylinder head.**

11 **Dismantling with hydraulic cylinders.**

a **Tighten the hydraulic cylinders to the studs.**

b **Connect the hose between the jack and the hydraulic pump, according to** *Fig 12-3* **B.**

c **Open the pressure release valve (2) from the hydraulic pump.**

d **Tighten the cylinder with a 24 mm spanner to expel the oil from cylinder.**

e **Make sure that the piston in the hydraulic cylinder is at the same level with the jack body.**

f **Remove the hose and repeat steps a-d for the rest of the jacks.**

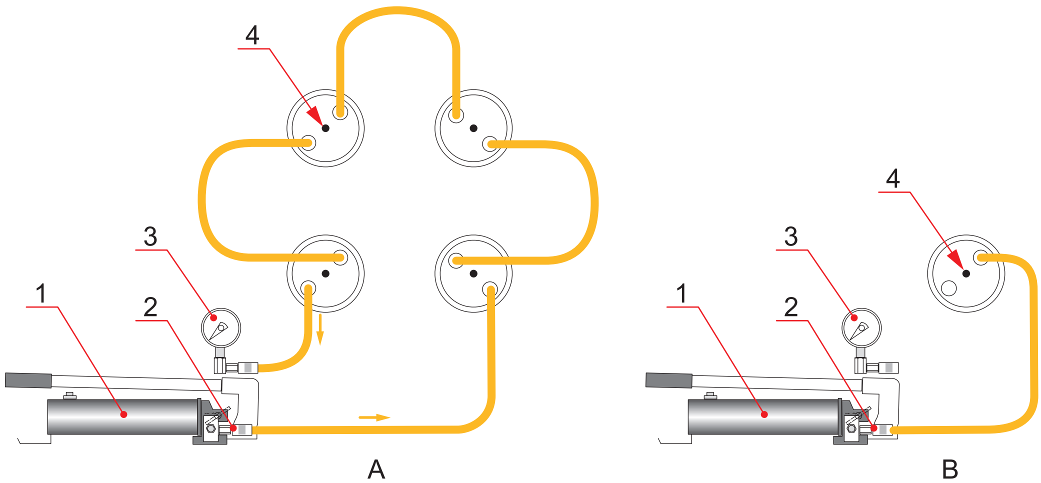
g **Turn the cylinders 180° counterclockwise.**

h **Connect the hoses according to** *Fig 12-3* **A.**

i **Close the pressure release valve (2) in the hydraulic pump. Pump the pressure till the pressure indicator (3) shows the stated value, see** *Fig 07-24* **in chapter 07 Tightening Torques and Use of Hydraulic Tools.**

j **Open the nuts about half a turn with the pin 800 049.**

k **Release the pressure and make sure that the nuts are loose.**



1 Hydraulic pump 800 053
2 Pressure release valve
3 Pressure indicator
4 Hexagon head 24 mm

Fig 12-3 Hydraulic cylinder

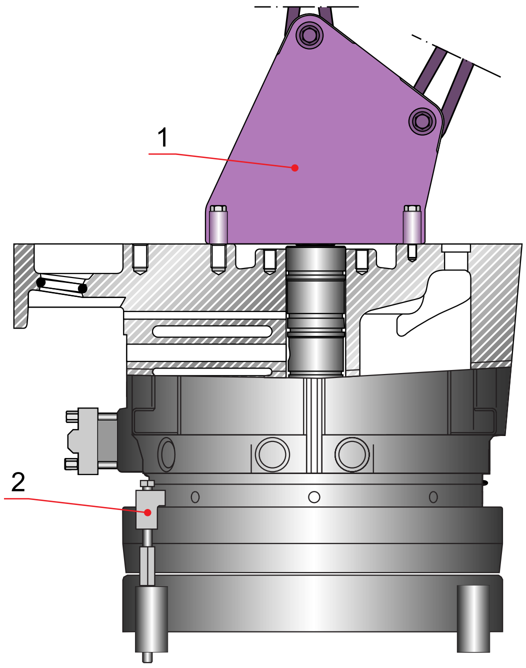
12 **Remove the hydraulic cylinders.**

13 **Remove the cylinder head nuts.**

14 **Apply the lifting tool (1) and lift off the cylinder head.**

NOTE

The fastening tool (2) must be installed to avoid the liner being lifted along with the cylinder head.



1 Lifting tool 800 026 for cylinder head
2 Fastening tool 800 123 for cylinder liner

Fig 12-4 Lifting the cylinder head

15 **Cover the cylinder opening with a piece of plywood or similar.**
Cover all air, fuel and oil connections with suitable plugs.

12.3 Maintaining the cylinder head v5

General maintenance of the cylinder head includes a thorough visual check, including water cooling spaces. Possible scale formation in cooling spaces can disturb the cooling effect and therefore it has to be cleaned. See *Fuel, Lubricating Oil, Cooling Water* .

- Inspect the combustion spaces for wear.
- Inspect and measure the valve seats.
- Inspect and measure the valves.
- Inspect the injection valve sleeve.
- Replace all O-rings with new ones.
- Check the water space for corrosion.
- Inspect and measure the valve guides and replace if necessary.
- Inspect the sealing surfaces between the cylinder head and cylinder liner. Recondition the surfaces if necessary.
- Carry out the pressure test for water leakage.
- Replace worn parts.
- Fill in the cylinder head overhaul report WS12V009 and check measurements against wear limits.

NOTE

It is recommended that the maintenance of cylinder head is carried out on the service trestle 800 159. The trestle helps turning the cylinder head upside down when required.

12.3.1 Inspecting and protecting the cylinder head screws v6

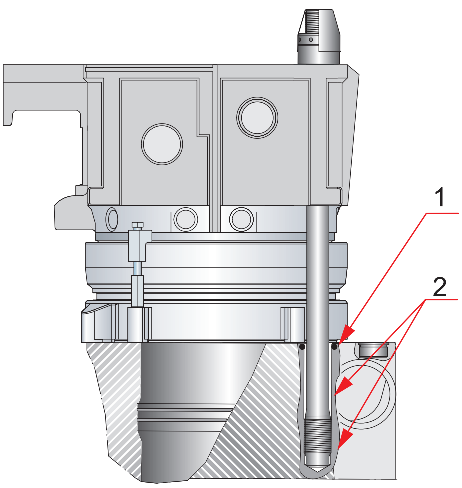
Procedure

1 **Inspect the cylinder head screws for corrosion.**

- If there are corrosion pits with a depth of less than 0.1 mm, polish them away.
- If the corrosion pits are deeper than 0.1 mm, change the screw.

CAUTION

If you find corrosion in the threads, it is recommended that you change the screws.



1 O-ring
2 Lubricant

Fig 12-5 Protecting the cylinder head stud against corrosion

2 **Lubricate the screw threads.**

Use a thin layer of corrosion protection agent Mobilarma 524 or similar.

3 **Mount the screw and tighten to specified torque.**

See chapter 7 for tightening torques.

4 **Fill the space between the screw and the engine block with Mobilarma 524 or similar.**

NOTE

Leave a space of about 2 mm for the O-ring.

5 **Mount the O-ring.**

12.4 Exhaust and inlet valves and seat rings v5

There are two inlet and two exhaust valves in the cylinder head. The inlet valves are bigger than the exhaust valves.

The valves move in cast iron guides, which are press-fitted in the cylinder head and can be replaced. Each valve guide has an O-ring (sealing against the valve stem), which is located at the top of the valve guide bore.

The valves are provided with one valve spring per valve, valve rotators and cotters.

Valve seat rings are fitted in the cylinder head for both inlet and exhaust valves. The exhaust valve seat rings are water cooled.

12.4.1 Dismantling the valves v7

Procedure

1 **Remove the rocker arm and injection valve from the cylinder head (see chapter 16 Injection System).**

2 **Fit the tool 800027 according to *Fig 12-6*.**

3 **Tighten the tool to the cylinder head by using the sleeve (6) and nut (5).**
The sleeve and nut are used for fastening the injection valve.

4 **Mount the hydraulic jack (2).**

5 **Mount the butterfly nut (3).**
Leave 30-40 mm (x) between the jack and the nut to allow the springs to expand, see *Fig 12-6*.

6 **Dismantle the valves with the hydraulic jack.**

a **Connect the hose (4) between the jack (2) and hydraulic pump (7), see *Fig 12-6*.**

b **Close the pressure release valve (9) from the hydraulic pump (7).**

c **Pump until the valves move down approximately 15 mm.**

d **Knock the valves against the valve seats with a plastic hammer.**

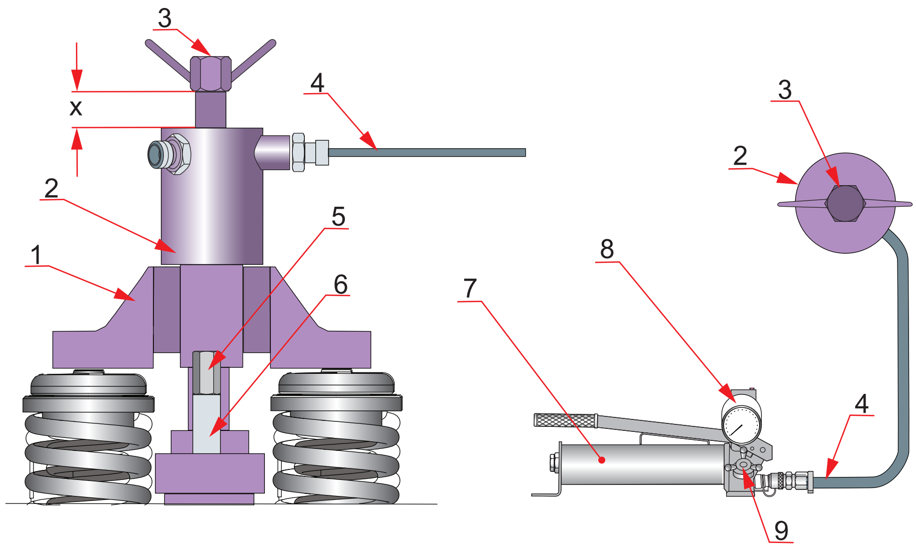
e **Remove the valve cotters.**

f **Open the pressure release valve (9) slowly.**

g **Open the butterfly nut (3) and remove the jack (2).**

h **Open the fastening nut (5).**

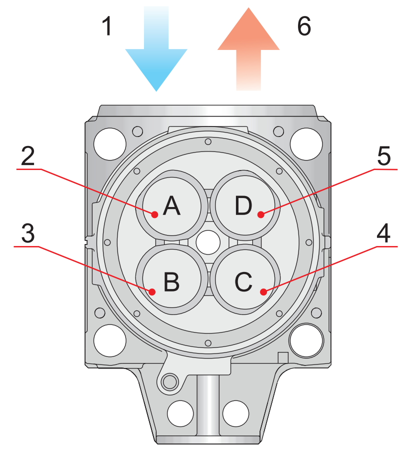
i **Remove the sleeve (6) and tool (1).**



x = 40 mm

1 Tool 800 027
2 Hydraulic jack 800 063
3 Butterfly nut
4 Hydraulic hose
5 Nut
6 Sleeve
7 Hydraulic pump 800 053
8 Pressure indicator
9 Pressure release valve

Fig 12-6 Tool assembly for dismantling valves



1 Intake air
2 Inlet valve A
3 Inlet valve B
4 Exhaust valve C
5 Exhaust valve D
6 Exhaust gas

Fig 12-7 Valve designation (bottom view)

7 **Remove the safety valve.**

See *section 12.9.1*.

12.4.2 Removing the seat ring

12.4.2.1 Removing the old seat ring with hydraulic tool v4

Prerequisites

The exhaust seat ring can most conveniently be removed hydraulically by using tool 846050, which can be ordered from the engine manufacturer. If the special tool is not available a scrapped valve can be used.

Procedure

1 **Mount the cylinder head to assembly trestle 800 159 and lock it.**

Using the trestle is the easiest way to turn the cylinder head upside down.

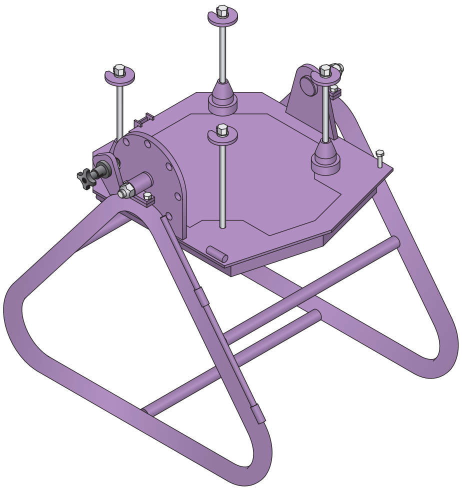


Fig 12-8 Assembly trestle

2 **Dismantle the valve seat with the hydraulic tool.**

a **Connect the hoses (3) between the jack (5) and hydraulic pump (1).**

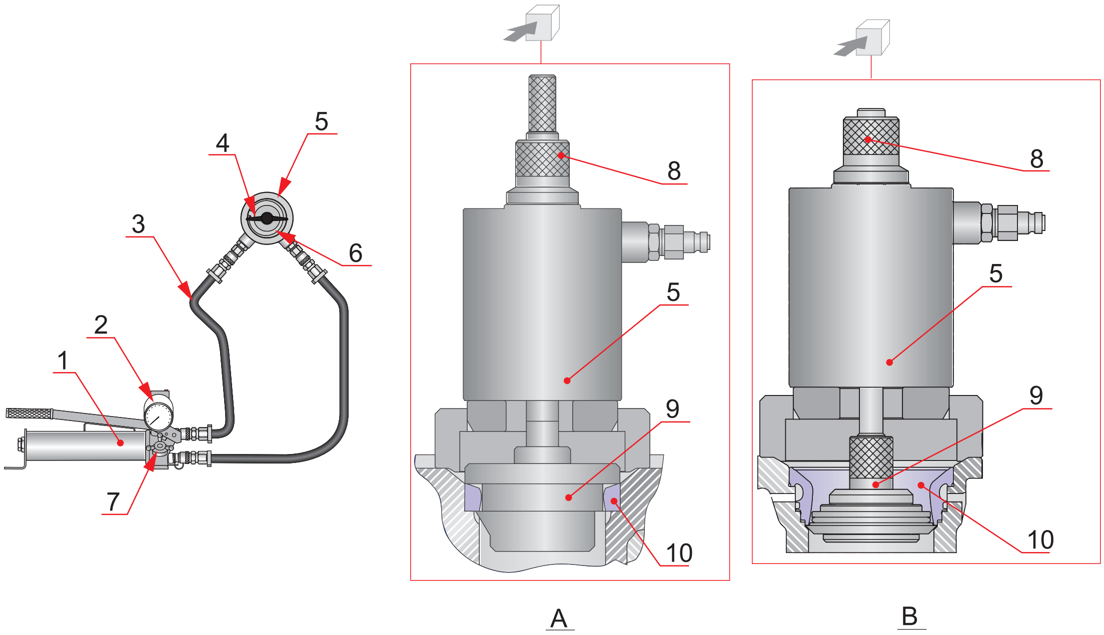
b **Close the pressure release valve (7) from the hydraulic pump (1).**

c **Pump until the valve seat comes off from the pocket.**

d **Open the pressure release valve (7) slowly.**

e **Open the pull screw (8) and remove the jack (5).**

f **Remove the extractor (6).**



A Extractor for inlet valve seat 800139 **B** Extractor for exhaust valve seat 800110

1	Hydraulic pump 800 053	6	Extractor valve seat
2	Pressure indicator	7	Pressure release valve
3	Hydraulic hose	8	Pull screw
4	Nut	9	Sleeve
5	Hydraulic jack 800 063	10	Valve seat

Fig 12-9 Changing the seat ring

12.4.2.2 Removing the old seat ring without hydraulic tool v1

If the tool is not available a scrapped valve can be used to remove the old exhaust and inlet seat ring.

Procedure

1 **Fit a scrapped valve to the seat.**

a **Weld it to the seat by means of electric beam welding or similar.**

b **The valve disc should preferably be machined to a diameter of 95-100 mm to get a better welding.**

2 **Press or knock out the seat ring.**

Be careful not to damage the valve guide.

12.4.3 Checking and reconditioning the valves and seats

v5

NOTE

Record all measurements and information to the cylinder head overhaul record WS12V009.

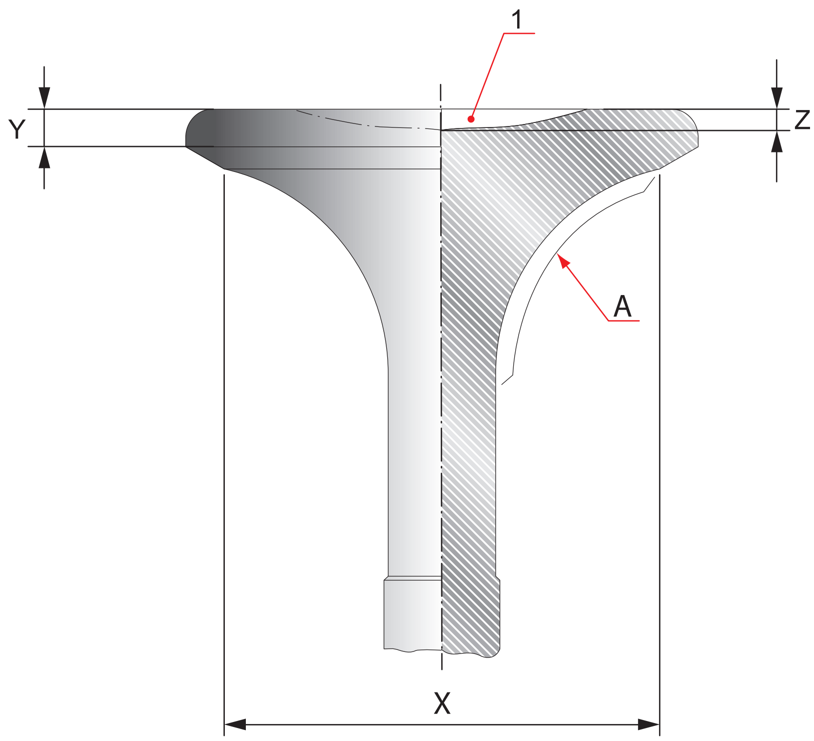
Procedure

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

NOTE

No scratches or notches are allowed on the valve surfaces, especially on the area marked with an "A" in *Fig 12-10*.

2 **Check the burn-off on the valve disc and compare the values with *Fig 12-10*.**



1 Burn-off area

Fig 12-10 Valve disc dimensions and burn-off area

Read the limit values given in chapter 06. If any of the dimensions exceed these limits, the valve must be replaced.

3 **Reconditioning of the inlet valve and inlet valve seat ring must be done by grinding or machining.**

If there is only slight pitting, lapping is enough. See *section 12.4.3.2* for machine grinding the valves and seats.

4 **Reconditioning of exhaust valve and exhaust valve seat ring must be done by grinding or machining.**

If the sealing faces are bright and there is a coherent sealing face, grinding is not necessary. See *section 12.4.3.2* for machine grinding the valves and seats.

NOTE
Blow-by increases the temperature and burns the O-ring, which results in water leakage into the cylinder. If blow-by has occurred, the O-ring for the corresponding valve seat ring must be changed.

5 **Before grinding, check the valve stem clearance by measuring the stem and guide.**
Change the worn parts if wear limits have exceeded.

6 **Press out the valve guide using tool 800126, if necessary.**

7 **Check the bore in the cylinder head.**

8 **Refit the valve guide.**
When refitting,

- Cooling in with liquid nitrogen is recommended.
- Pressing in with oil lubrication is also acceptable.

9 **After fitting in, check the guide bore and calibrate, if necessary.**

12.4.3.1 Lapping the valves v4

Prerequisites

If there are signs of pitting on the sealing faces of the valve, lap them by hand.

NOTE
Lapping is not allowed for Nimonic exhaust valves.

Procedure

1 **Fit the turning tool 800028 to the valve.**

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

3 **Rotate the valve back and forth in the valve seat with the turning tool 800028.**
While lapping, lift the valve from the seat periodically.

4 **Remove the smallest possible amount of material.**
It is not necessary to grind off all pits. Lapping is only for checking the contact surfaces between valve and valve seat.

5 **After lapping, clean the valve and the seat.**

12.4.3.2 Machine grinding the valves and seat rings v3

NOTE
Use the special tools available at Wärtsilä Services. For more information about grinding, refer to the instructions delivered with the tools.

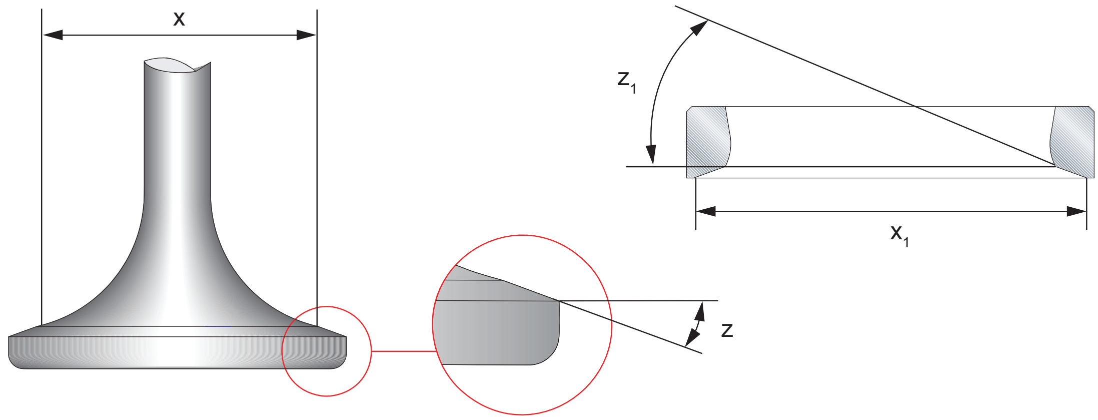
NOTE

The valves and the seat rings can only be machined until the allowable diameters are reached. After exceeding the limits, they should be replaced with new ones.

Procedure

1 **Grind the inlet valves and seat rings.**

For seat angle with tolerance and minimum seat face inner diameter of the inlet valve, see chapter 06 Adjustments, Clearances and Wear Limits.

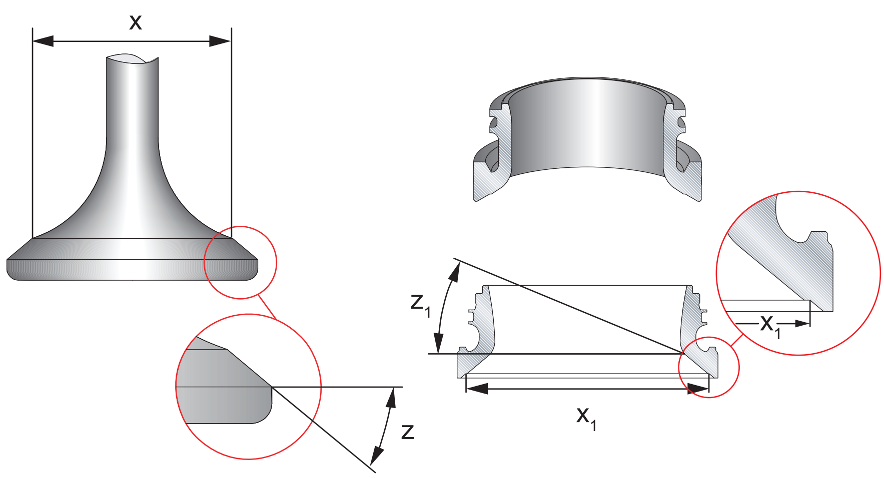


X. Inlet valve minimum allowable diameter
Z. Inlet valve angle
Z_1. Inlet valve seat angle
X_1. Inlet valve seat allowable diameter

Fig 12-11 Inlet valve and seat ring

2 **Grind the exhaust valves and seat rings.**

For seat angle with tolerance and minimum seat face inner diameter of the exhaust valve, see chapter 06 Adjustments, Clearances and Wear Limits.



X. Exhaust valve minimum allowable diameter
Z. Exhaust valve angle
Z_1. Exhaust valve seat angle
X_1. Exhaust valve seat allowable diameter

Fig 12-12 Exhaust valve and seat ring

NOTE

The maximum allowed grinding limit depends on the seat type. The small step in the seat indicates the grinding limit, see *Fig 12-12*.

12.4.4 Fitting a new inlet valve seat ring

v4

Procedure

1 **Clean the cylinder head bores carefully.**

   a **Grind gently with a grit 400 or finer emery cloth.**

   b **Clean the surface with Loctite 7063 cleaning spray.**

2 **Measure the bore diameter.**

3 **Assemble the new seat ring.**

   a **Freeze the seat ring with liquid nitrogen of -190°C, the cylinder head temperature being minimum 20°C.**

   b **Use the mounting tool for inlet valve seat ring 800172.**

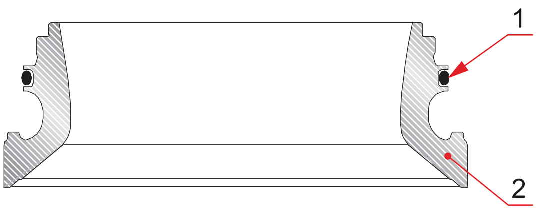
4 **Check the eccentricity of the sealing face in relation to the valve guide with tool 848124.**

   - If it exceeds 0.1 mm, the seat surface must be ground in with a seat grinding machine.
   - If it exceeds 0.25 mm, the seat must be replaced.

   Check the contact between the valve and seat with blue colour.

12.4.5 Fitting a new exhaust valve seat ring

v1



1 O-ring
2 Exhaust valve seat

Fig 12-13 Exhaust valve seat rings

Procedure

1 **Clean the cylinder head bores carefully.**

   a **Grind gently with a grit 400 or finer emery cloth.**

   b **Clean the surface with Loctite 7063 cleaning spray.**

2 **Measure the bore diameter in the cylinder head, see Chapter 06 Clearances and wear limits.**

3 **Heat up the entire cylinder head to 90-100°C with steam heating, burner or in a washing machine.**

NOTE

It is important that the entire cylinder head is heated up, not only the seat bore.

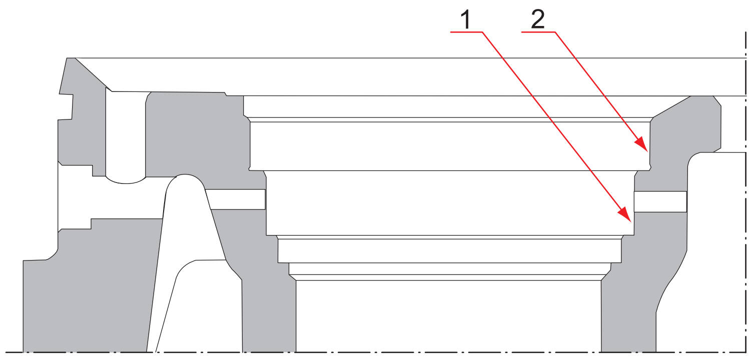
4 **Cool the valve seat ring to -18°C prior to fitting.**

Clean the seat with solvent before cooling.

NOTE

The O-ring may get damaged if a lower temperature is used.

5 **Lubricate the cylinder head lower bore (1) and chamfer using a water-soap solution or Molykote 55 (387056) O-ring grease.**



1 Cylinder head lower bore
2 Cylinder head upper bore

Fig 12-14 Cylinder head bores

NOTE

The soap used in the water-soap solution should have a pH ~7 and a mixture ratio ~1:2.

6 **Apply a thin smooth layer of Loctite 620 locking compound on the cylinder head upper bore (2).**

7 **Mount the O-ring to the valve seat and lubricate with the water-soap solution or Molykote 55 (387056) O-ring grease.**

8 **Mount the exhaust valve seat with one of the following methods:**

a **Put the seat ring into a guiding bush and press in the seat with a guided arbor. A tool 800148 is also available. This tool can be ordered from the engine manufacturer.**

b **Insert the seat ring by using a new or reconditioned exhaust valve. Knock on the valve until the seat ring is correctly seated.**

NOTE

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

9 **Check the eccentricity of the sealing face in relation to the valve guide.**

- If it exceeds 0.1 mm, the seat surface must be ground in a seat grinding machine. A tool 848124 is also available for checking the eccentricity. This tool can be ordered from the engine manufacturer.
- If it exceeds 0.25 mm, the seat must be replaced.

10 **Pressure test the cylinder head water side before mounting.**

a **Connect the pressure test device 2V84H0114 (1) to the cylinder head.**

b **Fill up the cylinder head with hot water.**

c **Connect the pressure testing device (2) 3V84H0123 to the cylinder head.**

d **Connect the hose (3) from the water pump (4) to the pressure testing device (2).**

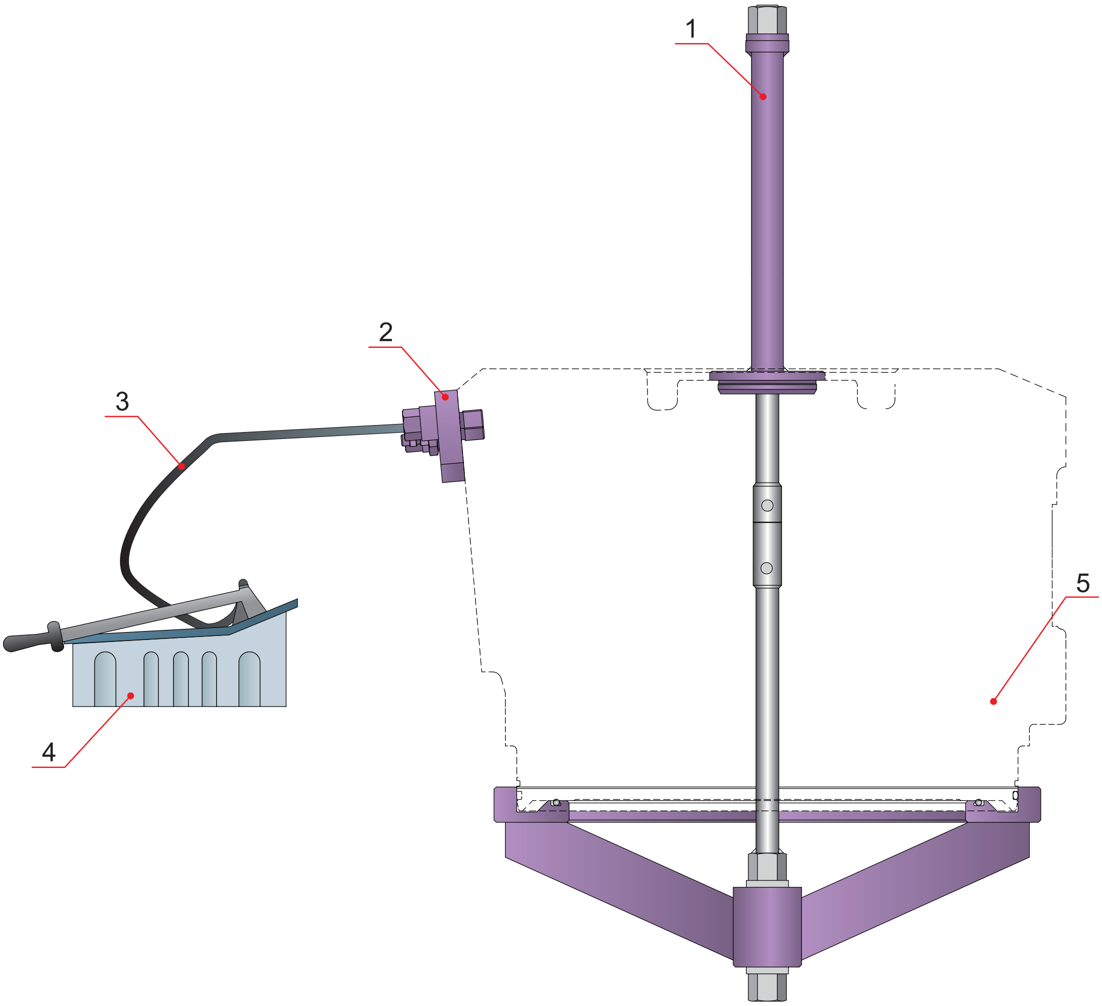
NOTE

The water pump (4) has an integrated pressure gauge.

e **Test the cylinder head with a test pressure of 10 bar.**

Continue the pressure test for 15 minutes. Check for leakages.

f **Remove the pressure testing devices.**



1 Pressure testing device 2V84H0114
2 Pressure testing device 3V84H0123
3 Hose
4 Water pump
5 Cylinder head

Fig 12-15 Pressure testing device

12.4.6 Assembling the valves

v4

Procedure

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

2 **Put new O-rings in the valve guides.**

3 **Lubricate the valve stems with engine oil.**

4 **Install the valves to the marked positions and check for free movement.**

5 **Install the valve springs and valve rotators.**

6 **Fit the tool 800027 according to *Fig 12-6*.**

7 **Tighten the tool to the cylinder head by using the sleeve (6) and nut (5).**
The sleeve and nut are used for fastening the injection valve.

8 **Mount the hydraulic jack (2).**

9 **Tighten the butterfly nut (3).**

10 **Mount the valves with the hydraulic jack.**

See *Fig 12-6*.

a **Connect the hose (4) between the jack (2) and hydraulic pump (7).**

b **Close the pressure release valve (9) from the hydraulic pump (7).**

c **Pump until the springs move down by approximately 10 mm and the valve cotters can be installed.**

d **Open the pressure release valve (9) slowly, while ensuring that the valve cotters remain in correct position.**

e **Open the butterfly nut (3) and remove the jack (2).**

f **Open the fastening nut (5).**

g **Remove the sleeve (6) and tool (1).**

11 **Use a pen marker to make a position mark on each valve rotator.**

Knock each valve stem with a non-recoiling hammer in axial direction to ensure proper fitting of the cotters and the rotation of the valves.

12 **Mount the safety valve.**

See *section 12.9.2*.

13 **Mount the starting air valve**

See chapter 21 starting air system.

14 **Mount the injection valve.**

See chapter 16 injection system.

12.5 Mounting the cylinder head

v9

Prerequisites

- Clean the sealing surfaces.
- Replace the cylinder head gasket and multiduct gasket with new ones with rivets.
- Replace the O-rings for push rod protecting pipe connections (upper and lower) and other sliding connections with new ones. Lubricate the O-rings with engine oil.

Procedure

1 **Fit the push rod protecting pipes.**

2 **Apply the lifting tool 800026 to the cylinder head.**

3 **Lift up the cylinder head.**

Clean the sealing surfaces and replace the O-rings for the cylinder head. Lubricate the O-rings and connecting surfaces of the liner with rubber grease or soap-water solution.

4 **Mount the cylinder head.**

NOTE

Make sure that all four sliding connections are in place.

5 **Mount the multiduct screws.**

Apply heat resistant grease to the screws and the collar of the screw head. Tighten the screws by hand.

6 **Mount the cylinder head nuts and tighten them by hand.**

7 **Install the distance sleeves 800096 and hydraulic cylinders together and mount the complete cylinders to the lifting tool DAAF008100.**

Lift the tools in place.

8 **Tighten the cylinder head nuts.**

a **Tighten the hydraulic cylinders to the studs.**

b **Connect the hose between the jack and hydraulic pump *Fig 12-3* B.**

c **Open the pressure release valve (2) from the hydraulic pump.**

d **Tighten the cylinder with a 24 mm spanner to expel the oil from the cylinder.**

e **Make sure that the piston in the hydraulic cylinder is at the same level with the jack body, that is, the piston is on the bottom of the jack.**

f **Remove the hose and repeat steps b-e for the rest of the jacks.**

g **Connect the hoses according to *Fig 12-3* A.**

h **Close the pressure release valve (2) in the hydraulic pump. Pump the pressure till the pressure indicator (3) shows the stated value (step 1), see chapter 07 Tightening Torques and Use of Hydraulic Tools.**

i **Tighten the nuts with the pin 800 049.**

NOTE

Count the pinhole turns. Each nut should turn the same amount.

j **Repeat steps d) and e).**

k **Close the pressure release valve (2) in the hydraulic pump.**

Pump the pressure till the pressure indicator (3) shows the stated value (step 2), see chapter 07 Tightening Torques and Use of Hydraulic Tools.

l **Tighten the nuts with the pin 800 049.**

m **Release the pressure.**

n **Disconnect the hoses and remove the hydraulic tools.**

CAUTION

Change the cylinder head screws, if the maximum pressure is exceeded when using the hydraulic tool.

9 **Tighten the multiduct screws to the stated torque.**

a **Carry out the tightening according to the given sequence see *Fig 07-6* in chapter 07.**

b **Carry out the second tightening according to the given sequence.**

c **After 50 running hours when the engine is in hot condition, tighten the multiduct must for the third time according to the given sequence.**

10 **Adjust the yoke if necessary.**

See *section 12.6*.

11 **Fit the rocker arm bracket and tighten the screws to torque stated in chapter 07 Tightening Torques and Use of Hydraulic Tools.**

Make sure that the cylinder concerned is in TDC at firing.

12 **Adjust the valve clearance.**

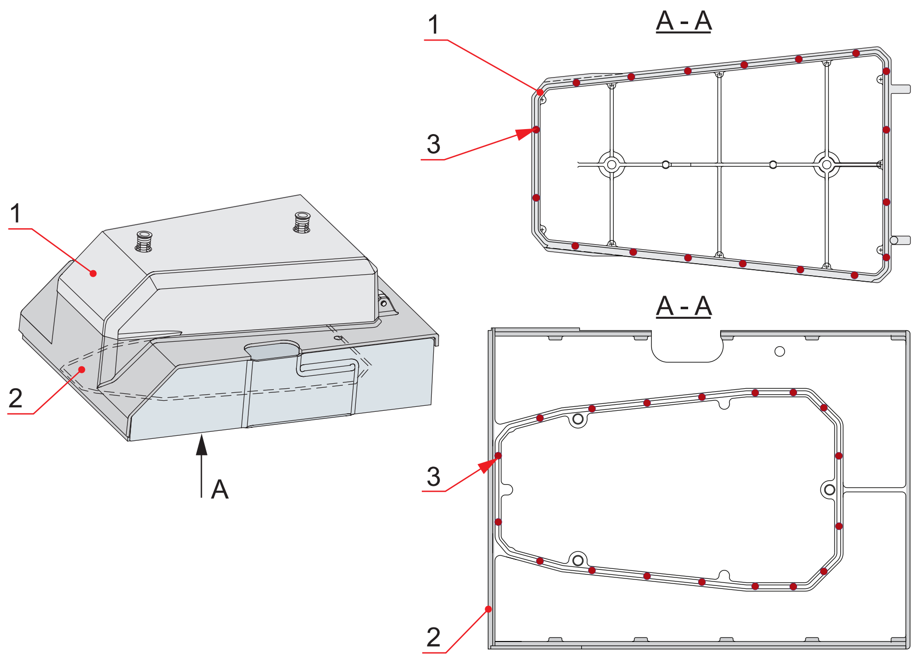
See *section 12.7* and chapter 06 Adjustments, Clearances and Wear Limits for clearances.

13 **Mount the injection pipe and tighten to the torque stated in chapter 07 Tightening Torques and Use of Hydraulic Tools.**

Tighten the screws to the torque given in *section 07.1*.

14 **Close the cylinder head cover.**

Renew the hose gaskets for the cover. The hose gaskets must be glued at points with Bostik-glue A3. Close the side cover.



1 Upper cover
2 Lower cover
3 Glue points

Fig 12-16 Cylinder head cover

Postrequisites

Before starting, fill the engine cooling water system. Turn the crankshaft two revolutions, with the indicator valves open, check for leakages.

12.6 Adjusting the yoke

v4

Procedure

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

2 **Loosen the counter nut (2) of the adjusting screws (1) and rotate the adjusting screw (1) counter-clockwise by two turns.**

3 **Loosen the counter nut (4) of the adjusting screws (3) on the yoke (5).**

4 **Turn the yoke adjusting screws (3) in the counter-clockwise direction one turn to provide enough clearance.**

5 **Press the yoke against the valve stem and downwards near the adjusting screw.**

Screw down the adjusting screw (3) until it touches the valve end. Mark the position of the spanner (position a). See *Fig 12-17*.

6 **Keep screwing down till the yoke tilts and the guide clearance is on the other side.**

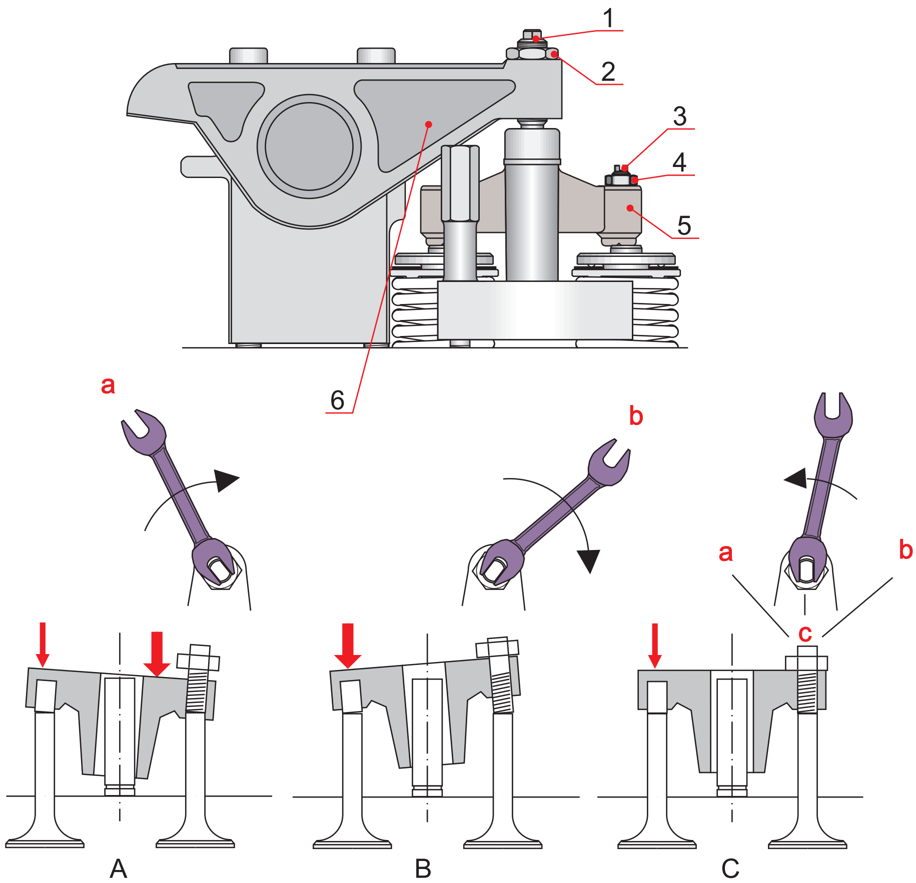
The fixed end of the yoke starts lifting from the valve stem. Mark the position of the spanner (b). See *Fig 12-17*.

7 **Turn the adjusting screw counter-clockwise to the middle position between "a" and "b", and lock the counter nut of the adjusting screw.**

This position is called “c”. See *Fig 12-17*.

NOTE

The yoke can be adjusted by using a dial indicator.



1 Adjusting screw for rocker arm
2 Counter nut
3 Adjusting screw for valve yoke
4 Counter nut
5 Yoke
6 Rocker arm

Fig 12-17 Adjusting the yoke

12.7 Adjusting the valve clearance

v3

Adjust the valve clearance at room temperature (20°C) or at operating temperature.

Procedure

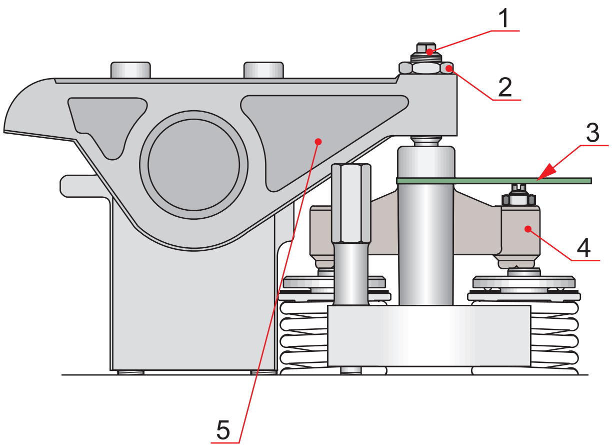
1 **Turn the crankshaft to TDC at ignition for the cylinder concerned.**

2 **Open the counter nut (2).**

See *Fig 12-17*.

3 **Hit the push rod side of the rocker arm with a plastic hammer to remove the oil film between the components.**

4 **Open the adjusting screws (1) one turn and place the clearance feeler gauge (3) (800 030) between the counter nut (2) and yoke (4).**



1 Adjusting screw for rocker arm
2 Counter nut
3 Feeler gauge 800 030
4 Yoke
5 Rocker arm

Fig 12-18 Adjusting the valve clearance

5 **Turn the adjusting screw until the valve starts to open.**

6 **Loosen the adjusting screw slowly until the valve clearance feeler can be moved with slight force.**

7 **Lock the counter nut (2).**

12.8 Indicator valve

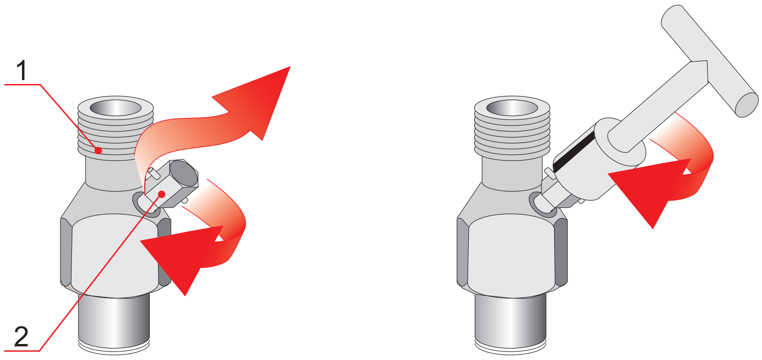
v5

The construction of the indicator valve is such that the pressure in the cylinder tightens it. Consequently the force needed to close the valve is relatively low. The valve has a left-handed cock and is opened and closed respectively as follows.

- Use the T-handle wrench 800 031 to open and close the indicator valve (1).
- The cock (2) moves upward when closing clockwise.

NOTE

Always use the special handle when closing.



1 Indicator valve
2 Cock

Fig 12-19 Open and close Indicator valve

CAUTION
When the indicator valve is opened, it must be turned open fully and then closed by half a turn. The indicator valves may be damaged if the valves are opened fully when the engine cools down.

12.8.1 Operating and maintaining the indicator valve

v4

CAUTION
Always use the T-handle wrench 800 031 to open and close the indicator valve.

Procedure

1 **When starting the engine.**

a **Close the indicator valves.**

Do not use excessive force when closing the valves.

2 **When stopping the engine.**

a **Open the indicator valves.**

The valves should be opened fully and then closed by half a turn.

3 **When opening the indicator valve for measuring the cylinder pressure.**

a **Tightening to open position by force must be avoided.**

WARNING
When measuring the maximum pressure while the engine is running, watch out for grease sprays from the indicator valve.

4 **When closing the indicator valve after measuring the cylinder pressure.**

Do not use excessive force when closing the valve.

5 **Apply high temperature resistant lubricant (up to 1000°C) to the valve stem thread if it does not move easily.**

12.8.2 Maximum firing pressure v3

The Maximum firing pressure "Pf" has to be measured at the indicator valve. The mean value is at least 32 cycles. Measure the Pf by using pressure indicator 848 033. For more information on operation and adjustments of the amplifier, see pressure indicator instructions in the pressure tester manual.

12.9 Safety valve v3

Each cylinder head is equipped with a spring-loaded safety valve. This valve prevents the build-up of excessive pressure in the cylinder, emitting an alarm sound when the limit is exceeded. The blow-off pressure is stamped on the top of the valve.

Replace the safety valve immediately if it shows any signs of leakage during operation.

NOTE

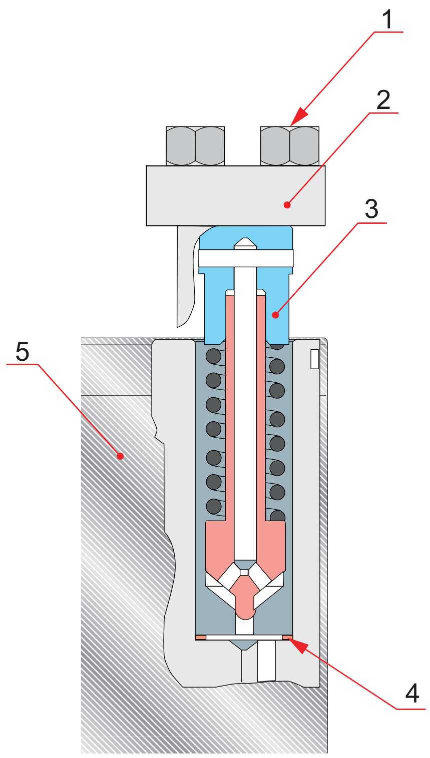
The safety valve can be readjusted and pressure tested in the nearest Wärtsilä workshop.

CAUTION

If the safety valve opens, do not restart the engine until you have found out the reason for this.

12.9.1 Removing the safety valve

v1



1 Nut
2 Flange
3 Safety valve
4 Sealing ring
5 Cylinder head

Fig 12-20 Safety valve

Procedure

1 **Open the nuts (1).**

2 **Remove the flange (2).**

3 **Remove the safety valve (3) and the sealing ring (4).**

12.9.2 Mounting the safety valve

v1

See *Fig 12-20*.

Procedure

1 **Lubricate the safety valve with high temperature lubricant.**

2 **Mount the safety valve (3) with new sealing ring (4).**

3 **Mount the flange (2).**

4 **Tighten the nuts to the stated torque.**
See chapter 07 Tightening Torques and Use of Hydraulic Tools.

12A. Testing the cylinder tightness

Prerequisites

A tool can be used to control the cylinder and valve tightness.

NOTE
Test the cylinder tightness immediately after the engine has stopped.

Procedure

1 **Turn the piston to ignition TDC (all valves closed) for the cylinder concerned.**

12A.1 Connecting the tool for Wärtsilä 32

v12

Procedure

1 **Connect the tool to the indicator valve in open position.**

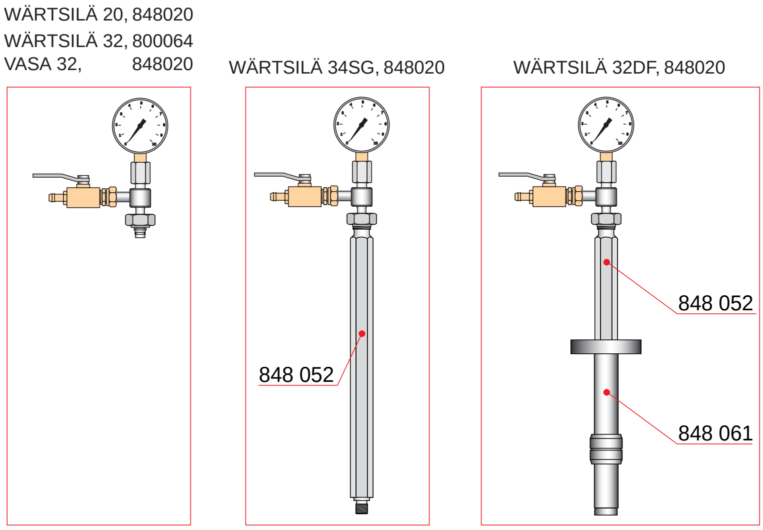


Fig 12A-1 Testing the cylinder tightness

2 **Measure the cylinder tightness.**
See, *section 12A.2*.

12A.2 Measurement

v5

Prerequisites

During the test:

- Keep the prelubricating pump running.
- Keep the turning gear engaged.

Procedure

1 **Connect air to the tool with a pressure of 6 bar.**

2 **Open the valve on the tool.**

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 seconds 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.
- 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

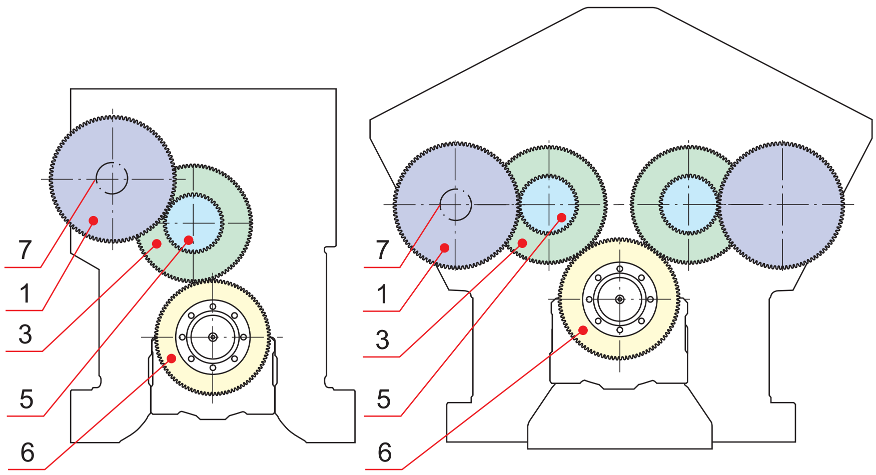
13.1 Camshaft driving gear

v7

The crankshaft drives the camshaft (7) through a gearing. The gearing consists of a gear wheel ring (6) that is split and fixed to a flange on the crankshaft with axial screws (26), see *Fig 13-6*, two intermediate gears (3 and 5), and a camshaft driving gear (1), see *Fig 13-1*.

The bearing pieces of the intermediate wheels are journalled in the engine block. The camshaft driving wheel (1) is fixed between camshaft extension piece (2) and bearing piece (8) by the hydraulic bolt (15). For the speed governor drive, a helical gear wheel (13) is located at the end of the camshaft. Lubricating oil nozzles provide lubrication and cooling of the gearing, see *Fig 13-6*.

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



1.*Drive gear for camshaft* 3.*Bigger intermediate gear for camshaft drive* 5.*Smaller intermediate gear for camshaft drive* 6.*Gear wheel for crankshaft* 7.*Camshaft*

Fig 13-1 Camshaft driving gear

13.2 Intermediate gears and camshaft gear

v7

The intermediate gear wheels are case-hardened. The wheels have a common shaft and are fixed to each other with a friction connection. The lubrication for the bearings is arranged through drillings in the crankshaft and the engine block and from a distributing pipe to the wheels through the nozzles.

The basic adjustment of valve timing and fuel injection can be done from the intermediate gear wheel or camshaft gear. The timing can be adjusted if the gear wheels or the camshaft wheels are rotated in relation to each other.

CAUTION
If the valve timing is not correct, the valves and pistons may come in contact with each other. This may cause serious damage to the engine.

13.2.1 Maintenance of camshaft gearing v4

Check the condition of the gears regularly. Measure tooth backlash and bearing clearances, see Adjustments, Clearances and Wear Limits. Early detection of any tooth damage can prevent serious engine damage.

13.2.2 Basic adjustment of valve timing v6

Prerequisites

The basic adjustment of valve timing can be done in two different ways:

1 By changing the relative position between the intermediate wheels (3) and (5), see *Fig 13-1*.

2 By changing the relative position between the camshaft gear (1) and camshaft (7), see *Fig 13-1*.

If the relative position between the gears and camshaft is changed, the base timing needs to be done before the injection timing.

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

The base timing needs to be done only if the relative position between the gears and camshaft is changed.

NOTE
In-line engine: Only cylinder 1 needs to be checked during camshaft base timing.

NOTE
V-engine: Clockwise-rotating engine Check cylinders A1 and B1 during camshaft base timing. Counterclockwise-rotating engine The cylinder to be inspected on B-bank depends on the firing order: • 12V, cylinders A1 and B4 • 16–20V, cylinders A1 and B5 Check the cylinders during camshaft base timing.

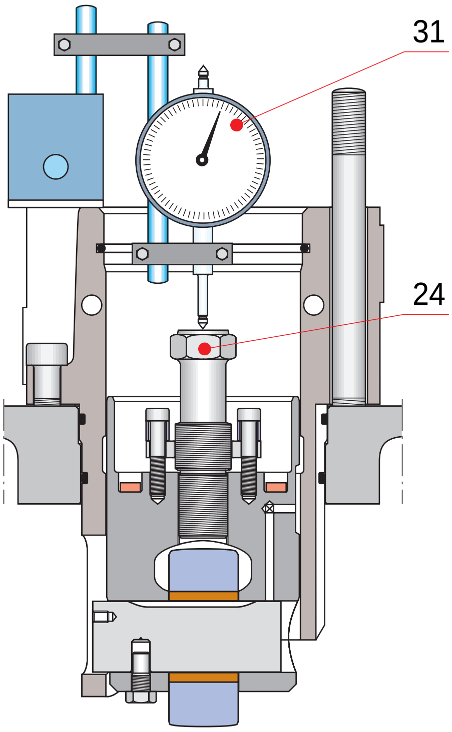
Procedure

1 **The basic adjustment of valve timing can be done with or without removing the injection pump.**

- When basic adjustment of valve timing is done with removing the injection pump:

a **Remove the injection pump on cylinder No. 1.**
See chapter Injection system.

b Place a dial indicator (31), at the adjusting screw (24) for the injection pump tappet.
See *Fig 13-2*.



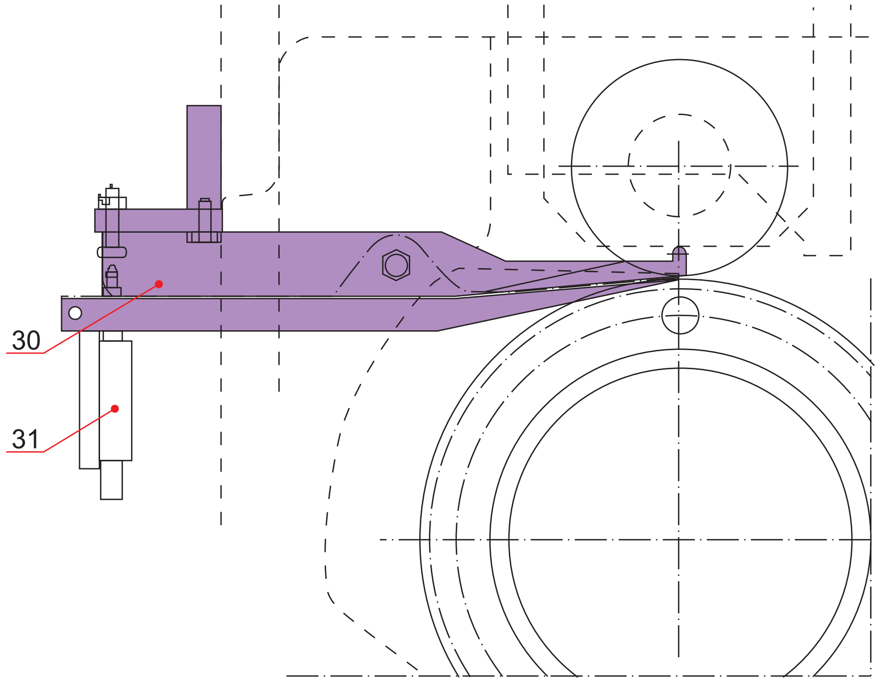
24. *Adjusting screw* 31. *Dial indicator*

Fig 13-2 Measuring the basic adjustment with dial indicator

- When basic adjustment of valve timing is done without removing the injection pump:

a **Use the tool 800 135 to check the timing.**

See *Fig 13-3*.

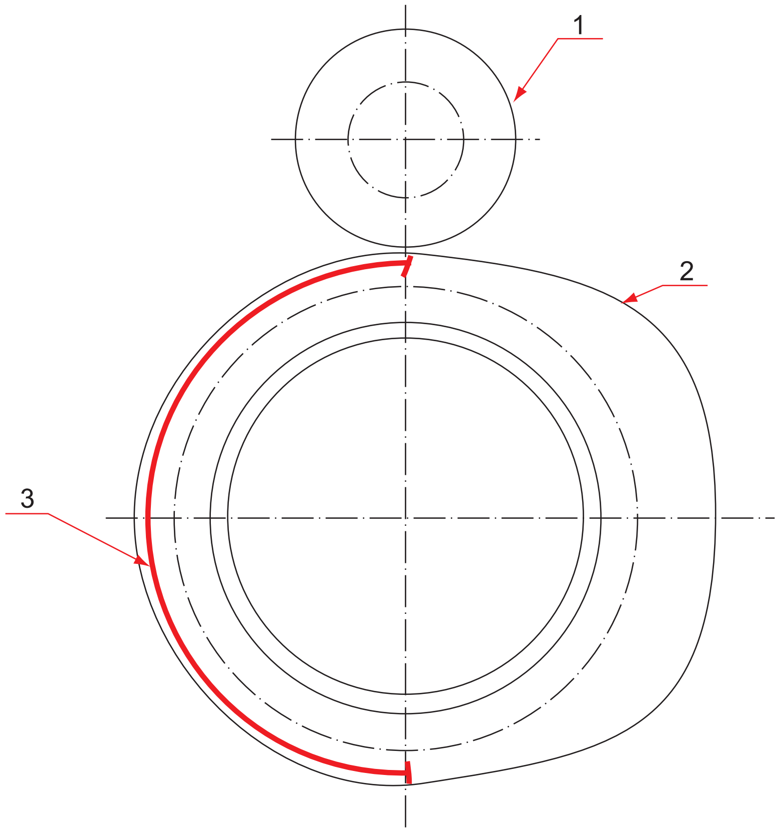


30. *Tool 800 135* 31. *Dial indicator*

Fig 13-3 Measuring the basic adjustment with tool 800 135

2 **Turn the engine until the injection pump tappet roller of cylinder No.1 (on V-engine A1) position is on the base circle of the camshaft.**

See *Fig 13-4*. Adjust the dial indicator to zero.



1. *Injection pump tappet roller* 2. *Camshaft* 3. *Base circle*

Fig 13-4 Camshaft base circle

3 **Turn the engine by the turning device in the direction of the rotation until the dial indicator (31) shows 6 mm lift.**

See *Fig 13-2* or *Fig 13-3*.

NOTE

It is recommended to do the final turning by using the hand wheel of the turning device. Make sure that the degrees on the flywheel are read correctly. See Contents, Instructions, Terminology.

4 **Read the timing at the flywheel pointer as degrees before TDC (top dead center).**

The timing of the engine can be found from Engine Test Protocol which is delivered with the engine.

- If the timing differs from the stated value, proceed as follows.

5 **Timing adjustment can be change in two different ways:**

By loosening the intermediate gears or by loosening the camshaft gear, see *Fig 13-1*.

6 **For loosening the intermediate or camshaft gear follow the instructions, see *section 13.2.4* and *section 13.2.5*.**

CAUTION

Turning of engine with the hydraulically tightened nut loosened is allowed only for some degrees (if the rocker arms are not removed) to adjust the timing. There is a great risk that the pistons and valves come in contact of each other.

7 **Turn the crankshaft to obtain the correct value.**

If needed, turn the engine some degree against rotation direction (clearance movement only). Then rotate the engine back in the rotational direction until the pointer at the flywheel corresponds to the specified timing (6 mm tappet lift) that is the base timing value, see Engine Test Protocol.

8 **For tightening the intermediate or camshaft gear, see** ***section 13.2.6*** **and** ***section 13.2.7*****.**

9 **On a V-engine, repeat steps 1 to 8 on B-bank.**

Before adjusting the B-bank, read the following special instructions for V-engine.

Special Instructions:

- For V-engines, turn the engine in direction of rotation when moving from A-bank to B-bank.
- The V-angle between the banks (A and B) is 55° and this is the base value when moving from A- bank to B-bank during base timing. This value is only to ensure that the engine is rotated in the correct direction.
- If the engine is equipped with mixed injection timing, set the camshaft base timing on the B-bank exactly the same as for cylinder A1. For example (for a clockwise-rotating engine): Engine Test Protocol mentions A1=10° and B1=9°. In this example, the base timing B1 has to be set to 10°.

13.2.3 Adjusting the injection timing v8

Prerequisites

The injection pump timing can vary due to manufacturing tolerances in the pumps, cams and gears or if the engine has been modified. To get the best possible results, make sure that the fuel pump has been adjusted properly and according to the setting table, see the Engine Test Protocol.

NOTE

Adjust the injection timing for all cylinders.

NOTE

If you adjust the injection timing immediately after camshaft base timing for cylinder No.1 (V-engine A1 and B1), turn the engine 10° against the rotation direction (clearance movement only). Then rotate it back in the rotation direction until the pointer at the flywheel shows the same timing as mentioned in the Engine Test Protocol.

Procedure

1 **Remove the injection pumps from the engine.**

See chapter Injection System.

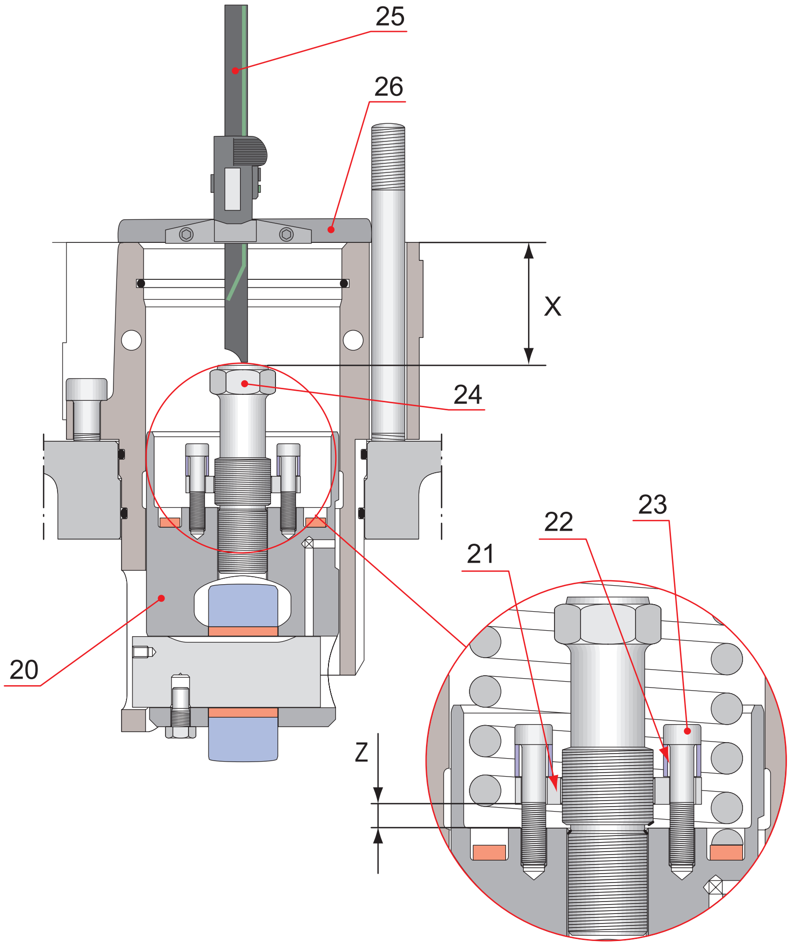
2 **Turn the engine in the rotation direction until the pointer at the flywheel corresponds to the value in the Engine Test Protocol for this particular cylinder (in-line engine cylinder No.1, V-engine A1).**

CAUTION

Make sure that you read the value on the flywheel correctly. For more information see Contents, Instructions, Terminology.

3 **Measure the distance “X” between the adjusting screw and the upper surface of the tappet housing with the digital T-gauge.**

Measure X = 74±0.02mm, see *Fig 13-5*.



20. *Tappet* 21. *Locking plate* 22. *Sleeve* 23. *Screw* 24. *Adjusting screw* 25. *Digital T-gauge 800 271* 26. *Extension piece 800 272*

Fig 13-5 Measuring with digital T-gauge.

4 **Open the locking screws (23), and adjust the distance “X” to the correct value by adjusting the screw (24).**

See *Fig 13-5*.

5 **If necessary, adjust the distance “Z” between the locking plate (21) and tappet.**

See *Fig 13-5*.

a **Remove the locking screws (23).**

b **Hold the adjusting screw (24), and screw the locking plate (21) down until it is in contact with the tappet (20).**

c **Hold the adjusting screw (24), and screw the locking plate (21) to 5 1/2 turns (“Z” = 10-11 mm).**

d **Mount the sleeves (22) and the screws (23).**

6 **Tighten the screws (23) to the right torque.**

See *Fig 13-5* and Tightening Torques and Use of Hydraulic Tools.

NOTE

When tightening, the measure “X” increases approximately 0.05 mm.

7 **Measure the distance “X”.**

The value must be within the specified tolerance limits.

8 **Turn the engine in the rotation direction to the following cylinder according to the firing order.**

Repeat steps 1 to 7 for every pump tappet.

9 **Mount the injection pumps to the engine.**

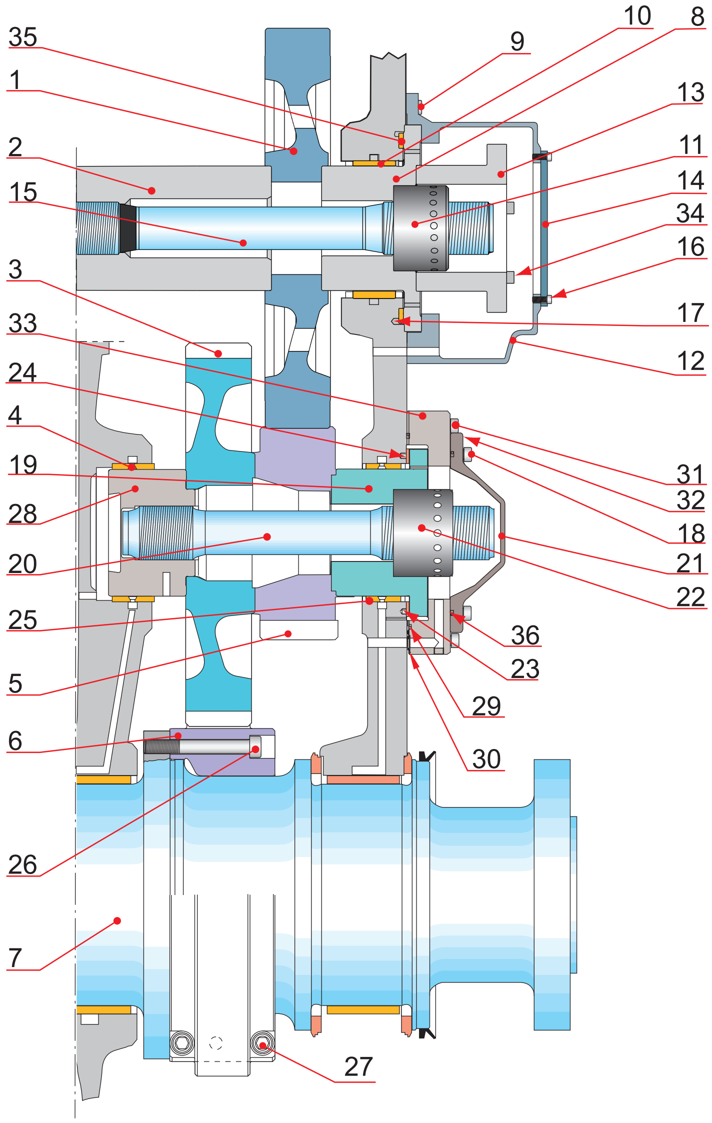
Tighten the nuts to the stated torque. See chapter Tightening Torques and Use of Hydraulic Tools.

10 **Mount all necessary pipes and injection, leak fuel and fuel pipes and locking plates.**

Connect the fuel rack.

13.2.4 Removing the camshaft gearing

v7



1 Gear wheel for camshaft
2 Extension piece
3 Bigger intermediate gear wheel
4 Bearing bush
5 Smaller intermediate gear wheel
6 Gear wheel for crankshaft
7 Crankshaft
8 Bearing piece
9 Screw
10 Bearing bush
11 Nut
12 Cover
13 Gear wheel for governor drive
14 Cover
15 Bolt
16 Screw
17 Guiding pin
19 Bearing piece
20 Bolt
21 Cover
22 Nut
23 Guiding pin
24 Thrust bearing
25 Bearing bush
26 Axial screw
27 Fastening screw
28 Bearing piece
29 O-ring
30 O-ring
31 Screw
32 Washer
33 Cover
34 Screw
35 Thrust bearing

18 Screw	36 O-ring

Fig 13-6 **Camshaft driving gear**

Procedure

1 **Remove the gearing covers and all camshaft covers.**

2 **Remove the rocker arm brackets of all cylinders, see chapter 14.**

CAUTION

Remove the rocker arm bracket(s)/push rods before the tappets are locked into the upper position. Otherwise when cranking the engine, the pistons will come into contact with the valves.

3 **Crank the engine and lock all valve- and injection pump tappets in upper position, see** *section 14.2.1***.**

4 **Remove the governor unit, the speed pick-ups and governor drive cover plate (14), see** *Fig 13-6***.**

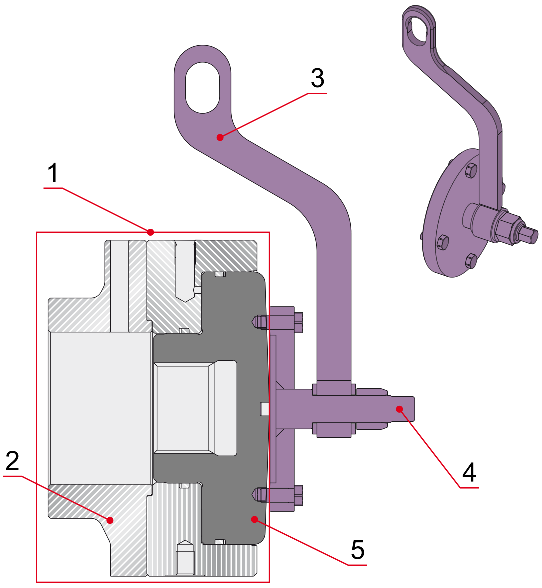
5 **Open the screws (9) and remove the complete governor drive assembly (12), see** *Fig 13-6***.**

6 **Open the screws (34) and remove the gear wheel (13) for the governor drive, see** *Fig 13-6***.**

7 **Open the nuts for the camshaft extension piece (2) on the back side of camshaft, see** *Fig 13-6***.**

8 **Turn the crankshaft to TDC at firing for cylinder No. 1. (V-engine A1).**

9 **Apply the lifting device to the hydraulic tool.**



1 Hydraulic tool 800 112, including distance sleeve
2 Distance sleeve (M80) 800 147 (V-engine) or 800 118 (in-line engine) for intermediate gears
3 Lifting tool 800 117
4 Screw
5 Hydraulic cylinder 2V86B0424

Fig 13-7 Lifting device for Hydraulic tool

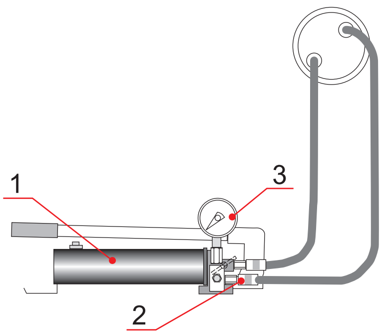
a **Attach the lifting tool 800 117 to the hydraulic cylinder 2V86B0424, see *Fig 13-7*.**

b **Mount the distance sleeve (V-engine 800 147 or in-line engine 800 118) and hydraulic cylinder together, see *Fig 13-7*.**

c **Attach the hydraulic tool 800 112 on to the camshaft stud (15), see *Fig 13-6*.**

Tighten the hydraulic tool to the stud with 19 mm spanner by using the screw (4), see *Fig 13-7*.

10 **Dismantle with the hydraulic tools.**



1 Hydraulic pump 800 053
2 Pressure release valve
3 Pressure indicator

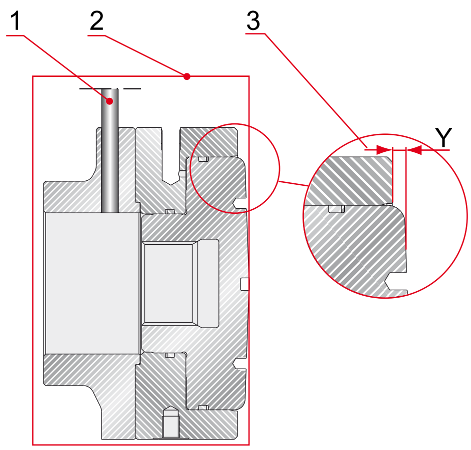
Fig 13-8 Hydraulic device

a **Connect the hoses to the hydraulic pump 800 053 (1), see *Fig 13-8*.**

b **Open the pressure release valve (2) from the hydraulic pump (800 053), see *Fig 13-8*.**

c **Tighten the cylinder with 19 mm spanner to expel oil from cylinder 2V88B0424 using screw (4), see *Fig 13-7*.**

d **Ensure that the piston position is correct (measure "Y" ≤ 8 mm), see *Fig 13-9*. The piston must go to the bottom of the cylinder.**



1 Pin 800 049
2 Hydraulic tool 800 112, including distance sleeve
3 Measure "Y"≤ 8 mm

Fig 13-9 Hydraulic tool with angle measure and pin

e **Turn the cylinder 180° counter-clockwise.**

f **Close the pressure release valve (2) on the hydraulic pump. Pump pressure till the pressure indicator (3) shows the stated value, see *Fig 13-8* and chapter 07.**

g **Open the nut about half a turn with the pin 800 049 (1), see *Fig 13-9*.**

h **Release the pressure release valve (2). Ensure that the nut loose, see *Fig 13-8*.**

i **Disconnect the hoses and remove the hydraulic tool.**

11 **Support the camshaft gear wheel (1), see *Fig 13-6* with a suitable tool.**

Use the lifting tool 836 020 (1V40T0038) or the mounting support 800 275 (DAAE094755) for camshaft gear wheel, see *Fig 13-10* and *Fig 13-11*.

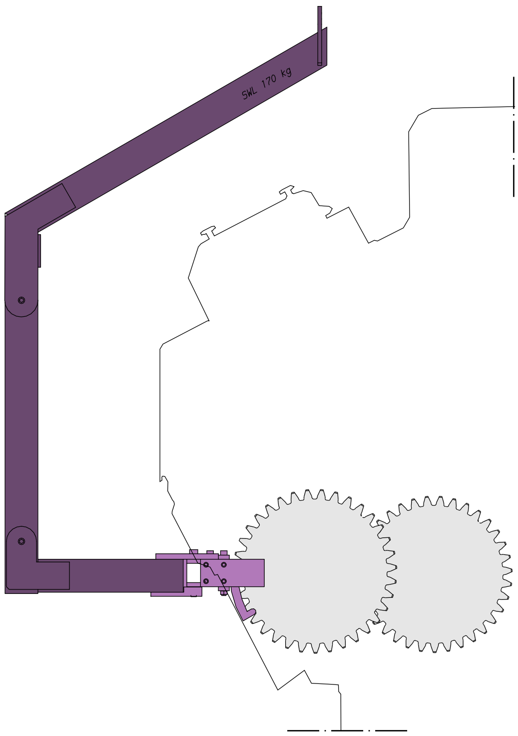


Fig 13-10 Lifting tool 836 020 for camshaft gear wheel

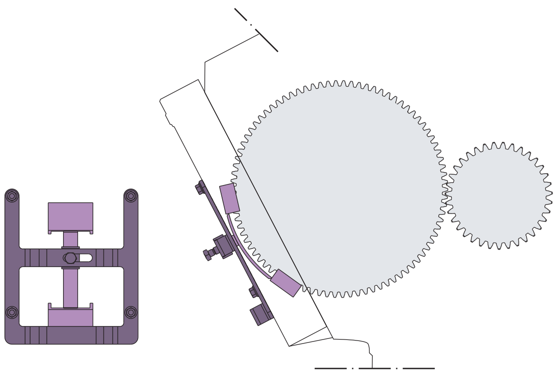


Fig 13-11 Mounting support 800 275 for camshaft gear wheel

WARNING

Before removing the camshaft nut (11), support the gear wheel with a suitable tool. Otherwise, the gear wheel may fall down.

12 **Remove the nut (11) and the bolt (15), see *Fig 13-6* using the tool 800 114, see *Fig 13-12*.**

NOTE

The locking screw of the tool has left-hand threads.

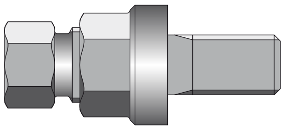


Fig 13-12 Removing tool 800 114

NOTE

When using the tool 800 114, the inner hexagon 36 key grip should be used to remove or tighten to torque. The outer left-hand hexagon 30 screw is only for locking the tool onto the stud. The tool will break if used to loosen.

13 **Remove the bearing piece (8) and thrust bearing (35), see *Fig 13-6*.**

14 **Remove the cover at the free end and the flange in the middle of starting air distributor (A-bank) and/or the flange from B-bank.**

15 **Mount the hydraulic cylinder 800 063 between the engine block and camshaft cam.**

Place a piece of wood or similar between cam and piston of the cylinder.

NOTE

The steps 15 and 16 need to be done only if more space is required before the gear wheel (1) can be removed.

16 **Rise the pressure slowly and move the camshaft sideways towards the free end until the gear wheel (1) can be removed, see *Fig 13-6*.**

NOTE

Do not damage the camshaft piece or engine block.

17 **Remove the camshaft gear wheel (1).**

18 **Remove the camshaft extension piece (2).**

13.2.5 Removing the intermediate gearing v5

Procedure

1 **Unscrew the cover fastening screws (18).**

Remove the intermediate gear wheel cover (21), see *Fig 13-6*.

2 **Unscrew the fastening screws (31) and remove the cover (33). Remove also the O-rings (29) and (30), see *Fig 13-6*.**

3 **Remove the oil spray nozzles.**

4 **Attach support tool 800 113 to the engine block, see *Fig 13-13*.**

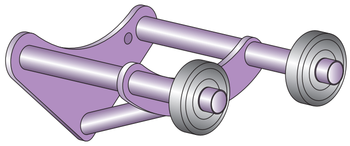
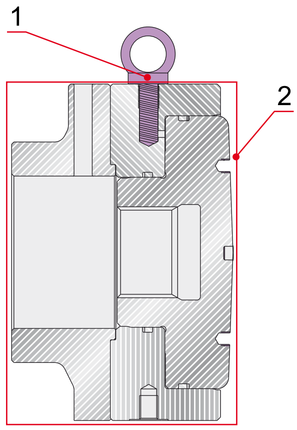


Fig 13-13 Support tool 800 113

5 Apply lifting eye bolt 800 068 to hydraulic cylinder 2V86B0424, see *Fig 13-14*.



1 Eye bolt 800 068
2 Hydraulic tool 800 112

Fig 13-14 Eye bolt 800 068

6 Mount the distance sleeve (800 147) and hydraulic cylinder together, see *Fig 13-7*.

7 Apply hydraulic tool (800 112) to the support tool (800 0113) and remove the lifting eye bolt (800 068).

8 Tighten the hydraulic tool to the bolt (20) by hand, see *Fig 13-6*.

9 Dismantling with hydraulic tools.

a Connect the hoses to the hydraulic pump 800 053, see *Fig 13-8*.

b Open the pressure release valve (2) of the hydraulic pump (800 053), see *Fig 13-8*.

c Tighten the cylinder with fastening arm 800 125 to expel oil from cylinder 2V88B0424, see *Fig 13-15*.

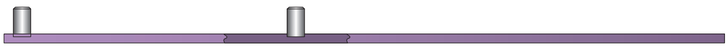


Fig 13-15 Fastening arm 800 125

d Ensure that the piston position is correct (measure “Y” ≤ 8 mm), see *Fig 13-9*. The piston must be at the bottom of the cylinder.

e Turn the cylinder 180° counter-clockwise.

f Close the pressure release valve (2) on the hydraulic pump. Pump pressure till the pressure indicator (3) shows the stated value, see *Fig 13-8* and Tightening Torques and Use of Hydraulic Tools.

g **Open the nut about half a turn with the pin 800 049 (1), see *Fig 13-9*.**

h **Release the pressure and ensure that the nut is loose.**

i **Disconnect the hoses and remove the hydraulic tool.**

10 **Support the gear wheels (3) and (5) with a suitable tool, see *Fig 13-6*.**
Use the lifting tool for camshaft gear wheel 836 020 (1V40T0038), see *Fig 13-10*.

WARNING

Before removing the nut (22) and the bolt (20), support the gear wheel with a suitable tool. Otherwise, the gear wheel may fall down.

11 **Remove the nut (22) and the bolt (20) using the tool 800 114.**

NOTE

The locking screw of the tool has left-hand threads.

NOTE

When using the tool 800 114 only, the inner hexagon 36 key grip should be used to remove or tighten to torque. The outer left-hand hexagon 30 screw is only for locking the tool onto the stud. The tool will break if smaller nut used to loosen.

12 **Remove the bearing piece (19), thrust bearing (24) and the small intermediate gear wheel (5), see *Fig 13-6*.**

13 **Remove the big intermediate gear wheel (3) and bearing piece (28), see *Fig 13-6*.**

13.2.6 Mounting of the intermediate gearing v4

Prerequisites

NOTE

Make sure that the crankshaft is in TDC at ignition for cylinder No. 1 before proceeding with the job.

Procedure

1 **Lubricate the bearing bushes (4) and (25), see *Fig 13-6*.**

2 **Lift the bearing piece (28) into position.**

3 **Lift the big intermediate gear wheel (3) onto the collar of the bearing piece.**

4 **Insert the small intermediate gear wheel (5) onto the collar of the big intermediate gear wheel.**

5 **Insert the thrust bearing (24) and bearing piece (19).**

6 **Screw the bolt (20) using the tool 800 114.**

a **Tighten the bolt to the required value, see Tightening Torques and Use of Hydraulic Tools.**

> **NOTE**
>
> The locking screw of the tool has left-hand threads.

> **NOTE**
>
> When using the stud mounting tool 800 114 only the inner hexagon 36 key grip should be used when to remove or tighten to torque. The outer left-hand hexagon 30 screw is only for locking the tool onto the stud. The tool will break if smaller nut used to loosen.

b **Remove the tool.**

7 **Tighten the nut (22) in two steps with hydraulic tool 800 112 to the stated pressure. See the step values from chapter 07.**

8 **Reassemble with hydraulic tools.**

a **Connect the hoses to the hydraulic pump 800 053, see *Fig 13-8*.**

b **Open the pressure release valve (2) of the hydraulic pump (800 053).**

c **Tighten the cylinder with fastening arm 800 125 to expel oil from cylinder (2V86B0424), see *Fig 13-15*.**

d **Ensure that the piston position is correct (measure “Y” ≤ 8 mm), see *Fig 13-9*. The piston must be at the bottom of the cylinder.**

e **Close the pressure release valve (2) on the hydraulic pump. Pump pressure till pressure indicator (3) shows the stated value, see *Fig 13-8* and Tightening Torques and Use of Hydraulic Tools.**

f **Tighten the nut with the pin (1) 800 049, see *Fig 13-9*.**

g **Release the pressure.**

h **Disconnect the hoses and remove the hydraulic tool.**

9 **Mount the cover (33) and replace the o-rings (29) and (30) with new ones. Tighten the screws (31) to stated torque.**

10 **Measure backlash and axial clearance, see Adjustments, Clearances and Wear Limits.**

11 **Mount the cover (21) and replace the O-rings with new ones. Tighten the screws (18) to stated torque.**

13.2.7 Mounting the camshaft gearing v4

Procedure

1 **Insert the extension piece (2) and tighten the nuts, see *Fig 13-6*.**

2 **Lift the camshaft gear wheel (1) onto the collar of the extension piece, see *Fig 13-6*.**

3 **Mount the trust bearing (35) and bearing piece (8).**

Lubricate the parts before assembly.

4 **Screw the bolt (15) using the tool 800 114.**

a **Tighten the bolt (15) to the required value, see Tightening Torques and Use of Hydraulic Tools.**

NOTE
The locking screw of the tool has left-hand threads.

NOTE
When using the tool 800 114 only, the inner hexagon 36 key grip should be used to remove or tighten to torque. The outer left-hand hexagon 30 screw is only for locking the tool onto the stud. The tool will break if smaller nut used to loosen.

b **Remove the tool.**

5 **Mount the nut (11) and tighten by hand.**

6 **Apply the lifting device to hydraulic tool.**

a **Attach the lifting tool 800 117 to the hydraulic cylinder 2V86B0424, see *Fig 13-7*.**

b **Mount the distance sleeve (V-engine 800 147 or in-line engine 800 118) and hydraulic cylinder together, see *Fig 13-7*.**

c **Attach the hydraulic tool 800 112 on to the camshaft bolt (15), see *Fig 13-6*.**

Tighten the hydraulic tool to the stud with 19 mm spanner using the screw (4), see *Fig 13-7*.

7 **Tighten the nut (11) in two steps with the hydraulic tool 800 112 to the stated pressure. See the step values from chapter 07.**

a **Connect the hoses to the hydraulic pump 800 053, see *Fig 13-8*.**

b **Open the pressure release valve (2) from hydraulic pump (800 053), see *Fig 13-8*.**

c **Tighten the cylinder with 19 mm spanner to expel oil from cylinder 2V86B0424 using the screw (4), see *Fig 13-7*.**

d **Ensure that the piston position is correct (measure “Y” ≤ 8 mm), see *Fig 13-9*. The piston must be at the bottom of the cylinder.**

e **Close the pressure release valve (2) on the hydraulic pump. Pump pressure till the pressure indicator (3) shows the stated value, see *Fig 13-8* and Tightening Torques and Use of Hydraulic Tools.**

f **Tighten the nut with the pin 800 049 (1), see *Fig 13-9*.**

g **Release the pressure.**

h **Disconnect the hoses and remove the hydraulic tool.**

8 **Check the basic adjustment of valve timing, change if necessary, see *section 13.2.2*.**

9 **Mount the governor drive gear wheel (13).**

Tighten the screws (34) crosswise to stated torque, see *Fig 13-6*.

10 **Check that the thrust bearing (35) is against the engine block and the bearing piece (8) is against the thrust bearing (35). Use a feeler gauge to confirm that there is no gap between the engine block and the parts.**

11 **Mount the cover (12) for the governor drive.**

Replace the O-rings with new ones. Tighten the screws (9) to stated torque, see *Fig 13-6*.

12 **Check axial bearing clearances and the backlash between the gear wheels.**

13 **Remove the locking devices from the tappets.**

14 **Mount the oil spray nozzles.**

15 **Mount the governor unit and the speed pick-ups, see Control Mechanism.**

16 **Mount the push rods and rocker arms.**

Tighten to the stated torque.

17 **Check the valve clearance.**

18 **Mount all covers, oil pipes and remaining parts.**

NOTE

Check the valve timing before the engine is started.

13.3 Crankshaft gear wheel v3

If the split gear wheel has to be changed, only one half of the wheel can be removed/ mounted at a time. Thus the valve timing is unchanged and it is not necessary to adjust it. However, the timing should be checked.

13.3.1 Removing the split gear wheel v7

Prerequisites

After the gearing is removed according to *section 13.2.4*, the split gear wheel (6) can be removed from the crankshaft.

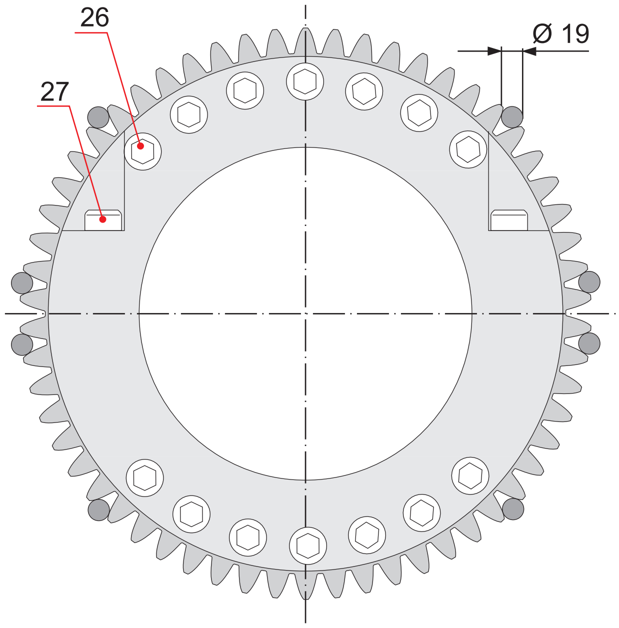
Procedure

1 **Lower the bearing cap for main bearing No.1, see Dismantling of the main bearing from chapter 10.**

2 **Loosen the fastening screws (27).**

3 **Unscrew the axial screws (26).**

4 **Unscrew the fastening screws (27) and remove the gear wheel halves.**



26. *Axial screw* 27. *Fastening screw*

Fig 13-16 Measuring split gear wheel

13.3.2 Mounting the split gear wheel

v6

Procedure

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 Dismantling of the main bearing from chapter 10.**

3 **Mount the drive gear so that the crankshaft and gear wheel stampings are in the same place.**

Use lifting tool (2V10T2217).

4 **Lubricate the threads and screw base (26) and (27) with clean engine oil.**

5 **Tighten screws (26 and 27) that hold the gear wheel to the crankshaft first by hand so that the drive gear is in contact the crankshaft flange and the split gears are in contact with each other.**

6 **Tighten the fastening screws (27) to a torque of 10 Nm. Check that contact is established between the gears.**

7 **Tighten the axial screws (26) to a torque of 10 Nm. Check that contact is established between gear wheel and the crankshaft flange.**

8 **Use tightening tool 820 014 for the split gear wheel.**

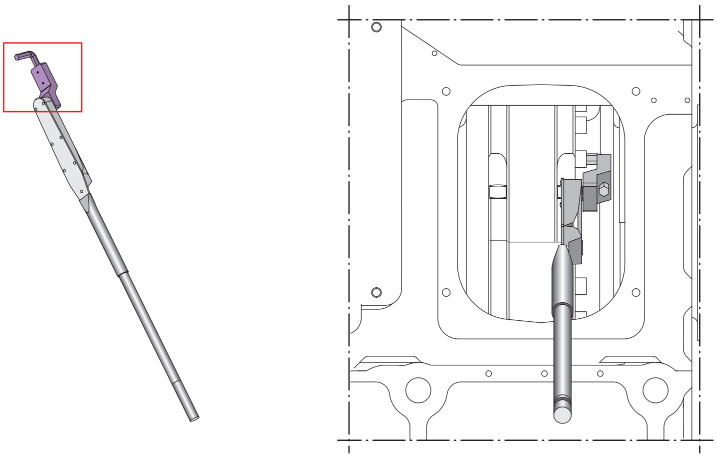


Fig 13-17 Tightening tool 820 014 for split gear wheel

a **Tighten the screws (27) and (26) to the correct torque.**

b **Torque wrench setting must be calculated according to the following formula.**

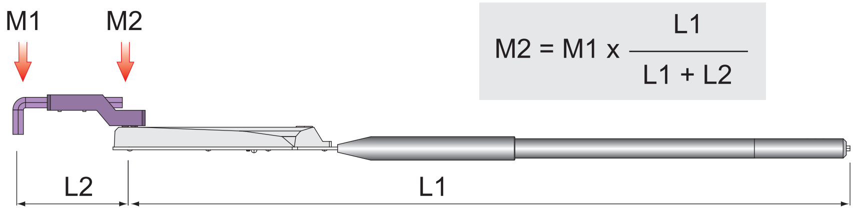


Fig 13-18 Torque calculation

Example:

M1 = 550 Nm

L1= 0.9 m

L2= 0.15 m

M2 = 550 Nm x 0.9 m / (0.9 m + 0.15 m) = 472 Nm

9 **Calculate the required torque for tightening screws (27), see *Fig 13-17* and *Fig 13-18*.**

a **Measure the L2 from tool 820 014 and L1 from used torque wrench, see *Fig 13-18*.**

b **Check required torque from chapter 07.**

c **Calculate required torque.**

10 **Tighten the fastening screws (27) in steps to the stated torque.**

11 **Calculate the required torque for tightening screws (26), see *Fig 13-17* and *Fig 13-18***

a **Measure the L2 from tool 820 014 and L1 from used torque wrench, see *Fig 13-18*.**

b **Check required torque from chapter 07.**

c **Calculate required torque.**

12 **Tighten the axial screws (26) to the stated torque.**

13 **Check the gear wheel roundness.**

a **Place a cylindrical pin (ø19 mm) in the tooth gap, see** *Fig 13-16*.

b **Measure the split gear wheel according to measurement record WS11V216.**

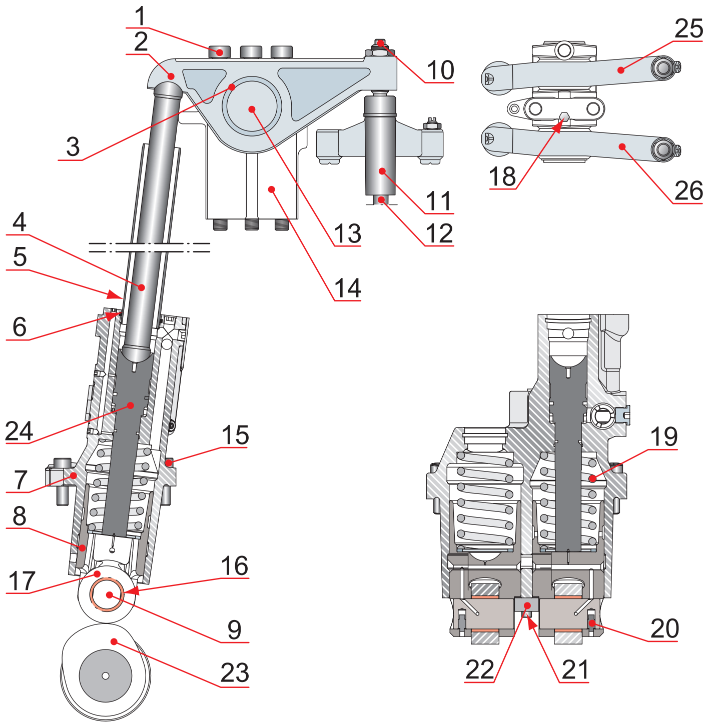
14 **Lift the bearing cap for main bearing No.1, see Dismantling of the main bearing from chapter 10.**

14. Valve Mechanism and Camshaft

14.1 Valve mechanism

v8

The valve mechanism operates the inlet and outlet valves at the required timing. The valve mechanism consists of piston type valve tappets (8) moving in guide blocks (7), push rods (4) with ball joints, rocker arms (2) journal on a rocker arm bracket (14) and yokes (11) guided by yoke pins (12) at the cylinder head.



1 Screw	14 Rocker arm bracket
2 Rocker arm	15 Screw
3 Retainer ring	16 Bearing bush
4 Push rod	17 Tappet roller
5 Protecting pipe	18 Locking screw
6 O-ring	19 Tappet spring
7 Guide block	20 Locking pin
8 Valve tappet	21 Securing screw
9 Roller pin	22 Guiding plate
10 Adjusting screw	23 Cam
11 Yoke	24 Piston
12 Yoke pin	25 Exhaust (EX) rocker arm
13 Shaft	26 Inlet (IN) rocker arm

Fig 14-1 Valve mechanism VIC

14.1.1 Function

v3

The movements of the valve tappets (8) are governed by the cams (23) on the camshaft, see *Fig 14-1*. The valve tappets transfer the movement through push rods (4) to the rocker arms (2). The rocker arms operate the inlet and exhaust valves through yokes (11).

The rocker arm bracket (14) is fastened to the cylinder head by three screws (1). The shaft (13) is positioned by one screw in the bracket. The positioning of the shaft is essential for the oil supply.

The adjusting screws in the rocker arms act on the valve yokes, which are guided by yoke pins. To compensate for heat expansion a clearance, valve clearance, must be set in the valve mechanism. The adjustments of the clearance is done on a cold engine, see chapter 12. Each valve yoke operates two valves simultaneously, two for inlet and two for exhaust.

The valve mechanism is lubricated by the main lubricating oil flow through drilling. Oil flows to the yokes and to the push rod upper ball joints through the rocker arm unit in an intermittent flow controlled by the drilling in the rocker arms and the shaft. The rocker arm is in position to supply oil only when it is in the "open valve" position. When the rocker arm is in "closed valve " position the surface between the rocker arm and the shaft is lubricated. Oil which is passed to the yoke lubricates the yoke guidance and the valve rotators. Oil is returned to the crankcase in a free flow through the protecting pipes (5) for the push rod.

NOTE

Intermittent oil flow will cause an optimised oil flow to the valve mechanism. To completely check the oil flow to a cylinder head, the engine must be cranked with turning gear during prelubrication.

14.1.2 Variable Inlet Valve Closing (VIC)

v3

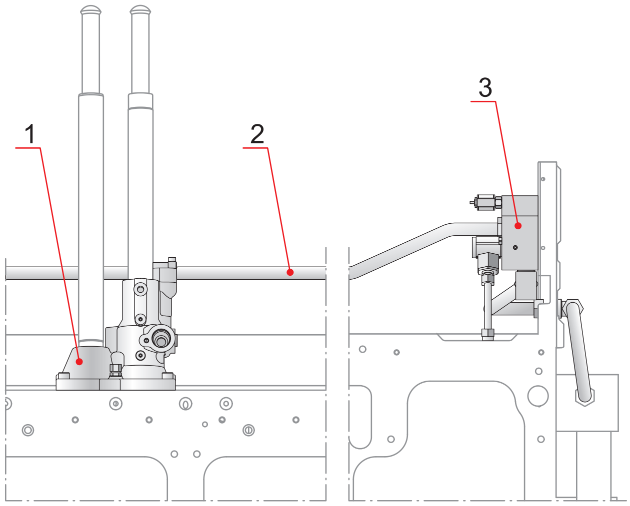
Variable Inlet Valve Closing is a system designed for reducing the effect of non-optimal combustion and extensive smoke emission on low load. The system controls the amount of inlet air to the cylinder. The valve closing adjustments are made by using different maps depending on load and speed. The time of open inlet valve is longer when VIC is activated (on).

The criteria for VIC on/off is the engine load and speed, and VIC is controlled by the UNIC control system.

VIC OFF: the inlet valve closure is governed by the profile of the cam.

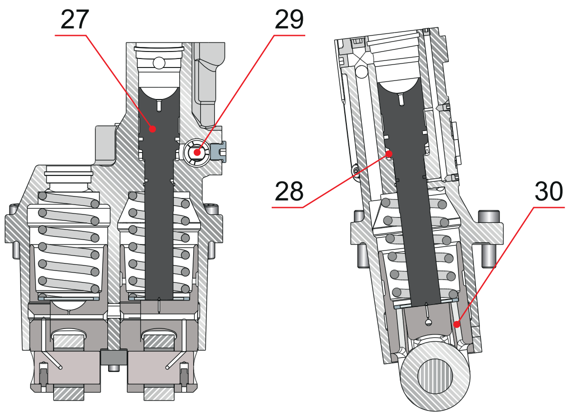
VIC ON: the inlet valve closure is being delayed and more air can enter the cylinder.

VIC is a hydraulic system installed in the inlet valve mechanism assembly, and the engine's lubricating oil is used as the hydraulic medium.



1 Guide block with VIC
2 Oil supply line
3 Control valve

Fig 14-2 VIC system in hotbox



27.*Piston* 28.*Chamber* 29.*Non-return valve* 30.*Tappet*

Fig 14-3 Guide block

CAUTION

Check after every maintenance that the control valve (3) is working properly. VIC only works at part loads.

When the control valve (3) is closed, no oil is supplied to the chamber (28) and the VIC function is inactive.

When the valve is open, the oil supply line (2) is pressurized and the VIC function is active. During the cam lift, the piston (27) creates suction and oil flows into the chamber (28) through the non-return valve (29). On the maximum cam lift, the piston (carrying the push rod for the inlet valve) stays on its highest position and keeps the inlet valve open as the return channel for the oil is blocked by the tappet (30). The tappet moves downwards, following the cam profile, and opens the oil return channel at the specified point. The oil returns to the oil sump and the pressure is released beneath the piston, resulting in inlet valve closure.

14.1.3 Maintenance of valve mechanism v3

Normally, the valve mechanism needs no maintenance, but inspection of the components and check for wear should be done at intervals stated in chapter 04.

If the valve mechanism is dismantled, the components should be marked and later assembled in the same position and cylinder as before to avoid unnecessary wear.

14.1.3.1 Dismantling the valve mechanism v5

Procedure

1 **Open the cylinder head cover and remove the camshaft cover for the cylinder concerned.**

2 **Turn the crankshaft to a position where the valve tappet rollers are on the base circle of the cam, see chapter 13.**

3 **Loosen the screws (1) and remove the rocker arm assembly from the cylinder head.**

See *Fig 14-1*.

4 **Dismantle the rocker arm assembly.**

NOTE

Dismantling the rocker arm assembly is required only in special cases.

a **Remove the retainer ring (3) by using pliers 800 002.**

b **Remove the (IN) inlet valve rocker arm (26).**

c **Remove the locking screw (18).**

d **Press out the shaft (13) and remove the (EX) exhaust valve rocker arm (25).**

5 **Remove the push rods (4) and the protecting pipes (5).**

6 **Remove necessary pipes.**

7 **Loosen the fastening screws (15) and remove the guide block.**

8 **Remove the screws (21) and the guiding plate (22).**

WARNING

The tappets are spring-loaded.

9 **Pull out the tappets (8).**

10 **The tappet roller (17) and pin (9) can now be separated by depressing the locking pin (20) and pushing out the roller pin.**

The tappet should be covered, as the locking pin is spring loaded.

11 **Pull out the spring (19).**

12 **Push out the piston (24).**

14.1.3.2 Inspecting the valve mechanism parts v3

Procedure

1 **Clean all parts. Pay special attention to the oil holes.**

2 **Measure wear and clearances. See chapter 06 for nominal values and wear limits.**

a **Valve tappet radial clearance**

b **Tappet roller bush, bore diameter**

c **For inlet rocker arm, bore diameter and shaft diameter**

d **Rocker arm-shaft radial clearance**

e **Yoke bore diameter**

f **Yoke-pin clearance**

3 **Replace the O-rings (6) for the protecting pipes (5).**

14.1.3.3 Assembling the valve mechanism v5

Procedure

1 **Lubricate the parts for the valve tappet unit with clean engine oil and assemble.**
Pay attention to the marks for correct positions.

2 **Insert the tappet springs (19) and the valve tappets (8) into the guide block.**
See *Fig 14-1*.

3 **Mount the guiding plate (22) and tighten the screws (21) to the correct torque.**
See chapter 07 for tightening torques.

4 **Mount the piston (24) to the guide block.**

5 **Mount the complete guide block on the engine and tighten the screws (15) to the stated torque.**
See chapter 07 for tightening torques.

6 **Mount the removed pipes.**

7 **Grease the O-rings (6) for the protecting pipes, and insert the protecting pipes and push rods (4) into the guide block.**

8 **Mount the yokes (11).**
For adjusting the yokes, see chapter 12.

9 **Lubricate the rocker arm bores with engine oil and reassemble the rocker arm assembly, if dismantled.**

a **Insert the (EX) exhaust rocker arm (25) and press in the shaft (13).**

b **Insert the locking screw (18) and tighten to stated torque.**

c **Mount the (IN) inlet rocker arm (26).**

d **Insert the retainer ring (3), by using pliers 800 002.**

10 **Mount the rocker arm assembly on the cylinder head and tighten the screws (1) to the stated torque.**

See chapter 07 for tightening torques.

11 **Check the axial clearance and free rotation of the rocker arms.**

12 **Mount the removed pipes.**

13 **Mount the covers.**

14.2 Camshaft v5

The camshaft is built up of one-cylinder camshaft pieces (7) and separate bearing pieces (6), see *Fig 14-4*. The camshaft pieces have integrated cams. The camshaft is driven by the crankshaft through a camshaft drive consisting of gear wheels at the driving end of the engine. At this end, the camshaft is provided with a helical gear wheel (23) for driving the speed governor. At the free end, the camshaft has an extension piece (3) with a cam (1) for operating the starting air distributor.

The camshaft has an axial bearing (21) at the driving end. The oil is supplied to the axial bearing from the driving end of the engine. The engine block has a drilling, through which oil is supplied to every camshaft bearing. The rotation speed of the camshaft is only half of the engine speed.

14.2.1 Removing the camshaft piece v8

NOTE

The camshaft pieces cannot be interchanged between the A- and B-bank. The position of a removed camshaft piece needs to be carefully marked.

Procedure

1 **Remove the camshaft covers and open the cylinder head covers.**

2 **Remove the rocker arm brackets and push rods from all cylinder heads.**

3 **Lift up the tappets (injection pump and valve tappets) and secure them in the upper position by means of the locking device 800066 (for the injection pump) and 800067 (for the tappets).**

4 **Remove the camshaft fastening screws (12) and nuts (10) from back side of the cam.**

5 **Remove the stud (11) using double nutting.**

6 **Rotate the camshaft so that the rest of the screws, bolts and studs can be removed.**

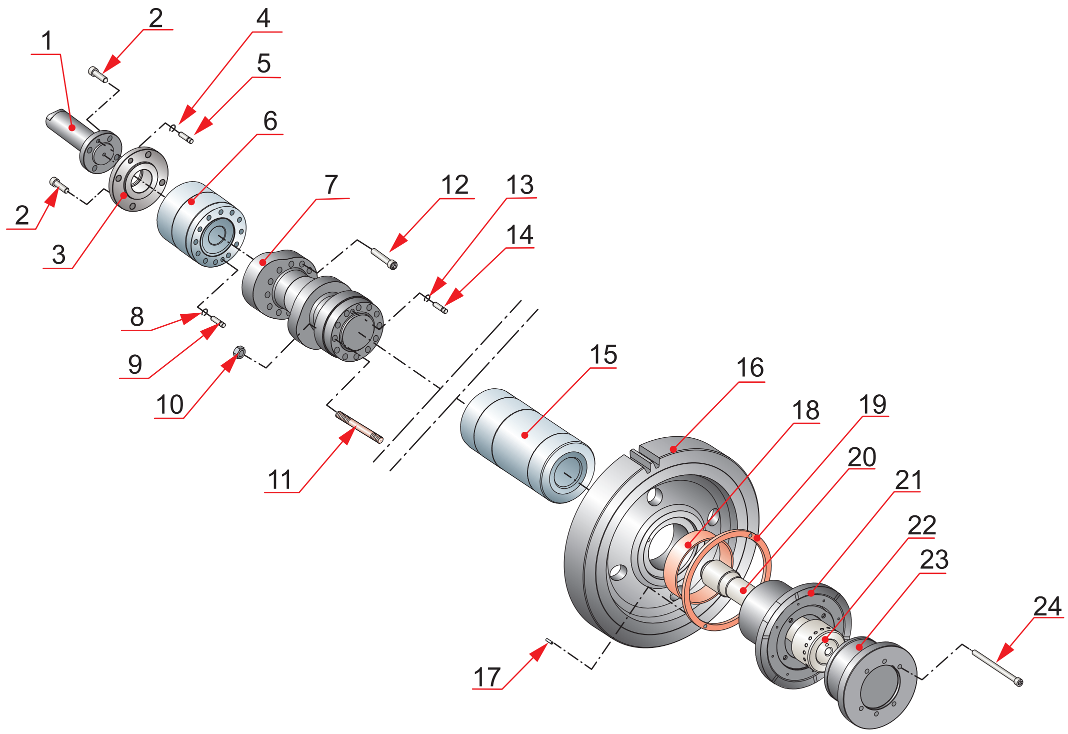
7 **Mount the support tool on the block using the camshaft cover fastening screws.**

8 **Remove the camshaft end cover from the starting air distributor.**

9 **Push the camshaft towards the free end of the engine.**

10 **Remove the camshaft piece.**

11 **Remove the guide pins (9).**



1 Starting air cam	13 Snap ring
2 Bearing connection screw	14 Guide pin
3 Extension piece	15 Extension piece
4 Snap ring	16 Driving gear wheel
5 Guide pin	17 Cylindrical pin
6 Bearing piece	18 Camshaft bearing bush
7 Camshaft piece	19 Thrust bearing
8 Snap ring	20 Stud
9 Guide pin	21 Axial bearing
10 Nut	22 Round nut
11 Stud	23 Helical gear wheel
12 Camshaft fastening screw	24 Head screw

Fig 14-4 Camshaft piece

14.2.2 Mounting the camshaft piece

v8

Procedure

1 **Check the valve tappets, rollers and bearing bushes carefully.**
Replace damaged parts.

2 **Clean the threads from bearing piece (6) with the thread tap.**
Clean the treads with degreaser.

3 **Apply the guide pins (9) to the camshaft piece (7).**

4 **Mount the camshaft piece (7) with the assembly tool and pull the camshaft together.**
Install 1-2 screws on both ends to hold the camshaft piece on place.

5 **Mount the studs (11) by using a double nut method.**

6 **Mount the new locking nut (10) and screws (12).**

NOTE
Loctite 243 must be used for screws (12).

7 **Tighten the screws (12) to the correct torque.**
See chapter 07 for tightening torques.

8 **Mount the cover of the starting air distributor.**

9 **Release the tappets and mount the rocker arm brackets.**

10 **Install push rods and rocker arms.**
Tighten the rocker arms to the stated torque, see chapter 07 for tightening torques.

11 **Check the valve clearances, see chapter 12, *section 12.7*.**

12 **Install removed covers.**

14.3 Camshaft bearing

14.3.1 Inspection of the camshaft bearing bush v4

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. Measure three diameters in a position 120° from each other. The average diameter to be compared with wear limit. The wear limit is stated in chapter 06, section Clearances and wear limits.

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, the camshaft piece and the bearing journal must be removed according to section *14.2.1*.

14.3.2 Removing the camshaft bearing bush v7

Procedure

1 **Remove the camshaft pieces and bearing piece adjacent to the bearing bush and bearing journal concerned according to section *14.2.1*.**

2 **Remove the camshaft bearing journal.**

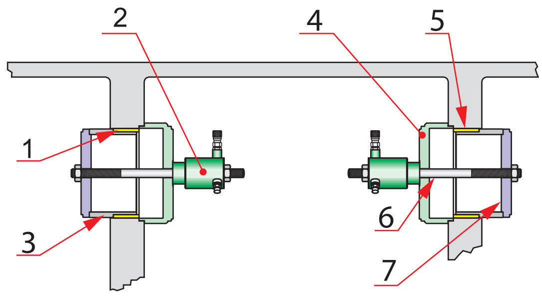
a **Assemble the removing tool 800062 according to *Fig 14-5*.**
Notice the difference in tool assembly for the bearing next to the driving end of the engine.

b **Tighten the hydraulic extractor (2) by tensioning the screw (6).**

c **Connect the hoses of the hydraulic pump 800053 to the hydraulic tool (2).**

d **Slowly raise the pressure in the hydraulic tool to withdraw the bearing bush. The maximum pressure must not be exceeded.**
If the bearing bush does not move when this pressure is achieved, a light knock on the pressure plate (7) may be needed.

e **Open the pressure release valve on the pump, disconnect the hoses from the hydraulic tool and dismantle the removing device.**



1 Camshaft bearing 2
2 Hydraulic extractor 800063
3 Guide sleeve DAAE045528
4 Distance piece DAAE014165
5 Camshaft bearing 1
6 Tension screw 836010
7 Pressure plate DAAE044919

Fig 14-5 Removing the camshaft bearing bush with the removing tool 800062

14.3.3 Mounting the camshaft bearing bush

v5

Mark with marker-pen the position of the oil bore in engine block and the bearing bush.

There are two options to mount the bearing bush, freezing or using hydraulic tool.

Procedure

1 **Option 1:**

a **Cool down the bearing bush to -130° C in a special freezer or liquid nitrogen.**

b **Align the markings in engine block and bearing bush, install the bearing bush into the block.**

c **Check that the oil bores in engine block and bearing bush are aligned.**

WARNING
Use proper gloves when working with frozen parts.

2 **Option 2:**

a **Assemble the mounting device according to *Fig 14-6*.**
Notice the difference in tool assembly for the bearing next to the flywheel end of the engine.

b **Tighten the hydraulic extractor (2) by tensioning the tension screw (6) lightly.**

c **Connect the hoses of the hydraulic pump 800053 to the hydraulic tool (2).**

d Raise the pressure in the hydraulic tool to mount the bearing bush.

CAUTION

Do not exceed the maximum pressure for the tools.

e Open the pressure release valve on the pump, disconnect the hoses of the hydraulic tool.

Dismantle the mounting device.

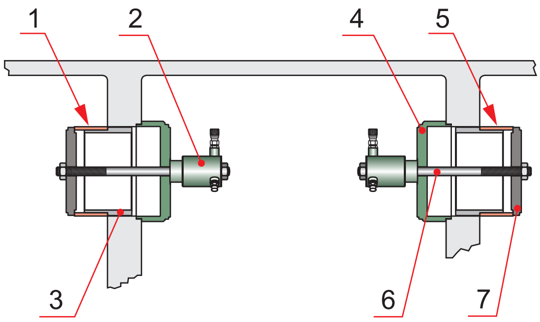
f Check that the oil hole in the bearing bush is in the correct position.

g Lubricate the bearing surface of the bearing bush and insert the camshaft bearing journal.

h Mount the camshaft pieces, bearing journals, guide blocks, injection pumps and camshaft covers. For more information see *14.2.2*.

CAUTION

Check that the oil bore in the engine block and the bearing bush are aligned with each other. Use 7,5 mm pin to check the alignment.



1 Camshaft bearing 2
2 Hydraulic extractor 800063
3 Guide sleeve DAAE045528
4 Distance piece DAAE014165
5 Camshaft bearing 1
6 Tension screw 836010
7 Pressure plate DAAE044919

Fig 14-6 Mounting the camshaft bearing bush

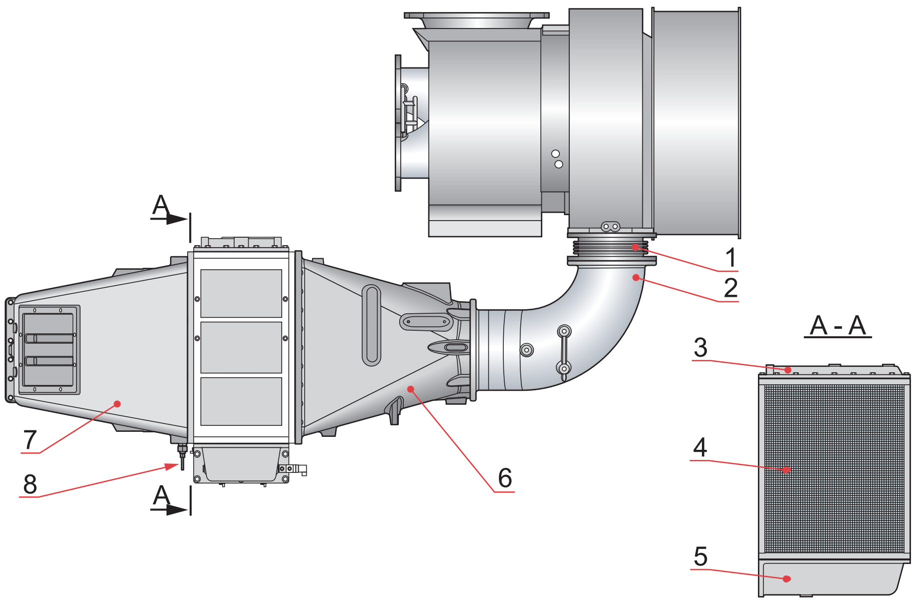
15. Turbocharging and air cooling

The charge air coolers are of rigid frame type and fitted to the side of the engine block.

The turbocharger is equipped with plain bearings and connected to the engine lubrication system.

The air outlet is connected to the air duct (2) with metal bellows (1). The exhaust pipes from the cylinders are also connected to the turbocharger(s) with metal bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions with a fixed support immediately after the bellows.

The turbocharger is equipped with cleaning devices for cleaning both the compressor and turbine by water injection.



1 Bellows
2 Air duct
3 Cover for water space
4 Charge air cooler
5 Water space
6 Diffuser
7 Air box
8 Drain pipe

Fig 15-1 Charge air system In-Line engine

15.1 Turbocharger maintenance

v7

The plain bearings of the turbocharger are lubricated by the engine lubricating oil system. The oil is fed through the turbocharger bracket and the pressure lowered with an orifice. The oil drain is connected to a channel in the turbocharger bracket from where the oil is led to the crankcase.

The cartridge design of the turbocharger allows all normal service work to be done from the compressor side of the turbocharger without removing the whole unit from the engine.

The oil can also be fed and drained through pipes, depending on configuration.

NOTE

When reassembling, use new seals.

Turbocharger maintenance is carried out according to *section 15.2*.

Contact Wärtsilä for further information and service.

15.2 Cleaning the turbocharger with water (during operation)

v3

15.2.1 Cleaning the turbine with water

v14

The dirt deposits on the turbine side can be reduced by periodic cleaning (washing) during operation. The overhaul periods can thus be extended. Dirty turbines effect the turbocharger speed and under certain circumstances cause the higher temperatures of the exhaust gas and higher stress to the bearings due to imbalance. Washing of the turbine side is necessary when running on heavy fuel.

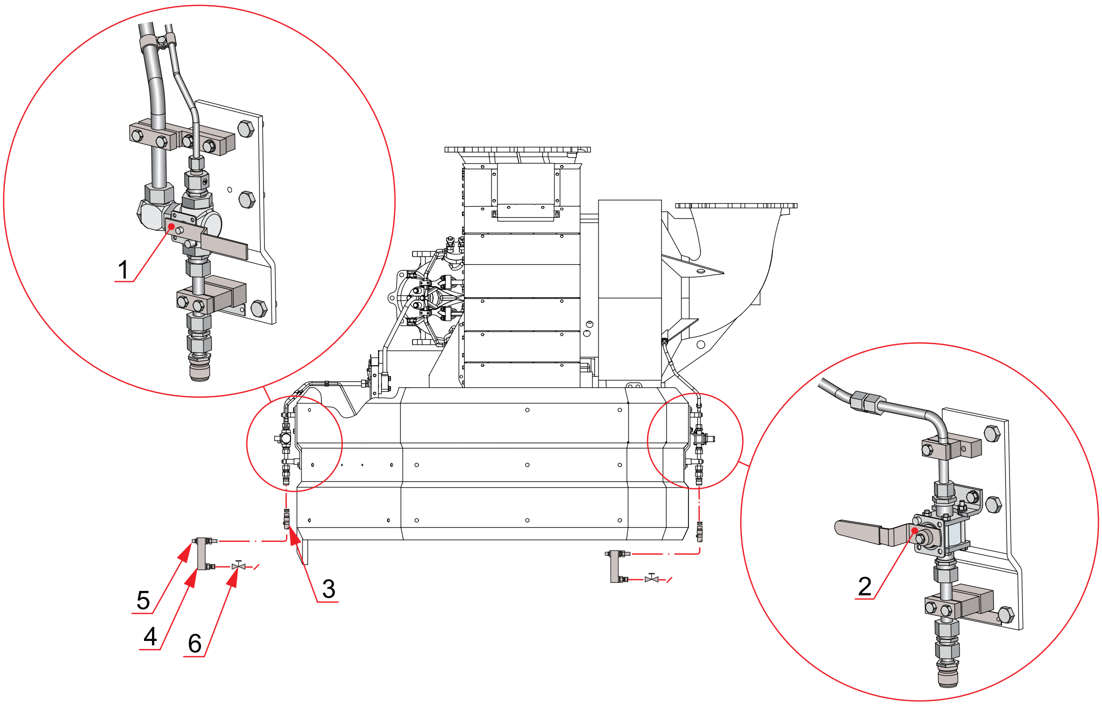
During long periods of operation, periodic water cleaning prevents the build-up of significant deposits on the turbine blades and nozzle blades. This cleaning method does not work on very dirty turbines which have not been washed regularly.

If the normal water cleaning of the turbine does not lower the turbocharger speed level, hard deposits have probably built-up on the nozzle ring and the turbine blades in the turbocharger. Mechanical cleaning of nozzle ring and the turbine blades are required. For that purpose, the rotor cartridge and the nozzle ring have to be removed from the turbocharger.

When washing with water, the water must be injected into the exhaust system with the engine running at reduced output, see Turbine cleaning procedure. The disadvantages of occasionally reducing the output is not significant as compared to the advantages of cleaning. The necessary water flow is basically dependent upon the volume of gas and its temperature. Additives or solvents must not be used in the cleaning water.

NOTE

Use of salt water is prohibited.



1 Valve for turbine cleaning
2 Valve for compressor cleaning
3 Quick-coupling
4 Flow meter
5 Flow adjustment valve
6 Main valve

Fig 15-2 Water cleaning of turbocharger

Every gas inlet of the charger is equipped with a washing nozzle. The nozzles are all connected to a common water connection which has a valve and a quick-coupling. The water flow is controlled by flow meter to a suitable flow rate.

Table 15-1 Turbine washing water flow rate

Water cleaning of turbine	
Turbocharger	Flow rate (l/min) [1]
TPS 61	12
TPL 65–A	15
TPL 67–C	18
TPL 69–A	18

[1] Per turbocharger

Cleaning should take place regularly according to Maintenance Schedule. Depending on the results obtained, the washing interval may be increased or reduced.

CAUTION

Ensure that you open the right valve, depending on compressor or turbine wash.

15.2.2 Turbine cleaning procedure

v12

Prerequisites

The turbocharger is designed without drain pipe.

Procedure

1 **Record charge air pressure, cylinder exhaust gas temperatures, charger speed at nominal load.**

These values are used later to evaluate efficiency of the cleaning process.

2 **Reduce the engine load corresponding to a maximum exhaust gas temperature at turbine inlet < 430°C.**

3 **Run the engine for 15 minutes on this load before the washing is started.**

> **CAUTION**
>
> Observe the above mentioned limits for engine speed or exhaust gas temperature.

> **CAUTION**
>
> Do not start to wash before running the engine 15 minutes on stable load. This may have negative consequences for the lifetime of the turbocharger components.

4 **Open the turbine wash valve (1) and check that the nozzles are not clogged.**

See *Fig 15-2*.

5 **Connect the water hose.**

6 **Open the main valve (6) and adjust the water flow to the correct value by the flow adjustment valve (5).**

Lock the valve in this position to use for compressor wash later.

7 **Close the main valve (6) and the turbine wash valve (1) 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 possibly enter exhaust pipes after washing.**

10 **Open the main valve (6) and drain the water.**

11 **Resume normal engine operation at higher output.**

12 **Repeat the readings taken in step 1 to evaluate the efficiency after 1 hour.**

13 **If the engine is stopped after the cleaning, run the engine 10-20 minutes after the turbocharger has been cleaned.**

It ensures that all the parts in the exhaust system are completely dry.

15.2.3 Water cleaning of compressor v7

The compressor can be cleaned by injecting water during operation. The method is efficient provided that contamination is not too far advanced. If the deposit is very heavy and hard, the compressor must be dismantled and 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 additivities 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.

CAUTION

Clean the compressor (air side) of the turbocharger at as high load as possible but not over 85%.

Cleaning should take place regularly, see Maintenance Schedule. Depending on the results obtained, the interval between two washings may be increased or reduced.

CAUTION

Ensure that you open the right valve, depending on compressor or turbine wash.

15.2.4 Compressor cleaning procedure v13

Procedure

1 **Record the charge air pressure, cylinder exhaust gas temperatures and charger speed.**

These are used to evaluate the efficiency of the cleaning.

2 **Open the compressor wash valve (2).**

See *Fig 15-2*.

3 **Connect the water hose.**

4 **Wash the compressor side by opening the main valve (6) without changing the flow meter valve setting from the turbine side.**

Table 15-2 Washing time for the compressor

Turbocharger type	Washing time (s)
TPL67–C	10

5 **Close the main valve (6) and the compressor wash valve (2).**

6 **Disconnect the water hose.**

7 **Open the compressor wash valve (2) and drain out the water.**

8 **Now record the charge air pressure, cylinder exhaust gas temperatures and charger speed again. Evaluate the efficiency of the cleaning.**

The change in charge air pressure and the exhaust gas temperature shows the cleaning effect.

9 **If the engine is stopped after cleaning, run the engine for 10 to 20 minutes after cleaning the turbocharger.**

This ensures that all the parts on the compressor side are completely dry.

NOTE

If washing is unsuccessful, wait for at least 10 minutes before repeating the procedure.

15.3 Operation with damaged turbocharger

v6

In case of a serious breakdown of the turbocharger, a blanking device can be fitted according to the instructions below. See also turbocharger manual, section 06.

In an emergency situation like this, the engine can be temporarily operated at maximum 20% output. The thermal overload is a limiting factor on the diesel engine. Therefore, the exhaust gas temperatures must be carefully monitored during operation with a blanked turbocharger.

NOTE

The exhaust gas temperature after the cylinder head must not exceed 500°C.

A marine engine can be operated in emergency cases for a short period with only the damaged turbocharger blanked, as requested by the classification societies.

In such cases, the damaged turbocharger must be blanked according to the instructions below.

However, Wärtsilä strongly recommends both turbochargers to be blanked in these emergency cases as well.

15.3.1 Mounting the blanking device

v9

Procedure

1 **Remove the insulation sheets from the turbocharger(s).**

2 **Remove the bellows between the turbocharger(s) and air cooler housing.**

3 **Mount the screen plate(s) (2) on the flange connection of the air cooler housing, see *Fig 15-3*.**

4 **Remove the silencer or air suction branch.**

5 **Disconnect the cable for speed sensor(s).**

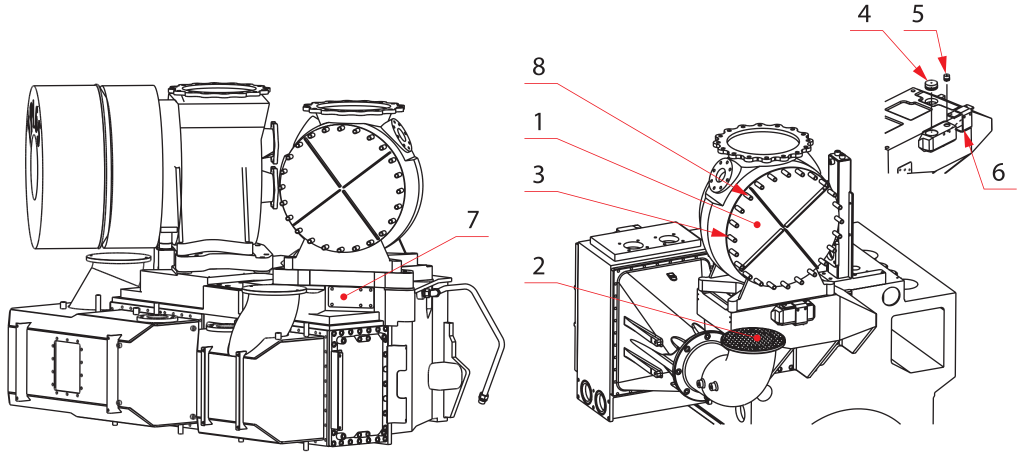
6 **Remove the locking plate for the lubricating oil connection pipes.**

Press the connection pipes downwards. On a V-engine, remove the lubricating oil connection piece.

7 **Mount the lifting equipment and open the nuts (8).**

Remove the compressor casing.

8 **Mount the lifting equipment and open the screws. Remove the cartridge assembly.**



1 Blanking cover
2 Screen plate
3 Distance sleeve
4 Plug
5 Plug
6 Cover plate
7 Flange
8 Nut

Fig 15-3 Blanking device

9 **Mount the plugs (4) and (5) with O-rings in the lubricating oil connection piece.**
Mount the cover plate (6) and tighten the screws. On a V-engine, mount the flange (7) with O-rings and tighten screws.

NOTE

The oil flow to and from the damaged turbocharger must be blocked in the turbocharger bracket by using suitable plugs or flanges.

10 **Mount the blanking cover(s) (1), attach the distance sleeves (3) and tighten the nuts (8).**

15.4 Charge air cooler

v7

Data and dimension

Material

- Tubes: copper alloy

- Water boxes: cast iron.

- Test pressure: 8 bar (water side)

The charge air cooler is of self-supported type. The cooler housing is fastened direct on the engine block by screws.

The air cooler is of tube-type, with thin fins on the tubes that ensures an efficient cooling of the air. The cooling water is circulated through the tubes and the charge air passes between the fins on the outside of the tubes.

15.4.1 Maintaining the charge air cooler v8

Procedure

1 **Verify regularly during engine operation that the drain pipe (8) is open and that there is no leakage in the cooler.**

> **NOTE**
>
> The cooler may be leaky if water drips or flows from the drain pipe for a longer period (unless humidity is very high or the LT temperature is too low because of a defective LT thermostatic valve).
>
> In that case, dismantle the cooler and perform a pressure test.

> **NOTE**
>
> At longer stops (several weeks), the cooler must be either completely full or completely empty. A half-full cooler increases the risk of corrosion.

2 **Clean the cooler and perform the pressure test at intervals stated in Chapter 04: Maintenance schedule.**

3 **Check for corrosion.**

15.4.2 Dismantling the air cooler (In-Line engine) v3

Procedure

1 **Drain the engine from cooling water.**
Drain the air cooler through the drain plugs under the cooler.

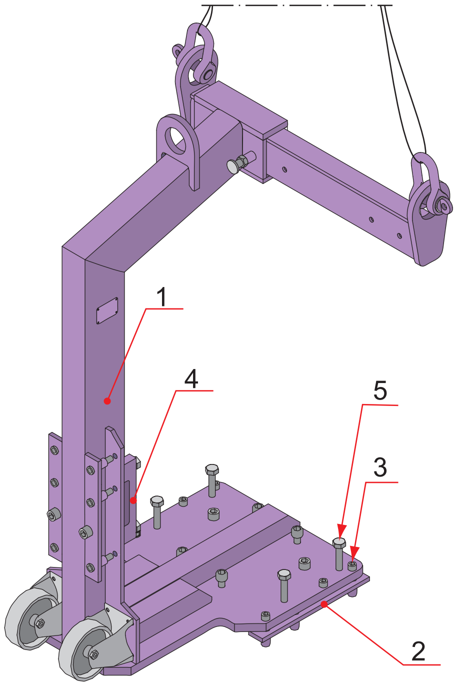
2 **Remove the necessary protection plates.**

3 **Remove the HT water connection box and pipes.**
In a 2-stage air cooler the connection box and the pipes are placed on top of the cooler.

   a **Disconnect the air ventilation pipes and remove the air plugs on the top of the cooler.**

   b **Disconnect the cables and pipes of the sensors.**

4 **Attach the lifting tool to the charge air cooler.**



1 Lifting tool 800 077 for charge air cooler
2 Distance piece (1-stage charge air cooler)
3 Fastening screws for the lifting tool (6 pcs)
4 Fastening plate (2-stage charge air cooler)
5 Fastening screws for the lifting tool (4 pcs)

Fig 15-4 Lifting tool

a **Attach the distance pieces to the lifting tool for 1-stage charge air cooler.**

b **Attach the fastening plate to the lifting tool for 2-stage charge air cooler.**

c **Tighten the fastening screws to secure the charge air cooler to the lifting tool.**
Location of the fastening screws depends on charge air cooler configuration.

5 **When lifting the charge air cooler along with the air inlet box.**

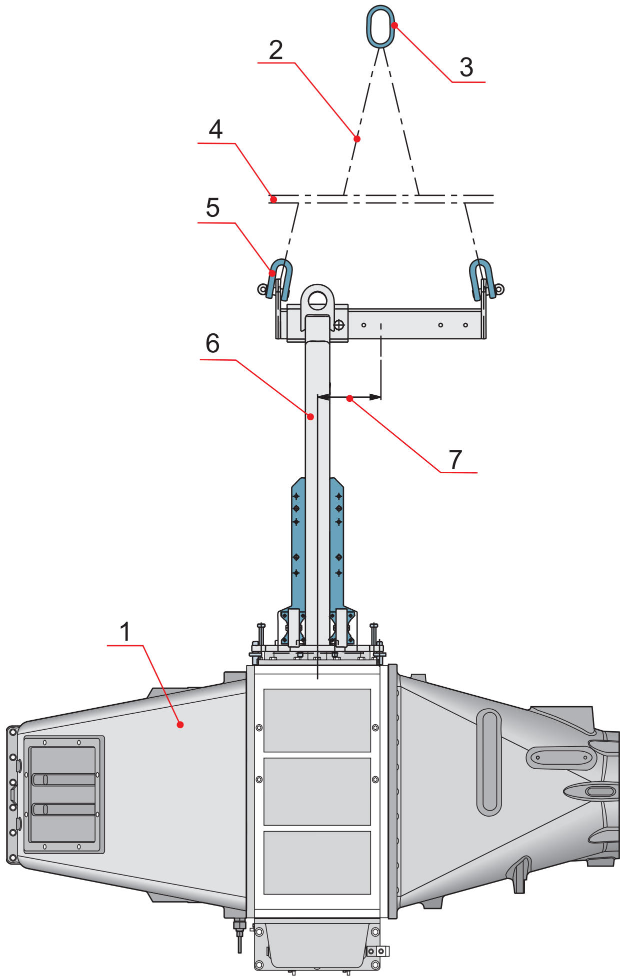
a **Attach the lifting straps from the eye bolt to the beam.**

b **Attach the lifting straps from the beam to the shackle bolt.**

c **Align the eye bolts correctly.**
Ensure that the angle and balance is maintained during lifting.

WARNING

Do not exceed the maximum distance between the frame body and the eye bolt. This may cause the lifting tool to lose balance d **Tighten the lifting straps.**



1 Air inlet box
2 Lifting strap
3 Eye bolt
4 Beam
5 Shackle bolt
6 Frame body
7 Maximum distance between the frame body and eye bolt is 208 mm

Fig 15-5 Lifting with the air inlet box

6 **When lifting the charge air cooler without the air inlet box.**

a **Attach one lifting strap from the eye bolt to the shackle bolt.**

b **Attach the other lifting strap from the eye bolt to the lifting shaft.**

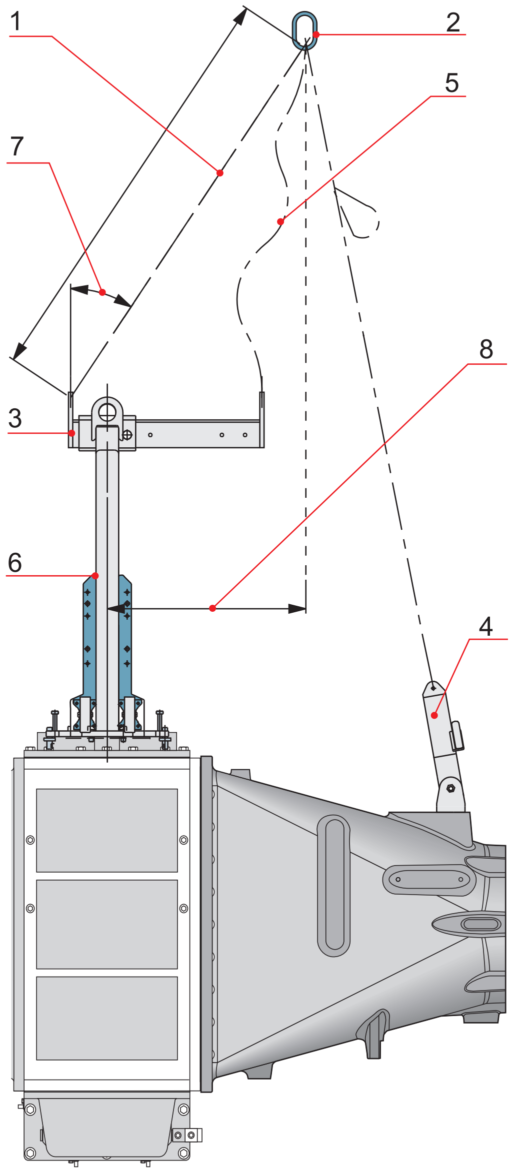
c **Attach the safety strap from to the eye bolt to the other shackle bolt.**

d **Align the eye bolts correctly.**

Ensure that the angle and balance is maintained during lifting.

WARNING
Do not exceed the maximum distance between the frame body and the eye bolt. This may cause the lifting tool to lose balance

e Tighten the lifting straps.



1 Lifting strap
2 Eye bolt
3 Shackle bolt
4 Lifting shaft
5 Safety strap
6 Frame body
7 Correct lifting angle ~35°
8 Maximum distance between the frame body and eye bolt is 700 mm

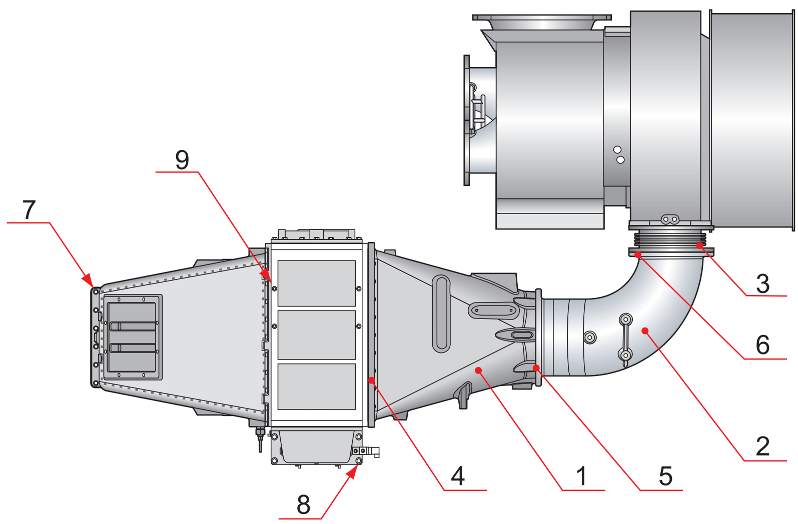
Fig 15-6 Lifting without the air inlet box

7 **If required, release the diffuser.**

Some of the diffusers are welded assemblies.

NOTE

Depending on the engine type or engine configuration , the diffuser need not be removed if the fastening screws are on the backside of the air cooler and cannot be accessed.



1 Diffuser
2 Airduct
3 Bellows
4 Fastening screws between the charge air cooler and the diffuser
5 Fastening screws between the diffuser and the airduct
6 Fastening screws between the airduct and bellows
7 Fastening screws between the air inlet box and the engine block.
8 Fastening screws between the water box and the engine block.
9 Fastening screws between the charge air cooler and the air inlet box.

Fig 15-7 Releasing the diffuser

Location of the fastening screws depends on cylinder configuration.

a **Depending on diffuser type, release the fastening screws between the diffuser and the airduct.**

b **Depending on diffuser type, release the fastening screws between the airduct and the bellows.**

8 **Lifting the charge air cooler.**

a **Open the inspection cover.**

b **When lifting with the air inlet box, release the fastening screws between the air inlet box and the engine block.**

c **When lifting without the air inlet box, release the fastening screws between the charge air cooler and the air inlet box.**

NOTE
Some of the screws are inside the air inlet box.

CAUTION
In case a screw comes loose it may cause serious damage to the engine.

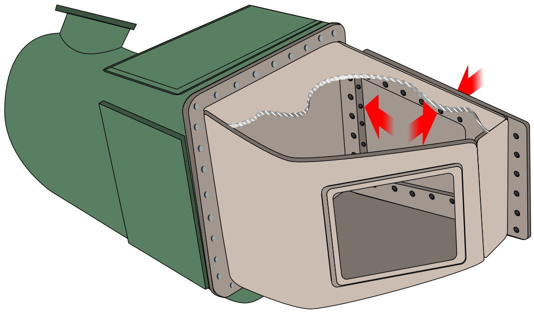


Fig 15-8 Air inlet box inside screws

d **Release the remaining fastening screws between the water box and the engine block.**

e **Lift off the charge air cooler assembly.**

f **Dismantle the remaining parts from the charge air cooler.**

15.4.3 Cleaning the air cooler

v8

Prerequisites

Clean air cooler heat exchange surfaces are essential for a long and trouble-free engine operation. Clean the air cooler at regular intervals to prevent pressure drop over the charge air cooler.

Procedure

1 **Remove the protecting plate of the air cooler housing.**

2 **Attach the lifting tool 800077.**

3 **Remove the cooler flange screws.**

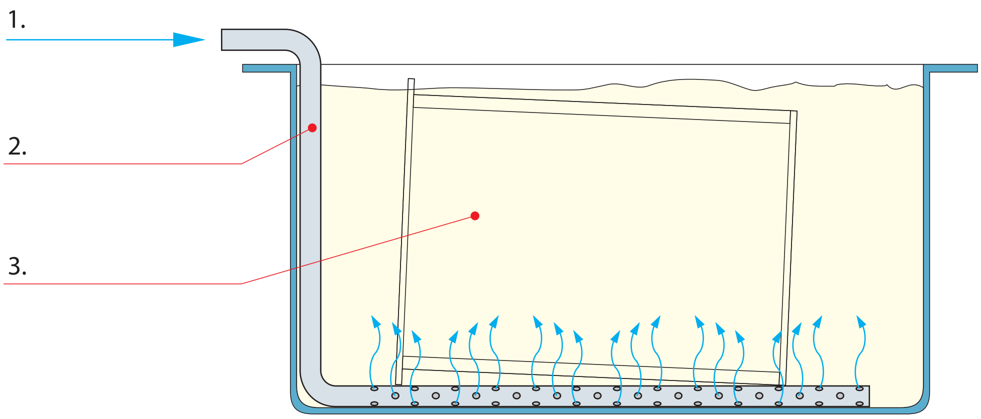
4 **Lower the cooler until it is clear from the cooler housing.**

5 **Clean the air side of the cooler by immersing it in a chemical cleaning bath for at least 24 hours.**

You can find the recommended cleaning detergents in Chapter 02.

a **Use perforated pipes on the bottom of the tank for the best cleaning effect.**

b Circulate steam or pressurised air to clean all pipe work.



1 Steam or air
2 Perforated pipes
3 Cooler insert

Fig 15-9 Air cooler cleaning tank

6 **Flush the cooler thoroughly with water.**

> **NOTE**
>
> Do not use a high pressure water jet on the cooling fins, it compacts the dirt and damages the fins leading to a lower cooling efficiency.

7 **Clean the water side.**

   a **Immerse the tube bundle into a chemical cleaning bath for at least 24 hours.**

   b **Follow the recommendations given for the air side.**

8 **Mount the cooler on the engine.**

15.4.4 Pressure testing the charge air cooler v4

Procedure

1 **Mount the testing tool, see *Fig 15-10*, onto the cooler and fill it up with water with the hand pump.**

2 **Pressure test the air cooler for 30 minutes.**

   See the instructions for testing device, according to cooler type in the air cooler tables.

3 **Drain the air cooler.**

4 **Remove the testing tool.**

Example

Table 15-3 Testing 2-stage air cooler, L-engine

Circuit	Water hose connection	Valves	Pressure (bar)
HT	HT-circuit	Valve 1 open, remove hose from LT-circuit	6
LT	HT-circuit	Valve 1 closed, connect hose to LT-circuit	6
LT and HT	HT-circuit	Valve 1 open, connect hose to LT-circuit	8

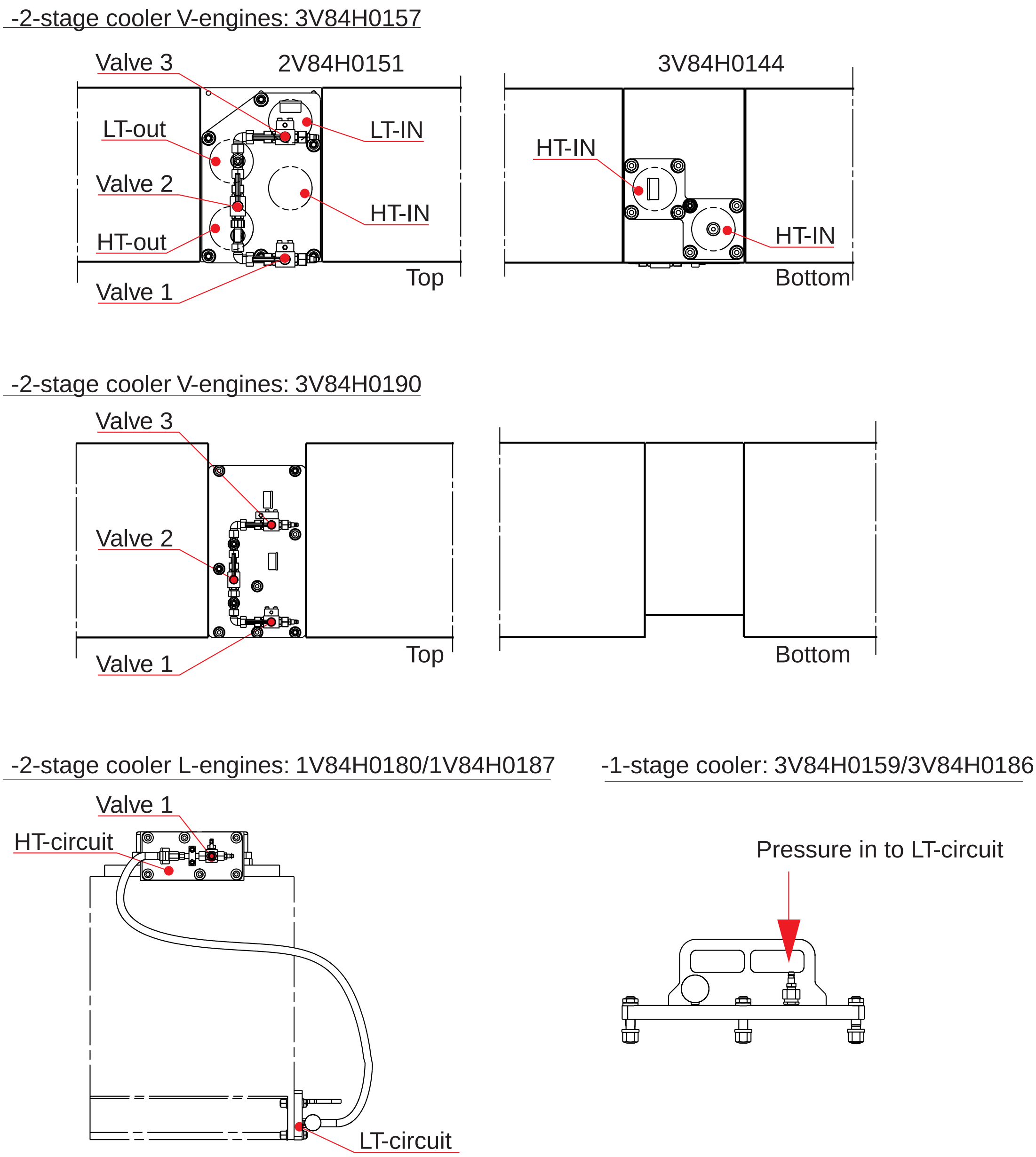
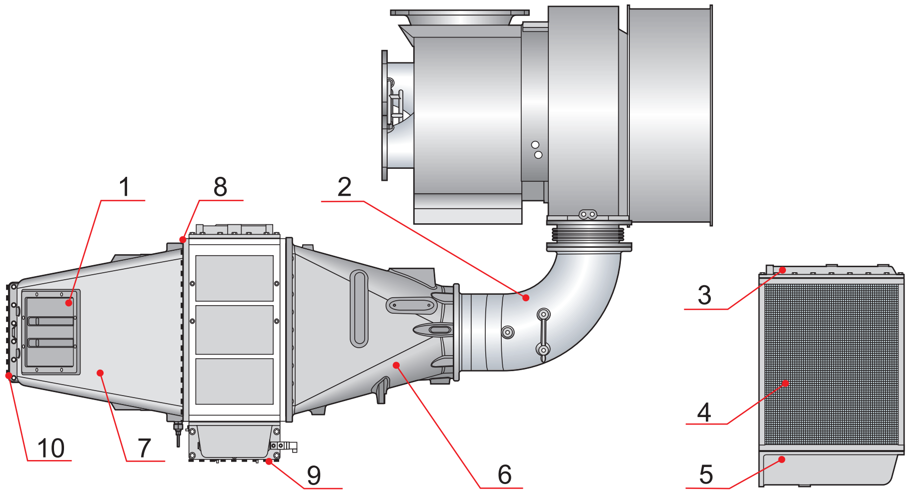


Fig 15-10 Pressure testing tools

15.4.5 Assembling the air cooler (In-Line engine) v5



1 Inspection cover
2 Airduct
3 Cover of charge air cooler
4 Charge air cooler
5 Water box
6 Diffuser
7 Air inlet box
8 Fastening screws between the charge air cooler and the air inlet box.
9 Fastening screws between the water box and the engine block.
10 Fastening screws between the air inlet box and the engine block.

Fig 15-11 Assembling charge air system

Procedure

1 **Reassemble the water box and the cover of the charge air cooler.**

NOTE

Renew all gaskets and o-rings.

2 **Put sealing compound on the sealing surfaces.**

For more information on use of sealing compound, see Charge air cooler assembly in the Spare Part Catalogue.

3 **Mount the diffuser of the charge air cooler.**

4 **If required, mount the air inlet box of the charge air cooler.**

Fasten the screws between the charge air cooler and the air inlet box by hand. Align it against the engine block.

5 **Mount the pressure tested cooler assembly in to place.**

a **Attach the lifting tool 800 077 for charge air cooler.**

NOTE
Confirm location of the lifting eye bolt, see Dismantling the air cooler (L-engines).

b **Place the air cooler assembly against the engine block.**

c **Check that the O-rings are in correct position.**

d **Fasten the screws between the water box and the engine block to the stated torque.**

e **Fasten the screws between the air inlet box and the engine block to the stated torque.**

6 **Tighten the screws between the charge air cooler and the air inlet box to the stated torque.**

Take care that the inlet box and the cooler are well aligned.

NOTE
Some of the screws are inside of the charge air cooler.

CAUTION
In case a screw comes loose it may cause serious damage to the engine.

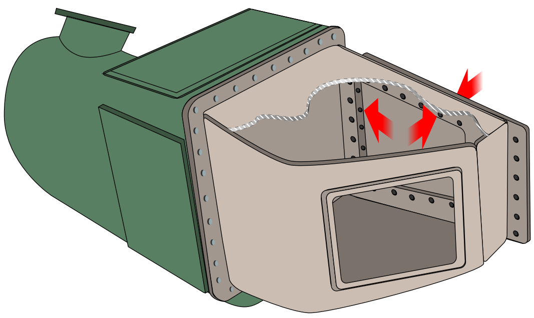


Fig 15-12 Air inlet box inside screws

7 **Tighten the screws between the water box and the engine block.**

8 **Tighten the screws between the air inlet box and the engine block.**

9 **Reassemble the inspection cover.**

10 **Tighten the airduct.**

Location of the remaining fastening screws depends on cylinder configuration.

a **Tighten the fastening screws between the diffuser and the airduct.**

b **Tighten the fastening screws between the airduct and bellows.**

11 **Mount the water connection box.**

In a 2-stage air cooler the connection box and pipes are on the top of the cooler.

a **Connect the air ventilation pipes.**

b **Connect the cables for the sensors.**

c **Connect the shield plates.**

d **Connect the water connection box and the necessary pipes.**

12 **Fill the cooling system with water.**

13 **Vent the cooler and check the fastening screws before starting up.**

15.4.6 Measuring differential pressure over charge air cooler v10

The charge air cooler maintains the thermal load of the diesel engine at a correct level. This is very important for keeping fuel consumption and operating costs down.

An increasing pressure drop (Δp) over the charge air cooler (on the "air side") causes an increasing thermal load and increasing fuel oil consumption.

By regularly measuring the Δp over the charge air cooler, the condition of the charge air cooler can be evaluated, and the air cooler can be cleaned or changed to a spare one at the right time.

The Δp in the factory test protocol for the new cooler is used as a reference point when measuring pressure difference over the cooler.

The cooler should be cleaned when Δp over cooler is more than 1.5 times the Δp of a cleaned or new cooler.

The pressure difference over the air cooler can be measured by using a U-tube manometer or pressure difference indicator .

Procedure

1 **Connect a water-filled U-tube manometer or a pressure difference indicator to the measuring points.**

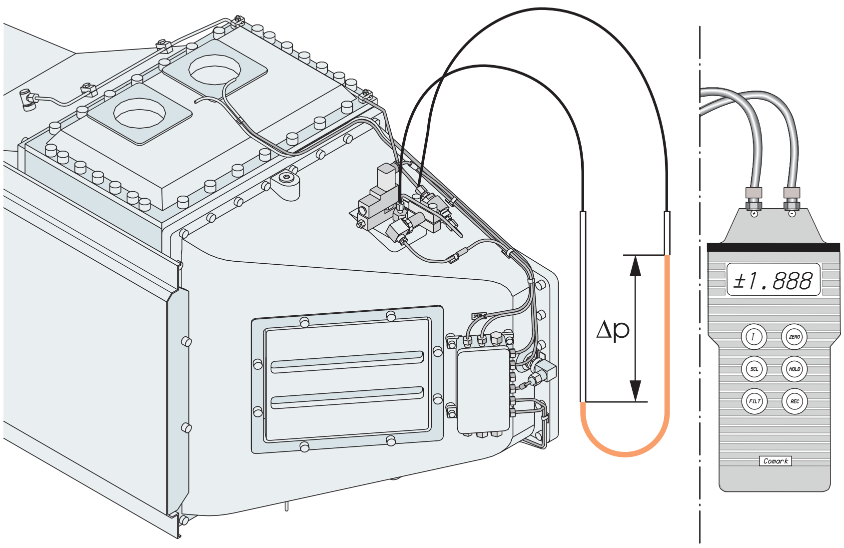


Fig 15-13 Measuring the pressure difference

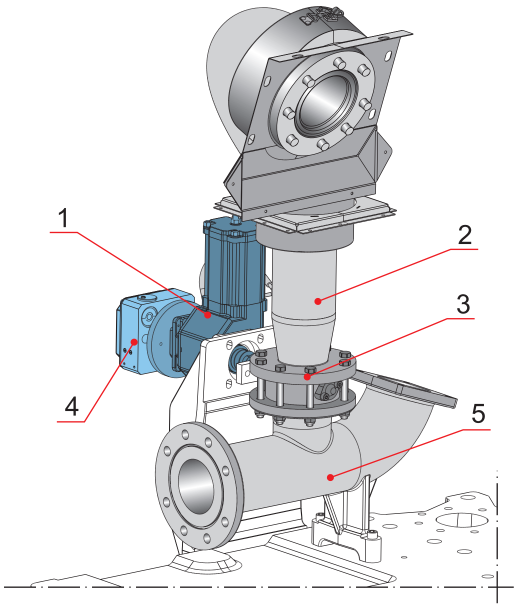
If using the U-tube manometer, measure the pressure difference by using a measuring tape.

15J. Exhaust gas wastegate

The wastegate valve functions as a regulator and is used for limiting the charge air pressure at high loads.

When opened, the exhaust gas wastegate valve partly by-passes the exhaust gases over the turbocharger thus reducing the turbocharger speed and charge air pressure in the receiver.

The exhaust gas wastegate system is built on the engine and consists of an actuator (1) and positioner (4) connected to the butterfly valve (3). The butterfly valve controls the exhaust by-pass flow via the pipes (2) and (5). The flow to the turbocharger exhaust gas outlet is regulated to maintain the correct charge air pressure.



1 Actuator
2 Exhaust pipe outlet
3 Butterfly valve
4 Positioner
5 Exhaust pipe inlet

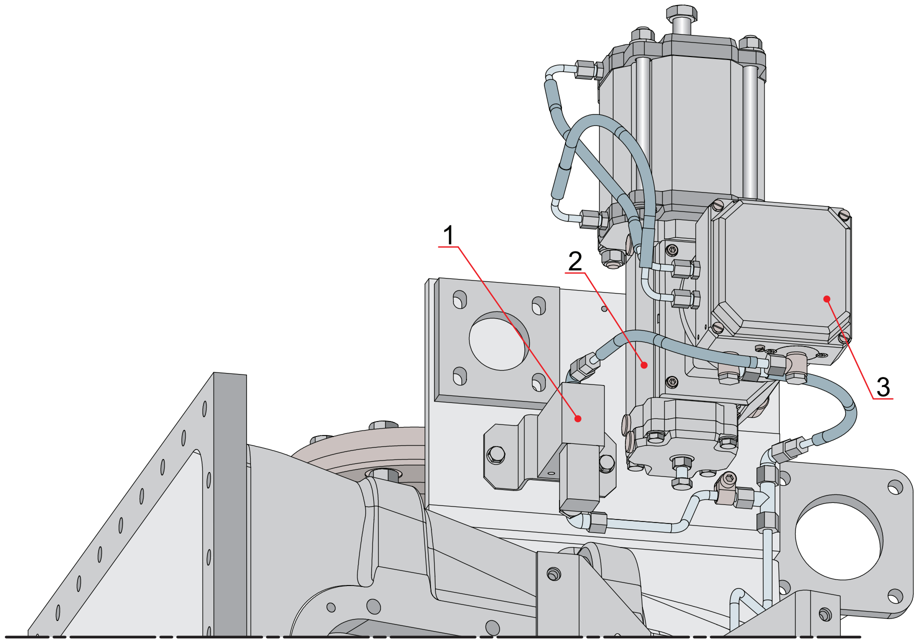
Fig 15J-1 Exhaust wastegate system

15J.1 Functioning of exhaust gas wastegate

v16

The wastegate control system gets compressed air from the instrument air system.

The air pressure is approximately 5 - 8 bar. The instrument air must be clean, dry and oil-free to ensure efficient functioning of the components. See, Chapter: 21 Starting air system.



1 I/P converter
2 Actuator
3 Positioner

Fig 15J-2 Control air system for wastegate

The wastegate system works as follows: When the engine is running, air is supplied to the I/P converter (1) and the positioner (3) in the actuator unit (2). The I/P converter supplies a 0.2-1.0 bar control air pressure to the positioner depending on the incoming 4-20 mA control signal. The positioner pilot valve (11 in *Fig 15J-3*) maintains air pressure to the actuator (2) according to the control air pressure from the I/P converter.

CAUTION

Do not change the I/P converter during engine operation.

15J.2 Built-in test

v3

To improve the mobility and reliability of the exhaust wastegate valve operation during running of the engine, a built-in test is performed before engine start.

The wastegate valve position is changed back and forth from close to open until it moves satisfactorily or/and a preset number of openings and closings has been done.

15J.3 Maintenance of exhaust gas wastegate

15J.3.1 Checking the wastegate system

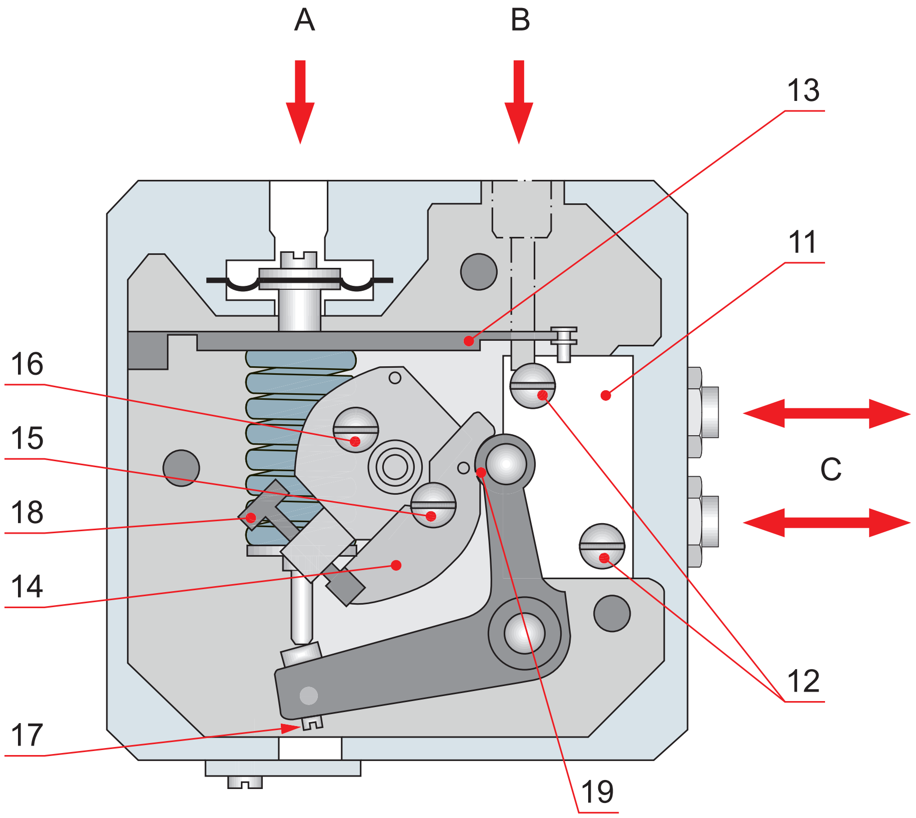
v5

The wastegate system requires a regular check for wear and function.

Procedure

1 **Check the key connection between the actuator and the positioner for wear.**

2 **Check for possible wear inside the actuator by moving the shaft.**



11. *Positioner pilot valve* 12. *Screw* 13. *Lever* 14. *Cam* 15. *Screw* 16. *Screw* 17. *Adjusting screw* 18. *Adjusting screw* 19. *Ball bearing* A. *Signal from I/P converter 0,2–1,0 bar* B. *Supply air 4–8 bar* C. *Connections to and from the actuator*

Fig 15J-3 Wastegate positioner

15J.3.2 Removing, dismantling and cleaning the positioner pilot valve

v6

The pilot valve in the positioner should be replaced with a new one according to chapter 04 Maintenance schedule or in case of malfunction.

Procedure

1 **Remove the positioner cover and the pilot valve screws (12), see *Fig 15J-3*.**

2 **Pay attention to the pilot valve stem and the lever (13), remove the pilot valve carefully.**

3 **Replace the pilot valve (11) with a new one and reassemble the positioner in the opposite order.**

4 **Adjust the wastegate positioner, see section *15J.4*.**

5 **Calibrate the wastegate I/P converter, see section *15J.7*.**

15J.3.3 Cleaning the pilot valve

v5

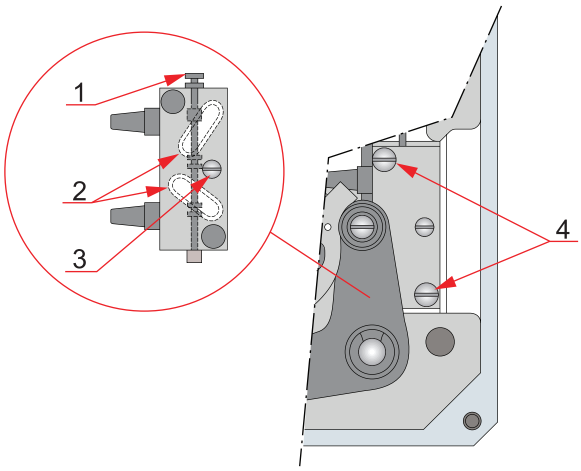
The positioner is in principle maintenance free. The supply air for positioner must be clean and free from oil and water.

Disturbances are mostly caused by contamination of the supply air.

The supply air must have a constant pressure within the range of 5–8 bar.

Procedure

1 **Check the function of the valve by following the positioner movement when the engine is restarted and runs on load.**



1 Slide	3 Screw
2 O-rings	4 Screw

Fig 15J-4 Cleaning the pilot valve

2 **Loosen the screw (4) and carefully remove the pilot valve.**

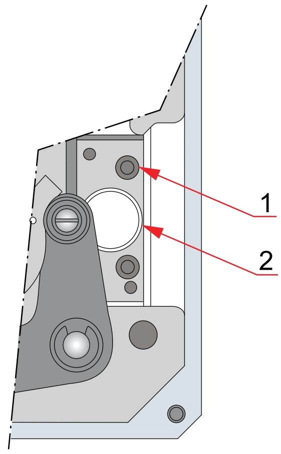
Remove the screw (3).

3 **Handle the components with care and pull out the slide (1).**

Wash housing and slide with solvent and blow clean.

4 **Remove the filter (2) located under the pilot valve and the O-rings (1).**

Wash with solvent of type acetone and blow clean.



1 O-rings.
2 Filter

Fig 15J-5 Removing the filter

5 **Replace with new filter and O-rings.**

6 **Assemble the pilot valve and remount the complete unit into the positioner.**

15J.4 Adjusting the wastegate positioner

v8

Prerequisites

Remove the screws (2), cover (3) and the yellow indicator (1). Make sure that the cam disc is in zero position when the actuator is closed (S-position). See *Fig 15J-6*.

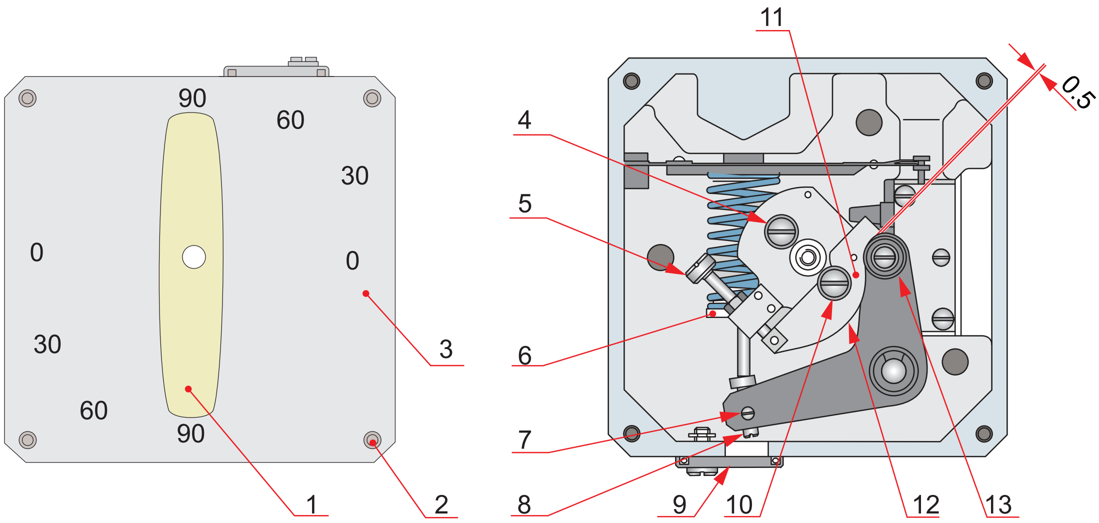
NOTE

Make sure there is a clearance of about 0.5 mm between the ball bearing (16) and the cam disc (12) at an input signal of 20 kPa (closed valve), see *Fig 15J-6*.

Procedure

1 **Loosen the top (4) and bottom (10) screws and position the cam disc (12) in accordance with the note, see *Fig 15J-6*.**

Tighten the top and bottom screws at correct position.



1 Yellow indicator
2 Screw
3 Cover
4 Top screw
5 Adjustment screw
6 Locking nut
7 Screw
8 Zero-point adjustment screw
9 Cover
10 Bottom screw
11 Cam scale
12 Cam disc
13 Ball bearing

Fig 15J-6 Zero point adjustment

2 **Zero adjustment is done with the zero-point adjustment screw (8), which can be reached through the cover (9).**

3 **Tighten the bottom screw (10) and the locking nut (6).**

4 **For adjustment of the zero-point adjustment screw (8), use the screw (7).**

NOTE

At reverse function, AC, use the adjustment screw (5) for zero adjustment and the zero-point adjustment screw (8) for range adjustment.

5 **Calibrate the wastegate I/P converter, see section** *15J.7***.**

6 **Mount the yellow indicator and the cover.**
Indicator reading on the cover should be the same as on the cam scale (11).

15J.5 Tuning the wastegate actuator

v1

Prerequisites

- Make sure that the positioner has not been damaged.
- Power supply must be 4 - 20 mA for connecting the turbocharger box.
- Check that the actuator is mounted properly to the bracket with the screws (3), see *Fig 15J-7*.

NOTE

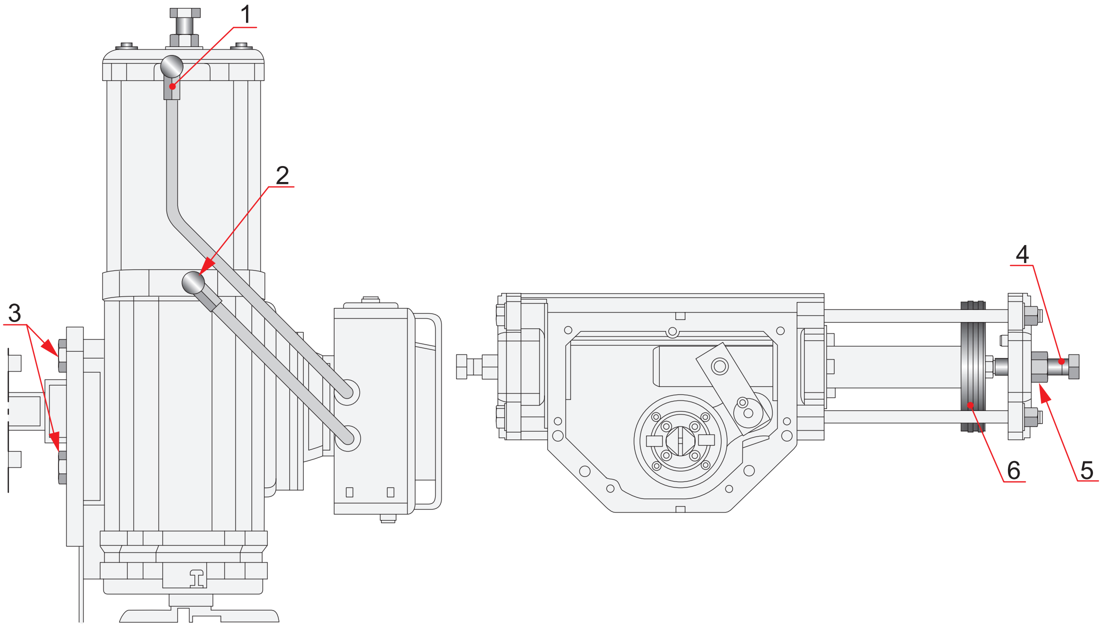
The supply air must be clean and dry instrument air with a constant pressure range of 5-8 bar.

Procedure

1 **Release the compressed air tubes from the actuators (1) and (2).**

2 **Open the locking nut (5) and loosen the adjustment screw (4).**

3 **Feed compressed air into the air hole of the actuator (2).**
Use a regular air gun.



1 Actuator
2 Actuator
3 Screw
4 Adjustment screw
5 Locking nut
6 Valve

Fig 15J-7 Tuning the actuator

4 **When feeding air into the actuator, screw the adjustment screw (4) at the same time towards closing and deflate.**
You can feel when the screw reaches the valve (6), when the valve is closed.

5 **Tighten the screw (4) a half to one turn and tighten the locking nut (5).**

6 **Re-insert the compressed air tubes to the actuators (1) and (2).**

15J.6 Tuning the wastegate pneumatic positioner v2

Procedure

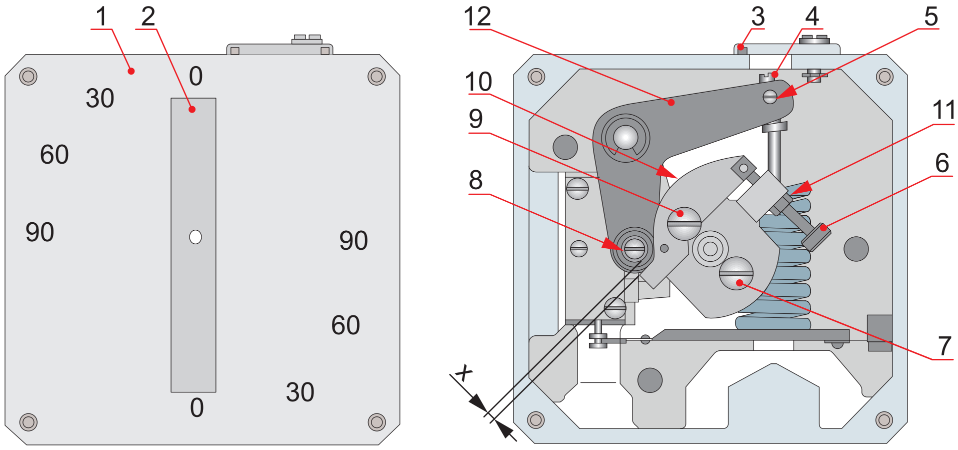
1 **Open the dust jacket (1) and remove the yellow pointer from the positioner (2).**

2 **Open the cover (3) and loosen the locking screw (5).**

3 **Turn the zero pint adjustment screw (4) so that both ends are equally visible.**

4 **Loosen the bottom and top screws (9) and (7).**

5 **Set the applicator (12) so that the plate (10) is in the cup.**



1 Jacket
2 Positioner
3 Cover
4 Zero point adjustment screw
5 Locking screw
6 Adjusting screw
7 Top screw
8 Ball bearing
9 Bottom screw
10 Plate
11 Locking nut
12 Applicator

X= 0.5 mm

Fig 15J-8 Pneumatic positioner

6 **Tighten the bottom and top screws (9) and (7).**

7 **Adjust the zero point adjustment screw (4) so that there is a gap of 0.5 mm between the ball bearing (8) and the plate (10).**

8 **Drive the positioner two times back and forth with a power supply and check that the gap still exists, see** *section 15J.7*.

9 **Tighten the locking screw (5) and mount the cover (3).**

10 **Check that the positioner is tuned to 0 degrees when the power supply input is 4 mA.**
The position is shown on the scale in the middle of the plate (10) in degrees.

11 **Adjust the positioner, if necessary.**

a **Loosen the bottom screw (9) and locking nut (11).**

b **Turn the adjusting screw (6).**

c **Drive the positioner a couple of times with a power supply and check the adjustment.**
Re-adjust if needed.

d **Tighten the bottom screw (9) and lock the adjusting screw (6) with the locking nut (11).**

12 **Insert the yellow pointer to the positioner (2) and mount the dust jacket (1).**

15J.7 Calibrating the wastegate I/P converter v1

Before starting calibration of the wastegate I/P converter, the wastegate positioner must first be adjusted. See section *15J.4*.

The calibration can be done by using a mA calibrator.

15J.7.1 Manually with mA calibrator v3

Prerequisites

- You need a 4-20 mA current calibrator for the calibration.

NOTE

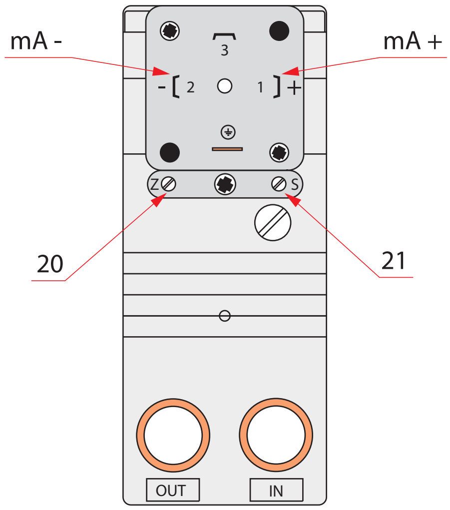
Check the actuator and positioner tuning before calibrating the I/P converter.

Procedure

1 **Ensure that the engine is stopped and in stop mode.**
For more information, see section 23 Alarm and safety system.

2 **Check that the control air is enabled.**

3 **Connect the mA calibrator to the I/P converter.**



20.*Zero adjustment screw* 21.*Span adjustment screw*

Fig 15J-9 Wastegate I/P converter

4 **Set the mA to equal 30 degrees on the cam (14), see *Fig 15J-3*.**
See *Table 15J-1*.

5 **Adjust the zero adjustment screw (20) on the I/P converter, so that the roller on the positioner cam points to the engraved scale at 30 degrees.**

6 **Set the mA to equal 60 degrees on the cam.**
See *Table 15J-1*.

7 **Adjust the span adjustment screw (21), so that the roller on the positioner cam points to the engraved scale at 60 degrees.**

8 **Repeat steps 4-7 above until it shows the correct values.**

9 **Check the whole range according to the table.**

NOTE

Note that the end points of the scale may be mechanically unreachable.

If 4.0 mA does not equal 0 degrees, adjust with the zero adjustment screw.

Table 15J-1

Degrees [°]	Current [mA]
0	4.0
15	6.7
30	9.3
45	12.0
60	14.7
75	17.3
90	20.0

16. Injection System

16.1 Injection pump

v6

The engine is designed with one injection pump per cylinder. The injection pump is located in a multihousing. The functions of the multihousing are:

- Housing for the injection pump element.
- Fuel supply channel along the whole engine.
- Fuel return channel from each injection pump.
- Lubricating oil supply to the tappet mechanism.

The arrangement with the multihousing represents a very safe fuel system. It also gives a compact design without fuel piping and with easy maintenance operations.

The injection pumps are one-cylinder pumps with separate roller tappets. The element, of mono element type, is fuel lubricated. The drain fuel is led in an integrated pipe system with atmospheric pressure back to the low pressure side of the injection pump.

Each injection pump is equipped with an emergency stop cylinder coupled to an electro-pneumatic overspeed protecting system.

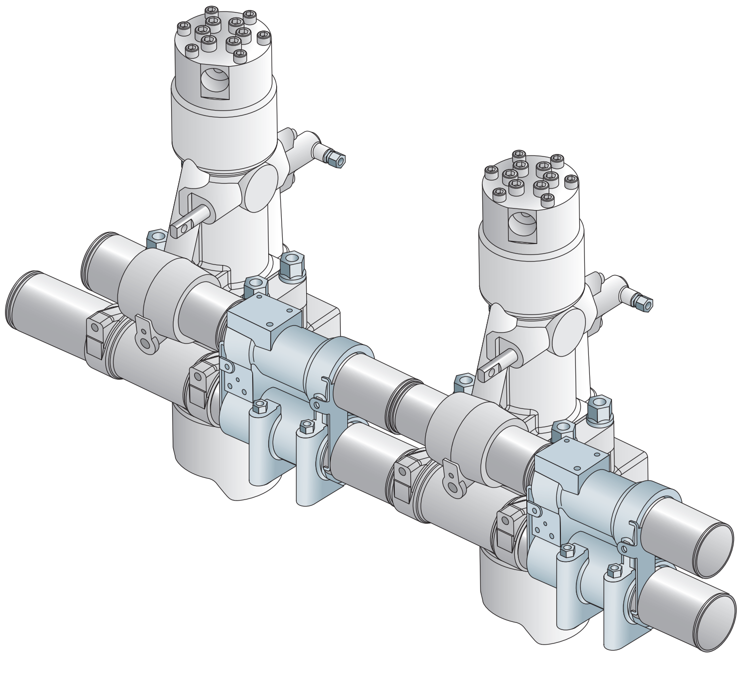


Fig 16-1 Injection pump and fuel piping

16.1.1 Functional description of injection pump

v5

The injection pump pressurises the fuel sent to the injection nozzle. It has a regulating mechanism for increasing or decreasing the fuel feed quantity according to the engine load and speed. The pumps are attached to the control shaft governed by the governor.

The plunger is pushed up by the camshaft via the roller tappet and pulled back by the spring acting on the plunger. This action reciprocates on the element at a predetermined stroke to feed fuel under pressure.

The plunger also controls the injected amount by adjusting the helix edge position relative to the discharge port. The plunger has an obliquely cut groove (lead) on its side. When the plunger is at the lowest position or bottom dead centre, fuel flows through the inlet port into the element bore. Rotation of the camshaft moves the plunger up. When the top edge of the plunger step aligns with the ports, the fuel is pressurised. As the plunger moves up further, and the helix of the plunger meets with the ports, the high pressure fuel flows through the lead to the ports and the pressurised fuel feed cycle is completed.

The plunger stroke during which the fuel is fed under pressure is called the effective stroke.

According to the engine load, the amount of fuel injected is increased or decreased by turning the plunger. The fuel rack is connected to the regulating mechanism of the governor. If the fuel rack is moved, the control sleeve in mesh with the rack is turned. Since the control sleeve acts on the plunger, the plunger turns with the control sleeve, thus the effective stroke changes and the fuel amount injected increases or decreases.

The fuel main delivery valve (MDV) and constant pressure valve (CPV) are located in the pump head piece.

The MDV, provided in the head piece, performs the function of discharging the pressurized fuel to the injection pipe. The fuel compressed to a high pressure by the plunger forces the MDV to open. Once the effective stroke of the plunger ends, the delivery valve is brought back to its original position by the spring and blocks the fuel path, thereby preventing counter flow of the fuel.

After the effective stroke, the fuel is drawn back through the CPV from the high pressure injection pipe to instantly lower the residual pressure between the MDV and the nozzle. This termination maintains constant pressure in the pipe line between injections.

The multihousing is provided with two erosion plugs, which can easily be replaced when necessary.

16.2 Maintenance of injection pump v4

Run the engine for 30 minutes on light fuel oil before commencing with injection pump maintenance.

Most maintenance operations can be done without removing the multihousing from the engine.

NOTE
During maintenance utmost cleanliness must be observed.

16.2.1 Removing the injection pump and the guide block v5

Procedure

1 **Shut off fuel supply to the engine and stop the pre-lubricating pump.**

Remove necessary covers.

2 **Drain out the fuel from the multihousing fuel pipes using the drain plug at the end part of the fuel pipes, see chapter 17.**

3 **Turn the crankshaft so that the injection pump tappet is in the bottom position, the roller resting on the base circle of the cam.**

4 **Remove necessary pipes, injection pipe, fuel leak pipes and lube oil pipe.**

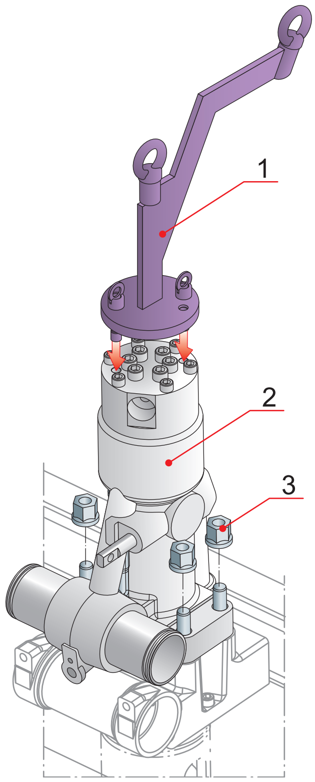
Disconnect the fuel rack.

5 **Open the fuel pipe connections between the injection pumps concerned.**

Open hexagon socket screws and remove locking plates. Move the fuel line connecting sleeves clear of the adjacent fuel pipes using the tool 800 039.

6 **Remove the injection pump.**

a **Open the injection pump fastening nuts (3).**



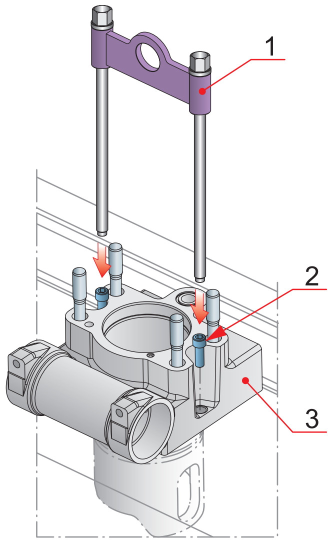
1 Lifting tool 800 073
2 Injection pump
3 Fastening nut

Fig 16-2 Lifting the injection pump

b **Mount the lifting tool 800 073 (1) and lift the injection pump (2).**

7 **Remove the guide block.**

a Open the guide block fastening screws (2).



1 Extractor tool 800 140
2 Guide block fastening screw
3 Guide block

Fig 16-3 Lifting the guide block

b Mount the extractor tool 800 140 (1) and lift the guide block (3).

8 **Cover all openings with tape or plugs to prevent dirt from entering the system.**

16.2.2 Overhauling the injection pump

v3

Prerequisites

- It is supposed that the multihousing is removed from the engine and it is properly cleaned.

NOTE

The element cylinder, plunger and delivery valve assembly are matched and must be kept together during the overhaul.

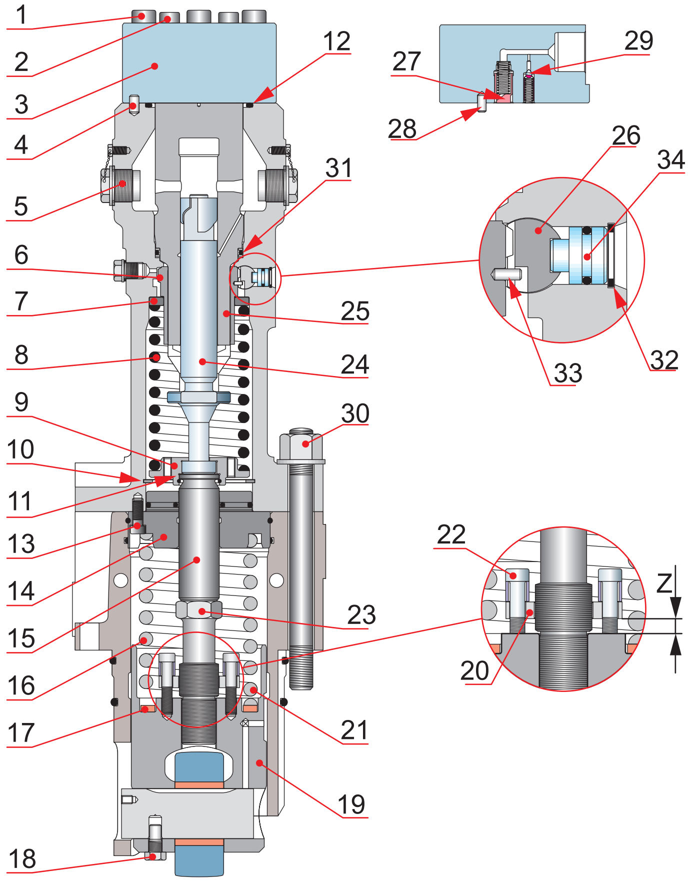
Procedure

1 **Attach the pump to a screw vice, in a positions that is convenient for the different operations.**

2 **Measure the tightness of CPV and MDV, see** *section 16.2.6*.

3 **Turn the pump up side down.**

4 **Open the screws (13) and remove the flange (14).**



1	Screw	18	Screw / Pin
2	Screw	19	Tappet
3	Head piece	20	Locking plate
4	Pin	21	Sleeve
5	Erosion plug	22	Screw
6	Control sleeve	23	Adjusting screw
7	Spring plate	24	Element plunger
8	Spring	25	Element cylinder
9	Spring holder	26	Fuel rack
10	Retainer ring	27	Main delivery valve + spring
11	Snap ring	28	Pin
12	Sealing ring	29	Constant pressure valve + spring
13	Screw	30	Nut
14	Flange	31	Sealing rings and Supporting rings
15	Push spindle	32	Retaining ring
16	Spring	33	Guiding pin
17	Spring disc	34	Guiding plug

Fig 16-4 Injection pump

5 **Secure the bush spindle assembly.**

Use the tool 800 033 and remove the retainer ring (10) using pliers.

WARNING

The push spindle is spring loaded. Be careful when loosening the tool.

6 **Release the spring tension and remove the tool.**

7 **Remove the push spindle (15), the spring holder (9), the spring (8), the snap ring (11) and the plunger (24).**

8 **Remove the spring plate (7) and control sleeve (6).**

9 **Remove the retaining ring (32) and guiding plug (34).**

10 **Remove the fuel rack (26).**

11 **Remove the head piece (3) and remove the main delivery valve (27) with spring and pressure relief valve (29) with spring.**

12 **Remove the element cylinder (25) using a soft tool.**

13 **Wash the parts in clean diesel oil and lubricate these with engine oil. Pay special attention to the grooves and bores for leak fuel and lubricating oil. Be careful, when handling small components of the injection equipment. Keep the parts together, the plunger being inserted in the element.**

14 **Keep the components of different pumps apart from each other, or mark them so they can be fitted into the same pump. Protect the parts against rust. Do not touch the running surface of the element plunger with bare hands.**

15 **Re-install the main delivery valve with spring (27) and pressure relief valve with spring (29) into the head piece (3). Mount new sealing ring (12).**

16 **Fit the element cylinder together with head piece using the screws (2).**

NOTE

The fixing pin (28) must be fitted properly.

17 **Mount new O-rings, sealing rings and supporting rings (31).**

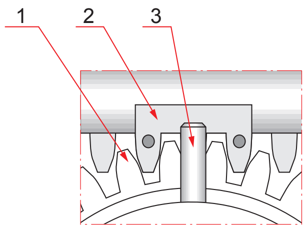
Re-install the element cylinder with the head piece into the multihousing, tighten the screws (1) lightly crosswise.

18 **Tighten the screws (2) crosswise in steps to the stated torque and then the screws (1) in the same way, see chapter 07.**

19 **Mount the fuel rack (26).**

20 **Mount the retaining ring (32) and guiding plug (34).**

21 **Turn the pump and assemble the control sleeve (1) with the fixing pin (3) aligned to the groove in the fuel rack (2), see *Fig 16-5*.**



1 Control sleeve
2 Fuel rack
3 Fixing pin

Fig 16-5 Fixing pin

22 **Re-install the spring plate (7) and the spring (8).**

23 **Re-install the element plunger (24) assembly with the spring holder (9) and the push spindle (15) carefully into correct position.**

NOTE

The marked plunger vane must slide into the fuel rack side of the control sleeve, that correspond to the marks on the fuel rack and the chamfered tooth of control sleeve.

24 **Press the push spindle down carefully using tool 800 033.**

To make the plunger vanes slide into the grooves on the control sleeve you can gently move the fuel rack.

25 **When plunger is deep enough install the retainer ring (10) with pliers.**

Turn the retainer ring opening towards the clean leak fuel line. Remove the tool and check that the fuel rack can be easily moved.

26 **Before installing the flange (14), check that the seal in flange is intact. If necessary, replace the sealing.**

27 **Mount the flange (14) and tighten the screws (13) to the required torque, see chapter 07.**

28 **Check that the fuel rack (26) can be easily moved.**

29 **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 the injection line connection must always be protected by plugs or tape.

16.2.3 Changing the erosion plugs v7

Procedure

1 **Remove the locking wire between the locking screws and erosion plugs (5).**

2 **Change erosion plugs and tighten to correct torque, see chapter 07.**

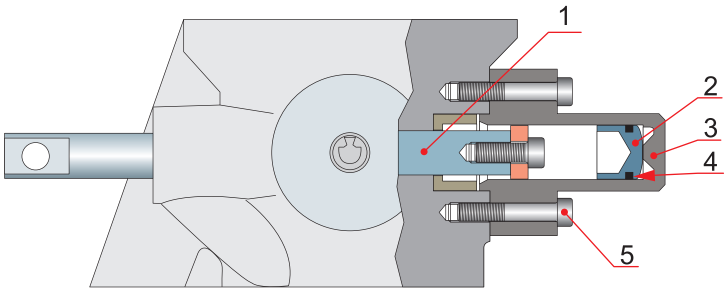
3 **Lock the erosion plugs with a locking wire to the fastening screw, see** *Fig 16-4***.**

NOTE

To prevent the risk of high pressure fuel leakage, the erosion plugs must be locked.

16.2.4 Pneumatic overspeed trip device v5

The pneumatic overspeed trip device is mounted on the multihousing and acts directly on the fuel rack. When the overspeed trip device is activated, pressurized air acts on the piston in a cylinder attached to the multihousing. The piston forces the fuel rack to a "no fuel" position. The force of the overspeed trip device is stronger than the torsion spring in the regulating mechanism. For maintenance of pneumatic overspeed trip device, see chapter 22.



1 Fuel rack
2 Piston
3 Cylinder
4 Slide ring
5 Screw

Fig 16-6 Pneumatic overspeed trip device

16.2.5 Mounting the injection pump and the guide block v6

Procedure

1 **Clean the contact faces of the guide block.**

Renew the O-rings and lubricate with grease or engine oil.

2 **Remove the protecting tapes or plugs.**

3 **Use the extractor tool 800 140 and lift the guide block into the engine block.**

4 **Check that the roller axis is parallel to the camshaft by measuring the distance to the engine block on both sides of the guide block with a feeler gauge, that is measures B1=B2.**

Tighten the screws to the required torque, see chapter 07.

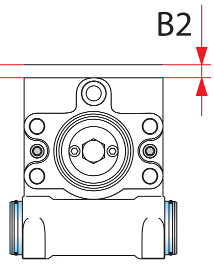


Fig 16-7 Guide block distance to the engine block

5 **Connect the fuel pipes between the multihousings concerned.**

Move the fuel line connecting sleeves on the fuel pipes using the tool 800 039.

6 **Check the injection timing, see chapter 13.**

7 **Clean the contact faces of the guide block and the injection pump.**

Renew the O-rings and lubricate with grease or engine oil. Mount the spring (16) in the guide block.

8 **Use the lifting tool 800 073 and lift the injection pump into the quide block.**

Tighten the fastening nuts lightly.

9 **Connect the fuel pipes between the injection pumps concerned.**

Move the fuel line connecting sleeves on the adjacent fuel pipes using the tool 800 039.

10 **Mount the locking plates and tighten the screws.**

11 **Tighten the fastening nuts to the required torque, see chapter 07.**

12 **Replace the O-rings and mount the leak fuel pipes to the high pressure pipe.**

Tighten the injection pipe to the required torque, see chapter 07. Connect the fuel rack.

NOTE

Check the injection pipe tightening torque on a hot engine, after running it for a few hours.

13 **Rotate the control shaft and check that all pumps follow the shaft movement.**

Check the fuel rack positions of all pumps, see chapter 22.

14 **Open fuel supply to the engine and vent the fuel system, see chapter 17.**

16.2.6 Testing the injection pump

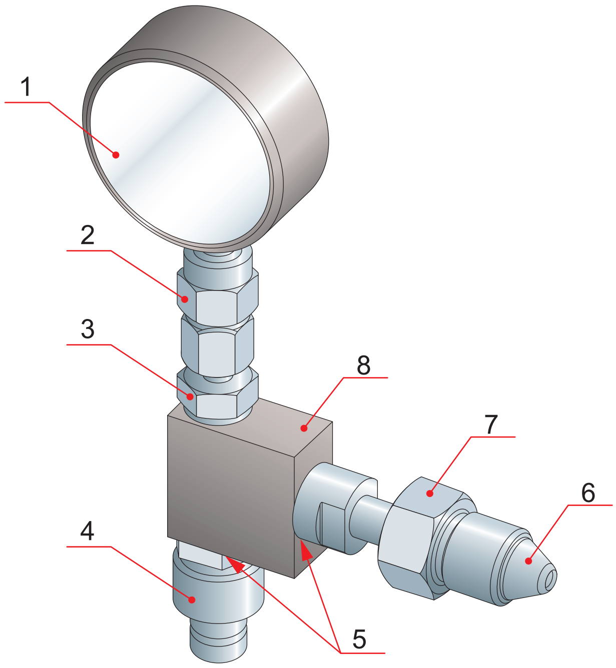
v2

Testing is carried out to check for leakages in the constant pressure valve (CPV) and the main delivery valve (MDV).

Procedure

1 **Attach the pressure testing tool 847 001 to the injection pump.**

Normal hydraulic oil or lubricating oil can be used as test oil.



1 Pressure gauge
2 Manometer union
3 Pipe union
4 Quick coupling
5 Sealing washer
6 Instrument adaptor
7 Fastening nut
8 Connection piece

Fig 16-8 Pressure testing tool 847 001

2 **Testing the injection pump CPV and MDV valves.**

a **Remove the high pressure pipe from the pump.**

b **Remove the erosion plug or open the low pressure pipe.**

c **Screw the pressure testing tool to the injection pump head.**

d **Connect the hydraulic pump to the quick coupling.**

e **Increase the pressure over the stated opening pressure (of the CPV).**

f **Stop pumping and record the reading when the pressure stops decreasing.**
Maximum waiting time is 2 seconds.

g **If the pressure drops continuously and approaches zero, the CPV or MDV is leaking.**
Change the injection pump head connection piece and valves.

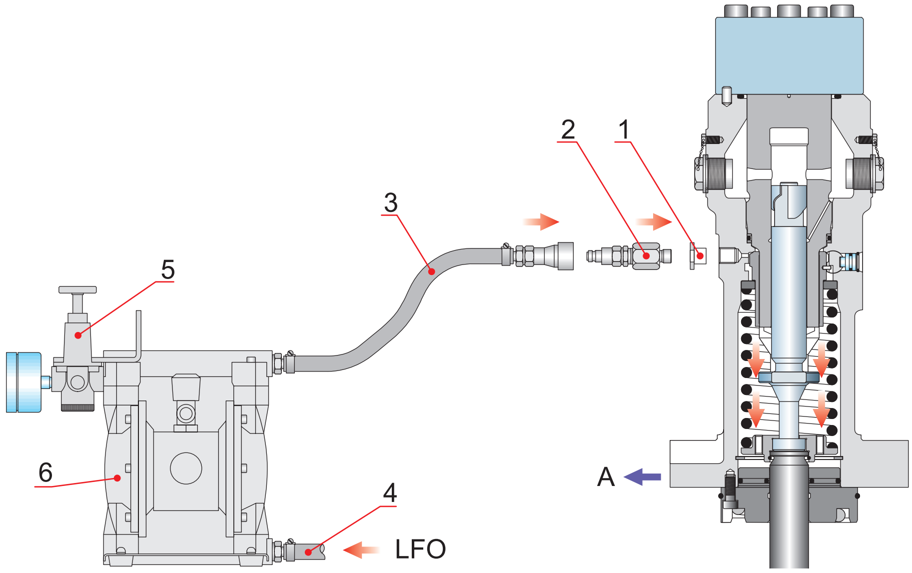
h **Typically the opening pressure is 20–60 bar below the nominal 130 bar.**

16.2.7 Cleaning the fuel injection pump v4

Prerequisites

Small heavy fuel oil leakages through the injection pump may, in some cases, block the fuel drain line and prevent free movement of the fuel rack.

Wärtsilä has developed a procedure to clean the interior of the lower part of the fuel injection pumps.



LFO Light fuel oil, A. To clean leak fuel system

1 Plug
2 Connection piece
3 Hose
4 Hose
5 Control valve
6 Washing device

Fig 16-9 Washing device for injection pump

NOTE

Before starting the washing procedure, check that the pipes to the clean leak fuel system are open.

Procedure

1 **Remove the plug (1) from the injection pump.**

2 **Fit the connection piece (2).**

3 **Connect the hose (3) to the connection piece (2).**

4 **Connect the suction hose (4) to a 10 litre canister containing clean light fuel oil.**

5 **Connect the air pressure hose to the washing device (6).**
Ensure that the valve before the control valve (5) is closed before connecting the air pressure hose.

6 **Slowly open the valve before the control valve (5).**

7 **Adjust the air pressure to 2 bar with the control valve (5).**

8 **Pump 4 to 5 litres of clean light fuel oil through the injection pump while moving the fuel rack back and forth.**

9 **Close the air supply to the washing device (6).**

10 **Remove the hose (3) and adapter (2), and mount the plug (1) with a new sealing ring.**
Tighten the plug to 80 Nm.

11 **Repeat the steps above on the remaining injection pumps.**

NOTE

If the injection pumps are very dirty, you can clean them mechanically and open the drain holes before using the cleaning device.

WARNING

Use necessary safety equipment like goggles, gloves and boiler suit to protect yourself. Do not leave the engine unattended while cleaning is in process. Be careful not to spill fuel on hot surfaces. Do not clean the injection pumps while the engine is running.

16.3 Injection line v9

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 in case only the injection pipe has been removed, because there is a risk of the connection piece coming loose when removing the pipe.

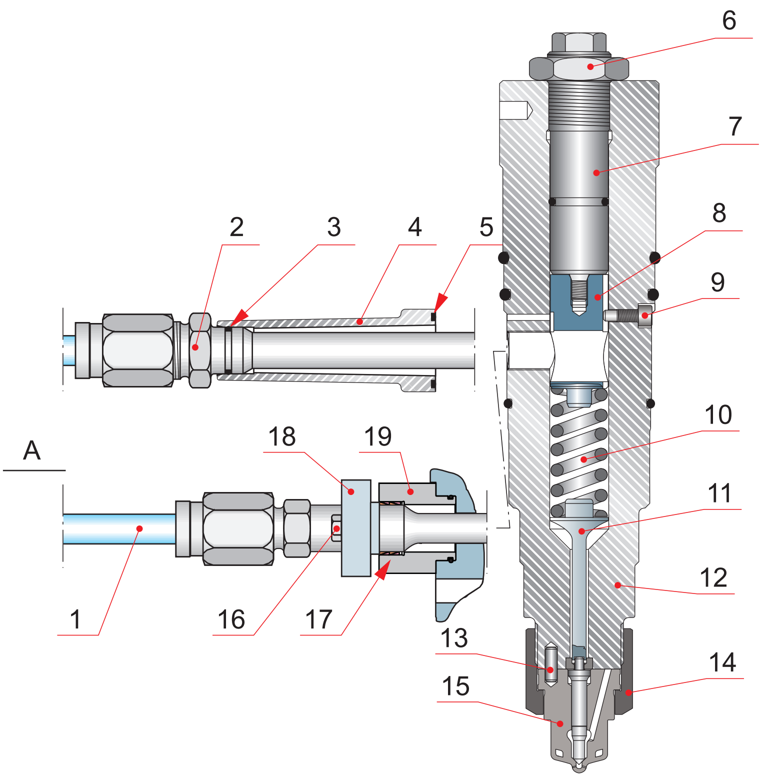
The injection pipe is double-walled to protect the engine environment from fuel leakages. The injection pipes are delivered complete with connection nuts assembled. Always tighten the connections to correct torque.

When removed, the injection line parts must be protected against dirt and rust.

16.4 Injection valve v7

The injection valve is centrally located in the cylinder head and includes the nozzle holder and the nozzle (15), see *Fig 16-10*. The fuel enters the nozzle holder sideways through a connection piece (2) mounted into the nozzle holder.

The nozzles receive high pressure fuel from the injection pipe and inject this fuel into the combustion chamber as a very fine spray. To correct the pressure at which the nozzle operate opens, adjust the pressure, turn the adjusting screw (7) in the injection valve.



A. *Friction ring design*
1 Injection pipe
2 Connection piece
3 O-ring
4 Protecting sleeve
5 O-ring
6 Counter nut
7 Adjusting screw
8 Spring retainer
9 Guiding screw
10 Spring
11 Push rod
12 Injection valve housing
13 Fixing pin
14 Nozzle nut
15 Nozzle
16 Screw
17 Conical ring elements
18 Flange
19 Flange

Fig 16-10 Injection valve

16.4.1 Removing the injection valve

v7

Procedure

1 **Remove the cylinder head cover and the hot box cover.**

2 **Remove the injection pipe (1), see** *Fig 16-10*.

3 **Remove the connection piece (2).**

Loosen the protecting sleeve (4). For Friction ring design, see text below.

4 **Loosen the screw (16).**

Unscrew the connection piece (2). The conical ring elements (17) come loose together with connection piece.

5 **Remove the fastening nuts of the injection valve.**

6 **Lift out the injection valve with the tool 800029.**

7 **Protect the fuel inlet hole of the injection valve and the bore in the cylinder head.**

16.4.2 Overhauling the injection valve

v5

Procedure

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 that the spring is broken. Clean the outside of the nozzle with a brass wire brush.

CAUTION

Do not use a steel wire brush.

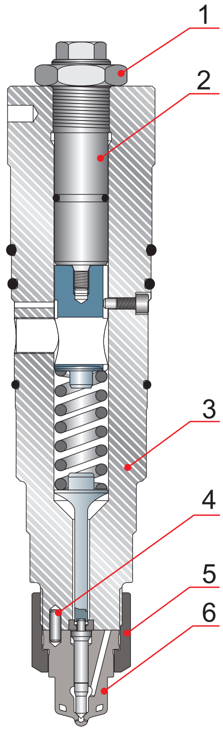
2 **Mount the injection valve in a test device and check the spray uniformity. Record the opening pressure.**

NOTE

Test the nozzle before dismantling the injection valve.

3 **Fit the injection valve in the injection valve holder (846070).**

4 **Release the nozzle spring tension by opening the counter nut (1). This in turn releases the adjusting screw (2).**



1	Counter nut	4	Dowel pins
2	Adjusting screw	5	Nozzle nut
3	Holder body	6	Nozzle

Fig 16-11 Injection valve

5 **Loosen the nozzle nut (5) using the socket wrench.**

6 **Remove the nozzle from the holder.**

Keep the nozzle (6) against the holder body (3) and do not let it turn up with the nut. The presence of coke between the nozzle and the nut may break the dowel pins (4) and damage the nozzle. To avoid this, knock on the nozzle nut (5), using a piece of pipe to keep it towards the holder.

CAUTION
Be careful not to drop the nozzle. Never knock directly on the nozzle tip.

7 **Check the nozzle needle movement.**

Do not remove the needle by force because this often results in complete jamming. If you cannot remove it easily, immerse the nozzle in lubricating oil, and the heat oil to 150–200°C. Normally, it's easy to remove the needle from a hot nozzle.

8 **Clean the components.**

a **Use a carbon dissolving chemical, to remove carbon deposits. If not available, immerse the details in clean diesel oil, white spirit, or similar to soak the carbon.**

b **Use the tools included in the tool set to clean the components.**

CAUTION
Do not use steel wire brushes or hard tools.

c **Clean the nozzle orifices using the needles kit 845 020.**

NOTE
Before inserting the needle in the nozzle body, immerse it in clean diesel oil or special oil for injection systems.

d **Check the seat surfaces, sliding surfaces (needle shaft), and sealing faces.**

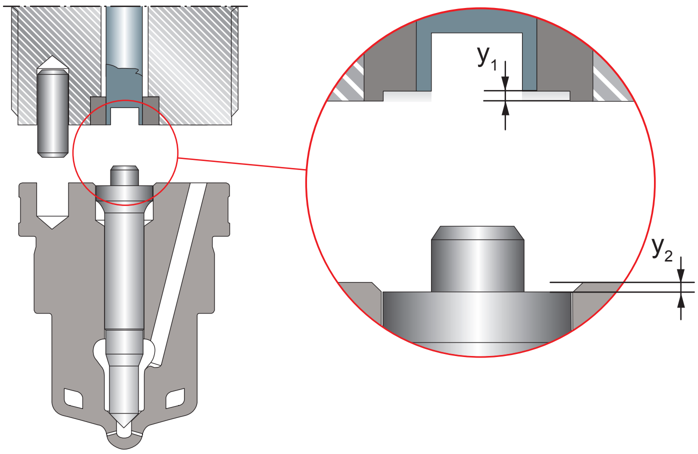
e **Rinse the details to remove carbon residues and dirt particles.**

9 **Clean the nozzle holder and the cap nut.**

Dismantle the nozzle holder to clean all details. Check the nozzle spring.

10 **Check the contact face of the nozzle and the bottom of the fuel inlet hole (high pressure sealing faces) of the nozzle holder.**

11 **Check the nozzle needle lift and wear of the impact bush in the nozzle holder.**



y_1.*Impact bush wear* y_2.*Needle seat wear*

Fig 16-12 Needle lift and wear

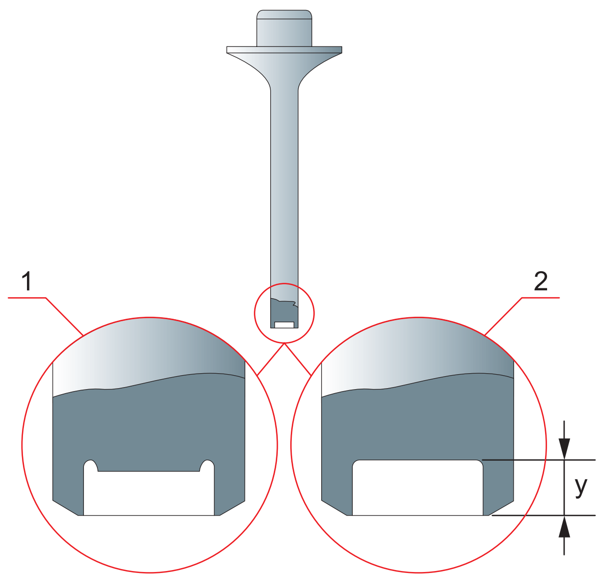
a **Measure the nozzle needle lift.**

Sum the measures y_1 and y_2. If the nozzle needle lift exceeds the required value, replace the nozzle with a new one. For the required values, see chapter 06.

b **Measure the wear of the impact bush in the nozzle holder y_1.**

If the impact bush wear exceeds the required value, the nozzle holder can be sent to the engine manufacturer for reconditioning. For the required values, see chapter 06.

12 **Check the push rod wear.**



1 New
2 Worn

y.*Push rod wear*

Fig 16-13 Push rod wear

a **Measure the push rod wear y.**

If the wear exceeds the required value, replace the push rod by a new one. For the required values, see chapter 06.

Compare all measured values against the values specified in the clearance and wear table.

13 **Reassemble the injection valve.**

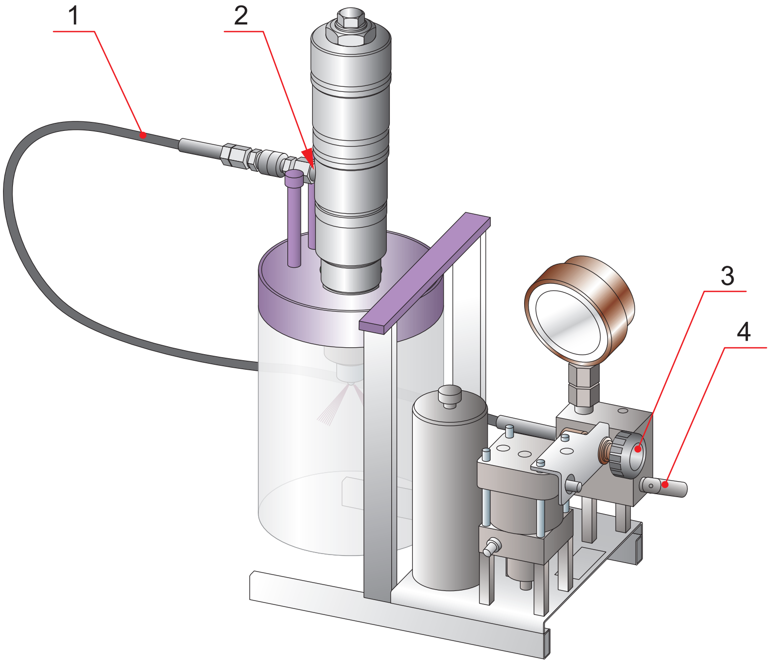
Tighten the nozzle nut (5) to the required torque, see chapter 07.

16.4.3 Testing the injection valve v3

Procedure

1 **Prepare the injection valve to test the opening pressure.**

a **Mount the injection valve in the test device.**



1 High pressure hose
2 Thrust piece
3 Pressure control valve
4 Oil return valve

Fig 16-14 Injection valve testing device

b **Connect the injection valve using the thrust piece (2) and the high pressure hose (1).**

c **Close the oil return valve (4).**

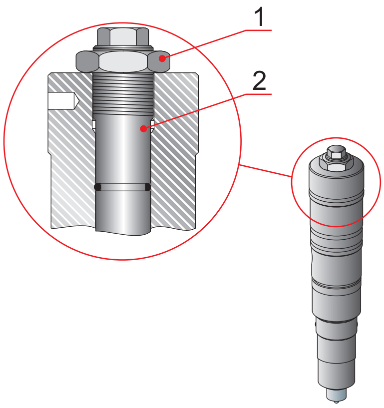
d **Open the pressure control valve (3) by turning it clockwise.**

The pressure increases until the nozzle needle opens.

e **Release the pressure by closing the pressure control valve and opening the oil return valve.**

2 **Adjust the needle opening pressure.**

a **Start from low spring tension, and increase the tension gradually by tightening the adjusting screw (2).**



1 Counter nut
2 Adjusting screw

Fig 16-15 Adjusting the needle opening pressure

b **When the needle opening pressure is reached, tighten the counter nut (1) to the required value.**

Used nozzle the needle opening pressure, see recorded opening pressure during overhauling the injection valve.

New nozzle the needle opening pressure, see chapter 06.

c **Check the fuel spray uniformity.**

Compare all measured values against the values specified in the clearance and wear table.

- When testing the injection valve with used nozzle proceed also the next step.

3 **Check the needle guide tightness.**

a **Increase the pressure to 300 bar.**

b **Close the pressure control valve.**

c **Measure the duration of the pressure drop until the pressure is 250 bar.**

If the pressure drop duration is 1/3 compared to a new nozzle measured with same equipment, the needle guide is too worn.

NOTE

Do not adjust the needle opening pressure for a used nozzle higher than recorded. If the needle opening pressure for an injection valve with used nozzle is adjusted back to the nominal value, the valve spring is more compressed and loaded. This can eventually lead to broken components in the injection valve.

Compare all measured values against the values specified in the clearance and wear table.

4 **If the tests does not give satisfactory results, replace the injector nozzle.**

5 **If leakage occurs, replace the damaged parts of the high pressure sealing surfaces with new one or recondition them.**

6 **If the injection valves or nozzles are to be stored, treat them with corrosion protecting oil.**

Postrequisites

Change the nozzle when:

- Maximum number of recommended service hours has been reached.
- The engine performance has deteriorated.
- Any signs of corrosion/cavitation damages can be noted.
- The leak tests have failed.
- Good fuel spray uniformity cannot be reached.

16.4.4 Mounting the injection valve

v5

Procedure

1 **Clean the injection valve sealing surface in the cylinder head.**
If necessary, clean or lap the surface using the tool 800 075.

NOTE

The injection valve seals directly to the bottom of the stainless sleeve.

2 **Renew the O-rings on the injection valve**
Lubricate the injection valve with clean engine oil.

3 **Fit the injection valve into the cylinder head bore. Tighten the valve fastening nuts by hand.**

NOTE

Check the guiding pin position.

4 **Replace the O-rings on the connection piece and on the protecting sleeve.**

5 **Mount the protecting sleeve on the connection piece.**
Screw the connection piece by hand. Tighten to the required torque. Tighten the protecting sleeve screws.

6 **Mounting the connection piece with friction ring design.**

a **Mount the connection piece into the cylinder head.**
Screw the connection piece by hand. Tighten to the required torque.

b **Tighten the fastening screws (16) of the flange (18) to the required torque, see chapter 07.**

7 **Mount the injection pipe. Tighten the cap nuts to the required torque.**

8 **Close the covers.**

17. Fuel System

The engine is designed for continuous Light, Heavy or Crude Oil duty. The recommendations for the fuel feed system pressure adjustment vary depending on the fuel quality and installation. 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 section *17.5* and chapter*01.2*.

It is of great importance that the fuel treatment before the engine is done properly e.g. necessary filter maintenance is carried out according to schedule. The efficiency of the fuel filtration influences directly on the lifetime of the injection equipment and thus on the engine performance.

17.1 Functional description of fuel system

v8

The fuel is pressurized by the pump (9) and filtered through the filter (4), see *Fig 17-1*. The pressure control valve (11) maintains correct pressure in the system and valve (1) at each engine.

Fuel feed pressure and temperature sensors are located on the engine inlet piping and monitored on the engine control room.

Fuel leaking from injection pumps and injection valves is collected (103) in a separate enclosed system. This fuel can be reused. 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.

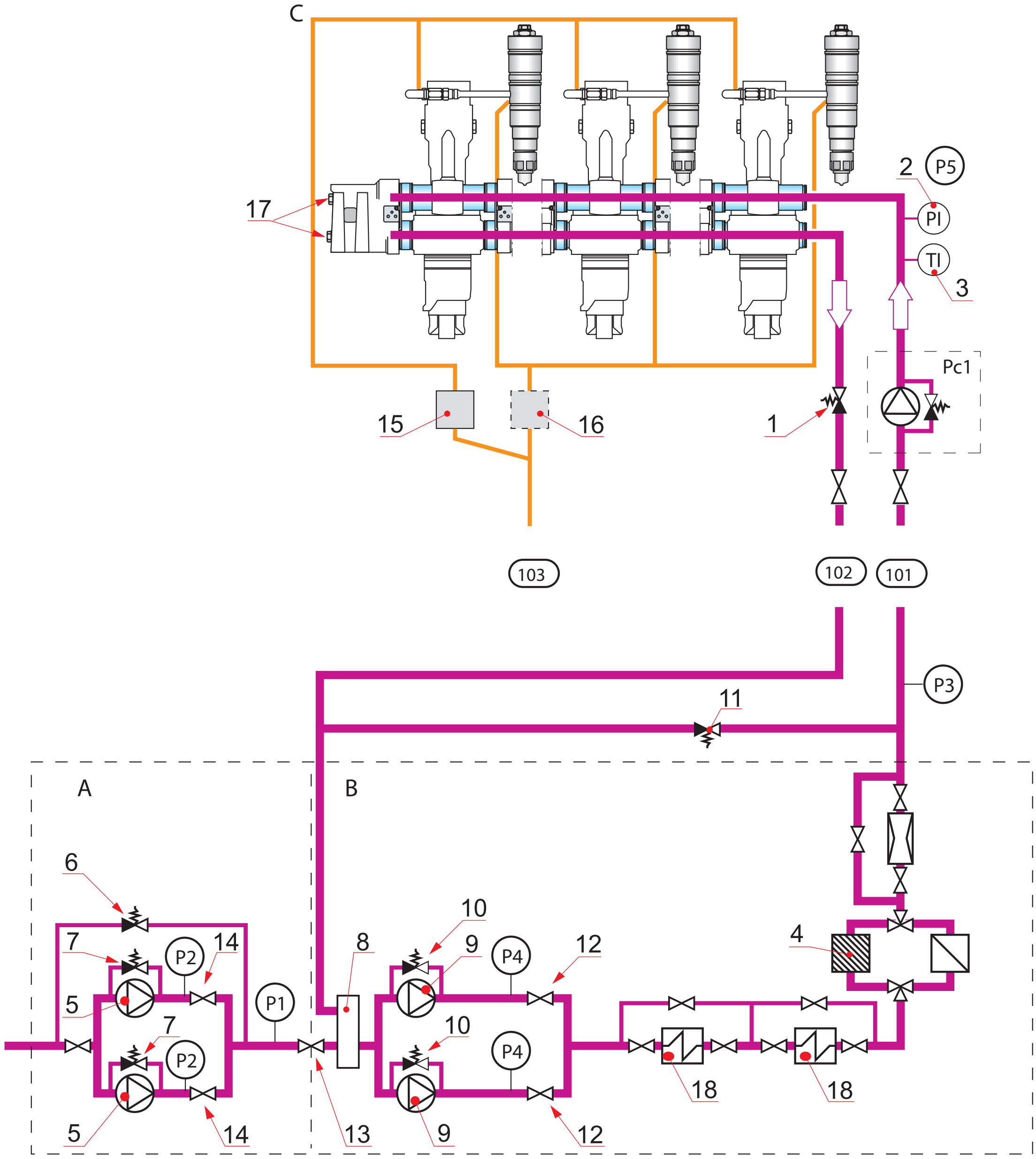
Fuel feed and circulating unit

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 engine/engines (C) and circulates the fuel in the main system.

NOTE

The external low pressure fuel system must have a by-pass overflow valve in order to avoid too high pressure at a engine emergency shutdown and when operating with both fuel feed pumps parallel.



1 Pressure control valve (optional)
2 Pressure transmitter
3 Temperature sensor
4 Fuel filter
5 Fuel feed pump
6 Pressure regulating valve
7 Safety valve
8 Deaeration tank
9 Circulating pump
10 Safety valve
11 Pressure regulating valve
12 Valve
13 Valve
14 Valve
15 Leakage alarm, injection pipe
16 Clean leak fuel drain (optional)
17 Plug
18 Heater

Pc1.*Fuel circulation pump (multi engine installations)* 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*

Fig 17-1 Fuel system

17.2 Fuel system maintenance v5

When maintaining the fuel system, always observe the utmost cleanliness. Clean all pipes, tanks and the fuel treatment equipment such as pumps, filters, heaters and viscosimeters carefully before taking them into use.

Heavy and crude oil fuel qualities should always be separated before use.

For maintenance of the fuel treatment equipment not mounted on the engine, see separate instructions.

17.3 Adjustments of fuel feed system v4

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.

17.3.1 Adjusting fuel feed pumps in unit (A) v4

The fuel feed pumps (5, *Fig 17-1*) maintain the system pressure P1. For fuel feed system pressure values, see *section 17.5*.

Procedure

1 **Close the valve (13) and adjust the pressure (P1) on the regulating valve (6). Open the valve (13).**

2 **Close the valves (14) and adjust the pressure (P2) on the safety valve (7) located on the pump. Open the valves (14).**

CAUTION

Adjust the pump safety valve rapidly as the pump may run hot if the system is closed for a lengthy time.

NOTE

The purpose of this safety valve is only to protect the pump.

17.3.2 Adjusting fuel circulating pumps in unit (B) v4

Prerequisites

The fuel circulating pumps (9) keep the fuel in the system in constant circulation and maintain a system pressure (P3) between the circulating pumps and the pressure regulating valve (11), see *Fig 17-1*.

Procedure

1 **Adjust the system pressure (P3) at the pressure regulating valve (11).**

2 **Close the valve (12) and adjust the pressure (P4) on the safety valve (10) located on the pump.**

NOTE

The purpose of this safety valve is only to protect the pump.

3 **Open the valve (12).**

17.3.3 Adjusting fuel feed pressure at each engine (C) v3

Prerequisites

The fuel feed pumps (5) maintain the engine(s) fuel feed system pressure P5, see *Fig 17-1* and section *17.5*.

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.

Procedure

1 **Adjust the system pressure (P5) at the pressure control valve (1) on each engine.**

17.3.4 Start and stop procedure with different fuels v3

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 is stopped for maintenance, the engine should be operated on diesel oil (LFO) at high load at least 30 minutes before it is 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 injection equipment sufficiently preheated also during engine stop.

17.4 Venting the fuel system v9

Procedure

1 **Start the fuel feed pumps if the static pressure from the day tank is not sufficient.**
Vent the fuel feed system at plug (17). Renew the seal ring if necessary.

CAUTION

Only use steel seal ring on the plug. A deformed copper seal ring may cause leakage.

NOTE

Always vent the filter(s) when cartridges or filter candles have been renewed.

17.5 System operating values

v3

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.

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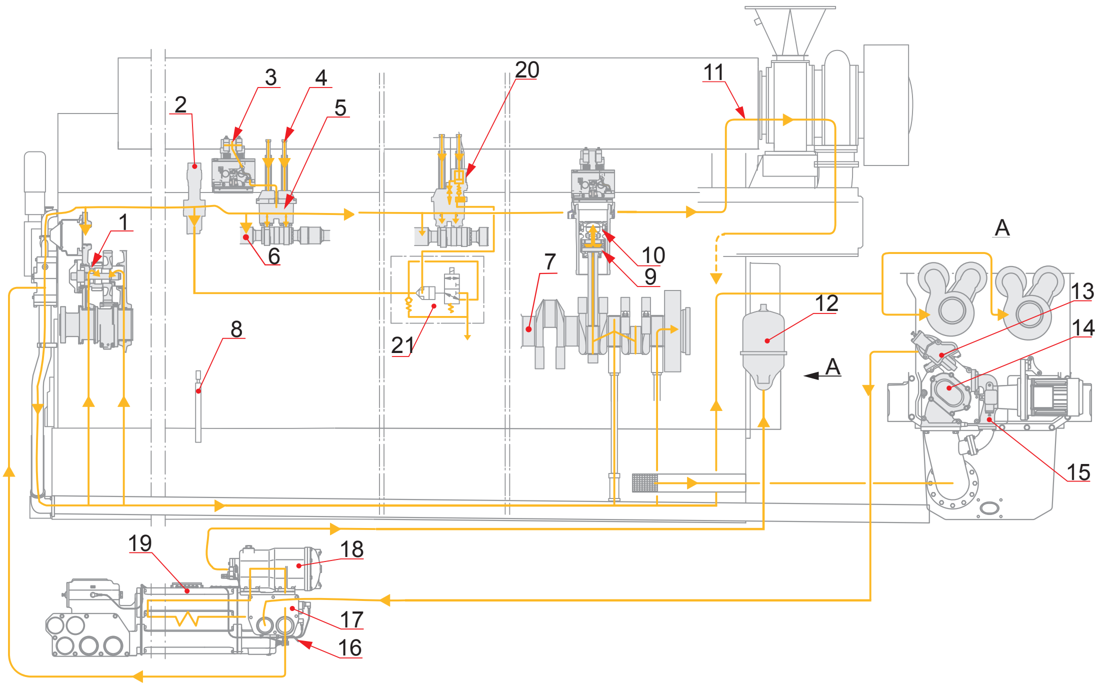
18. Lubricating Oil System



1 Intermediate gear wheel bearings
2 Injection pump
3 Rocker arms
4 Push rods
5 Valve tappets
6 Camshaft bearings
7 Crankshaft bearings
8 Oil dipstick
9 Gudgeon pins
10 Piston
11 Lubricating oil to turbocharger
12 Centrifugal filter
13 Pressure regulating valve
14 Lubricating oil pump
15 Prelubricating oil pump
16 Lubricating oil sample valve
17 Thermostatic valve
18 Lubricating oil automatic filter
19 Lubricating oil cooler
20 On/Off control valve for VIC (optional)
21 Guide block for VIC (optional)

Fig 18-1 Lubricating oil system

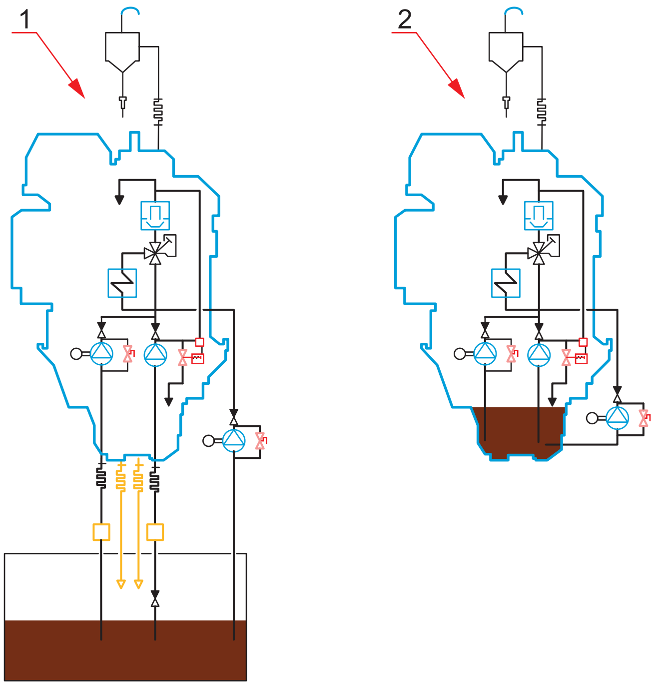
The engine is provided with a lubricating oil pump (14) that is driven directly by the pump gear at the free end of the engine. It is possible to connect an electrically driven standby pump in parallel, if needed.

The pump draws oil from the engine oil sump or system oil tank and forces it through the lubricating oil cooler (19). The cooler is equipped with a thermostatic valve (17) to regulate the oil temperature. The oil flows through the lubricating oil automatic filter (18) to the main distributing pipe in the oil sump and then through the hydraulic jacks (in this respect acting as ordinary pipes) to the main bearings (7). Through bores in the connecting rods to the gudgeon pins (9), the piston skirt and piston cooling spaces.

The oil system consists of:

- Engine-driven oil pump
- Electrically-driven prelubricating oil pump
- Cooler
- Oil thermostatic valve
- Automatic filter
- Oil sump (built on the engine)

Depending on the installation, the prelubricating oil pump can also be installed in an external system.



1 Dry oil sump
2 Wet oil sump

Fig 18-2 Dry and wet oil sump

The figures shows only the principles.

The engine can be provided with a wet or a dry oil sump system.

For a detailed schematic about the lubricating oil system, see Installation specific data.

The oil is stored in the oil sump under the engine or in the system oil tank. Return oil from the engine system is led back to the oil sump. The lubricating oil separator (if used) is connected directly to the engine oil sump or system oil tank.

Oil is led through bores to other lubricating points, including:

- Camshaft bearings (6)
- Injection pump tappets and valves
- Rocker arms (3)
- Intermediate gear wheel bearings
- Oil nozzles

The turbocharger is also connected to the engine lubricating oil system (11).

Back-flushing oil from the automatic filter (18) flows through pipes to the centrifugal filter (12) and back to the oil sump.

The oil pressure in the distributing pipe is regulated by a pressure regulating valve on the pump. The pressure can be adjusted on the set screw of the control valve. See *section 18.3.2*.

It is essential to maintain correct pressure to ensure appropriate lubrication of the bearings and cooling of the pistons. Normally, the oil pressure remains constant when adjusted to the correct value, although varying with the temperature. The oil pressure can rise above the nominal value when starting with cold oil but returns to the normal value when the oil is heated. To avoid any problems caused by cold oil, the engine oil must be heated up to 40–50°C level before starting the prelubricating oil pump. The lubricating oil pressure before the engine is indicated on the local display unit. The system includes three pressure switches or pressure sensors that indicate low lubricating oil pressure, connected to the automatic alarm and stop system. See chapter 23.

Depending on the installation, the oil temperature can be checked from the instrument panel, the thermometer, display unit, or operator interface system. See chapter 01.

A temperature sensor for high lubricating oil temperature is connected to the automatic alarm system. See chapter 23.

The oil dipstick (8) is located in the middle of the engine. Optional connections for an oil separator are mounted on the oil sump at the free end of the engine. For oil sampling, a valve is fitted after the oil filter.

18.1 Lubricating oil system maintenance v11

Use only high-quality oils approved by the engine manufacturer. See *Chapter 02 Fuel, lubricating oil, cooling water*.

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. The dipstick scale is graduated in centimeters. This scale can be used when checking the lubricating oil consumption.

NOTE

Separate scales are marked for a running and a stopped engine on the oil dipstick. Make sure you use the correct scale when checking the oil level.

Change the oil regularly at intervals determined by experience of the installation concerned, see *Chapter 02 Fuel, lubricating oil, cooling water*, and *Chapter 04 Maintenance schedule*.

Drain the oil system, including the oil cooler and filter, when the oil is warm. Clean the crankcase and the oil sump with clean rags (do not use cotton waste). Clean the centrifugal filter.

Centrifuging the oil is mandatory when using heavy fuels. See the approved lubricating oils.

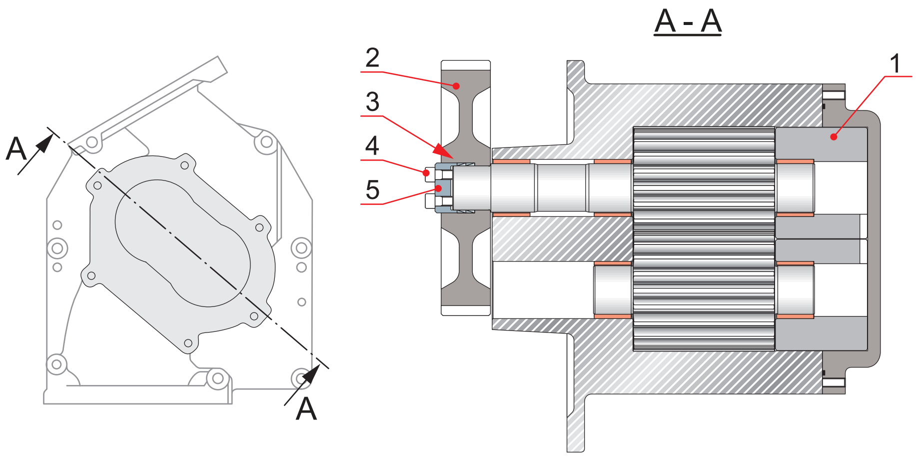
CAUTION

Observe utmost cleanliness when performing any maintenance in the lubricating oil system. Dirt, metal particles, and similar may cause serious bearing damage. When dismantling pipes or accessories from the system, cover all openings with blank gaskets, tape, or clean rags. When storing and transporting oil, prevent dirt and foreign matter from entering the oil. When refilling oil, use a screen.

18.2 Lubricating oil pump

v11

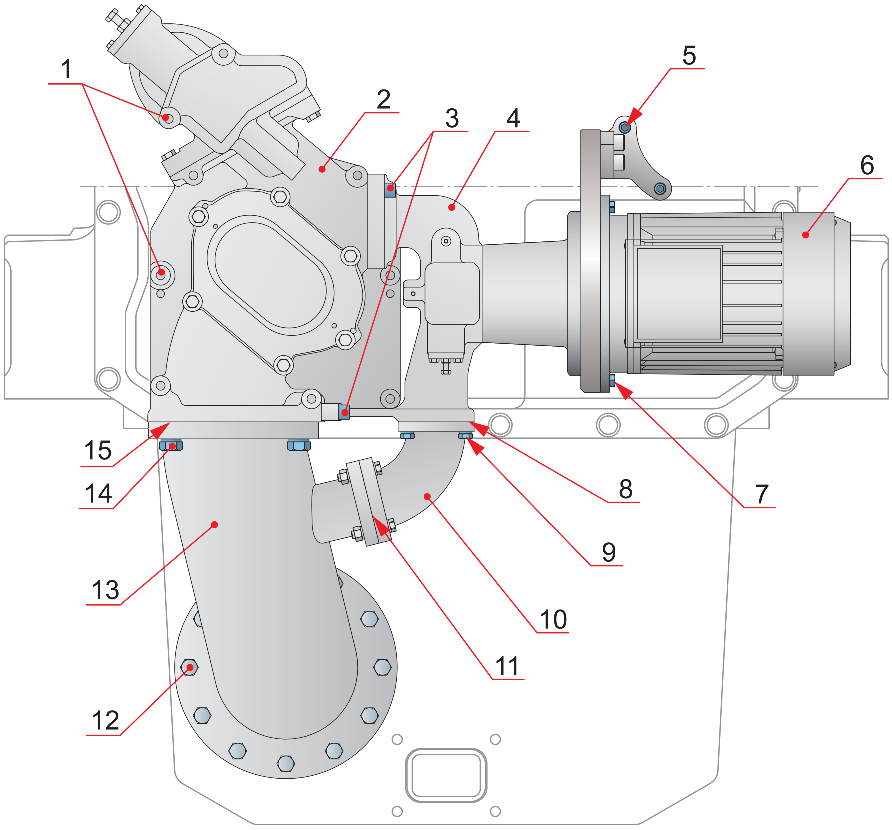
The lubricating oil pump is a gear-type pump. A combined pressure regulating and safety valve is installed on the pump. External lubrication is not required.



1 Sleeve
2 Drive gear
3 Frictional rings
4 Screw
5 Pressure plate

Fig 18-3 Lubricating oil pump

18.2.1 Removing the lubricating and prelubricating oil pumps v7



1	Screw	9	Screw
2	Lubricating oil pump	10	Prelubricating suction pipe
3	Screw	11	O-ring
4	Prelubricating oil pump	12	Screw
5	Screw	13	Suction pipe
6	Electric motor	14	Screw
7	Screw	15	O-ring
8	O-ring		

Fig 18-4 Lubricating and prelubricating oil pumps

Procedure

1. **Drain the oil sump.**
2. **Disconnect the power from the prelubricating pump, and remove the wires.**
3. **Remove the screws (14), (12), (9), and pull out the complete suction pipes.**
4. **Remove the suction pipe O-rings (15), and (8).**
5. **Open the screws (7).**
6. **Pull out the electric motor (6) with a suitable lifting device.**
7. **Open the screws (3), and remove the prelubricating oil pump housing (4).**
8. **Support the lubricating pump (2) with a suitable lifting device.**

9 **Remove the lubricating pump unit screws (1).**

10 **Pull out the complete lubricating oil pump (2).**

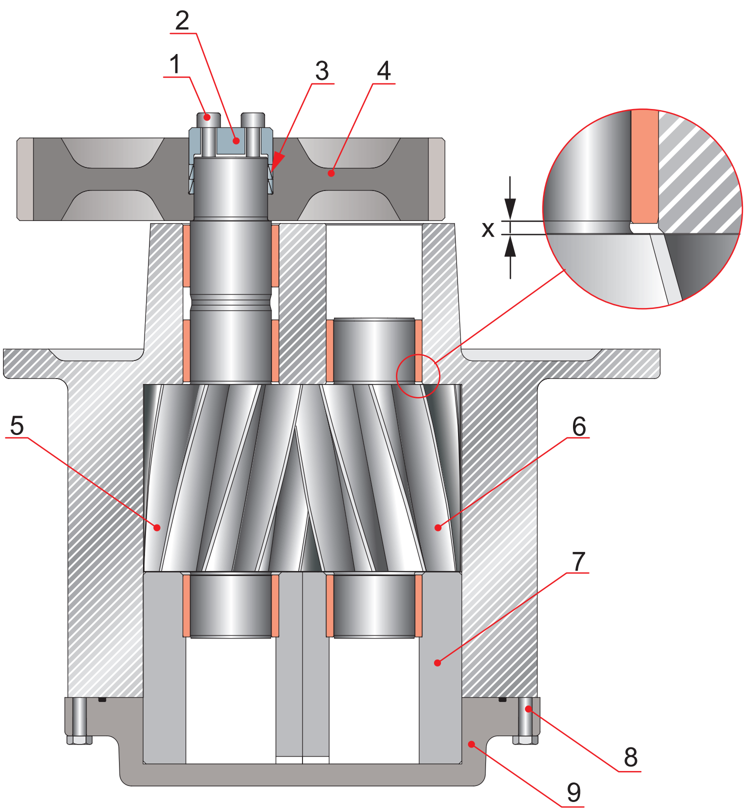
18.2.2 Dismantling the lubricating oil pump

v8

Procedure

1 **Remove and inspect the oil pressure regulating valve. See section *18.3*.**

2 **Open the pressure plate fastening screws (1) and remove the pressure plate (2).**



1 Pressure plate fastening screw
2 Pressure plate
3 Friction ring elements
4 Gear wheel
5 Driving shaft
6 Driven shaft
7 Sleeves
8 Pump cover fastening screws
9 Pump cover

Fig 18-5 Lubricating oil pump

3 **Pull off the gear wheel (4) without using any tool.**

If the gear wheel does not come loose, a few strokes with a non-recoiling hammer may be needed. The friction ring elements (3) come loose together with the gear wheel.

CAUTION
Do not use an extractor. It may cause axial scratches to the shaft.

4 **Open the pump cover fastening screws (8).**

5 **Withdraw the pump cover (9) by using two M10 screws in the threaded holes located in the pump cover.**

6 **Mark the sleeve positions and remove the sleeves (7).**

7 **Pull out the driven shaft (6) and the driving shaft (5).**

18.2.3 Inspecting the lubricating oil pump v10

Procedure

1 **Check all parts for wear and replace worn parts.**
See Chapter 06 *Adjustments, Clearances and Wear Limits*.

2 **Remove the worn bearings from the sleeves and the housing by driving them out with a suitable mandrel.**

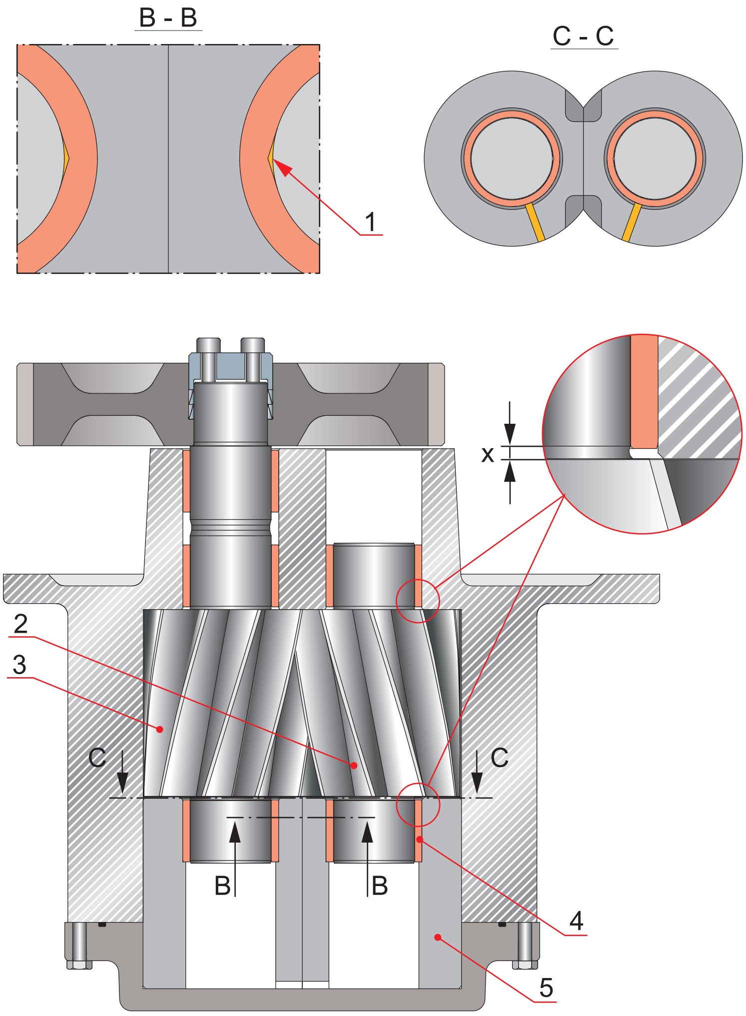
18.2.4 Assembling the lubricating oil pump v9

Prerequisites

Clean all parts before assembling. Replace worn parts and renew all O-rings.

Procedure

1 **Turn the lubrication groove (1) in the bearing bush (4) towards the centre of the lubricating oil pump.**
See the section B-B in *Fig 18-6*.



1 Lubrication grooves
2 Driven gear
3 Driving gear
4 Bearing bush
5 Sleeves

X. *2.5 mm*

Fig 18-6 Lubricating oil pump

> **NOTE**
>
> Freeze the bearing bushes before mounting them.

2 **Mount new bearing bushes 2.5 mm below the housing level.**

See position X.

3 **After mounting, check the bearing diameter.**

See chapter 06.

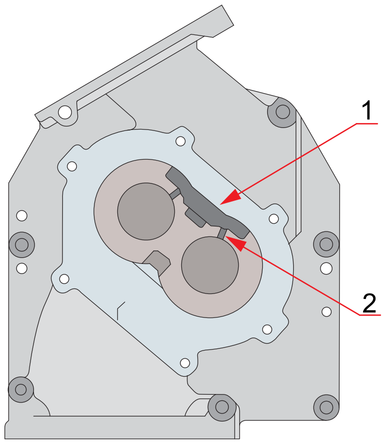
4 **Mount the driving gear (3) and driven gear (2) into the housing.**

5 **Mount the sleeves (5) on the pump gear shafts.**

See *Fig 18-7*.

CAUTION

The oil grooves (2) in the sleeves must point towards the pressure side (1) of the pump.



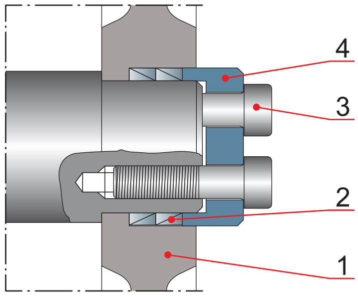
1 Pressure side
2 Oil groove

Fig 18-7 Lubricating oil pump housing

6 **Mount the pump cover and tighten the screws.**

7 **Check the pump driving and driven gear axial clearance and backlash.**
See chapter 06.

8 **Clean the contact surfaces and install the gear wheel (1).**
See *Fig 18-8*.



1 Gear wheel
2 Friction rings
3 Screw
4 Pressure plate

Fig 18-8 Mounting the gear wheel

9 **Reinstall the friction rings (2) in correct positions as shown in *Fig 18-8*.**

NOTE

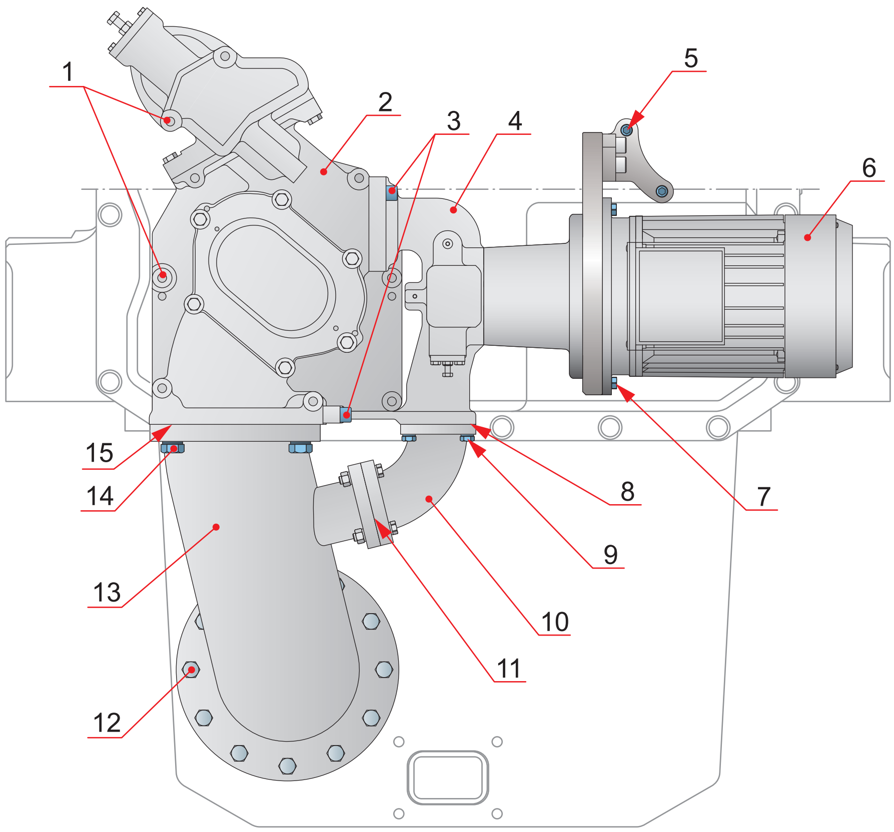
The friction ring elements should fall easily into place.

10 **Reinstall the pressure plate (4).**

11 **Tighten the screws (3) hand tight, and check the gear wheel is resting on the drive shaft collar.**

12 **Tighten the screws to the stated torque.**
See chapter 07.

18.2.5 Mounting the lubricating and prelubricating oil pumps v9



1 Screw	9 Screw
2 Lubricating oil pump	10 Prelubricating suction pipe
3 Screw	11 O-ring
4 Prelubricating oil pump	12 Screw
5 Screw	13 Suction pipe
6 Electric motor	14 Screw
7 Screw	15 O-ring
8 O-ring	

Fig 18-9 Lubricating and prelubricating oil pumps

Procedure

1 **Clean all sealing surfaces carefully, and renew the O-rings.**

2 **Mount the lubricating oil pump (2).**

a **Lift the pump with suitable lifting device.**

b **Tighten the screws (1).**

3 **Mount the prelubricating oil pump, and tighten the screws (3), (5).**

4 **Mount the prelubricating oil pump's electric motor (6), and tighten screws (7).**

5 **Mount the suction pipe (13), prelubricating suction pipe (10) and new O-rings (15) and (8).**

6 **Tighten the screws (14), (12) and (9).**

7 **Check the backlash (A) of the drive gear wheel after mounting.**

See *Chapter 06 Adjustments, clearances and wear limits*.

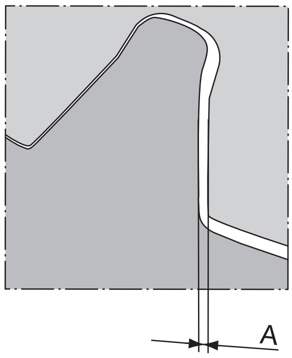


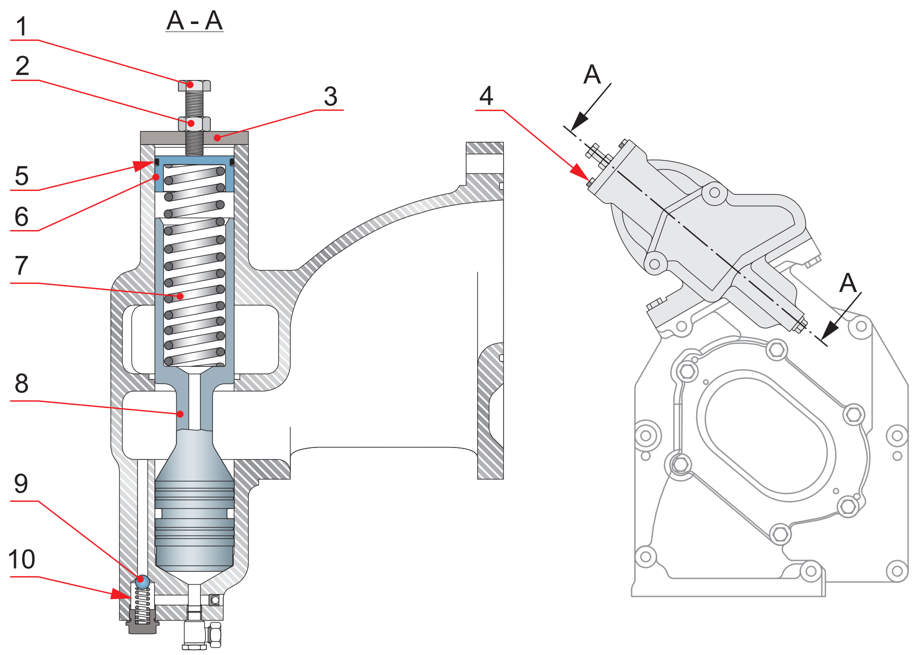
Fig 18-10 Gear wheel backlash

8 **Connect the wiring and power connections of the prelubricating oil pump.**

9 **Fill the oil sump.**

18.3 Lubricating oil pressure regulating valve and safety valve

v15



1 Adjusting screw
2 Locking nut
3 Cover
4 Screw
5 Sealing ring
6 Spring holder
7 Spring
8 Regulating piston
9 Ball for safety valve
10 Spring

Fig 18-11 Pressure regulating valve

The pressure regulating valve is integrated into the lubricating oil pump. It regulates the feed oil pressure into the engine by returning the surplus oil directly from the pressure side of the pump back to the suction side.

The oil pressure actuates the regulating piston (8), and the spring (7) is tensioned to maintain 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, higher oil pressure is obtained.

In engines running at varying speeds, the valve maintains the pressure depending on the operating pressures recommended at various speeds. See *Chapter 01 Main data, operating data and general design*.

If, for some reason, the pressure should increase too much in the pressure pipe, for example if the system is clogged, the ball (9) opens and allows the oil to pass to the regulating piston (8). This serves as a safety valve.

18.3.1 Maintaining the pressure regulating valve

v16

Procedure

1 **Dismantle all moving parts.**

See *Fig 18-11*.

a **Open the locking nut (2).**

b **Loosen the adjusting screw (1).**
Calculate the turns.

CAUTION
The adjusting screw is spring-loaded.

c **Open the screw (4).**

d **Remove the cover (3).**

e **Remove the spring holder (6) and the spring (7).**

f **Remove the piston (8).**

2 **Check the parts for wear.**

3 **Renew the O-rings.**

4 **Replace worn or damaged parts with new ones.**

5 **Clean the parts.**

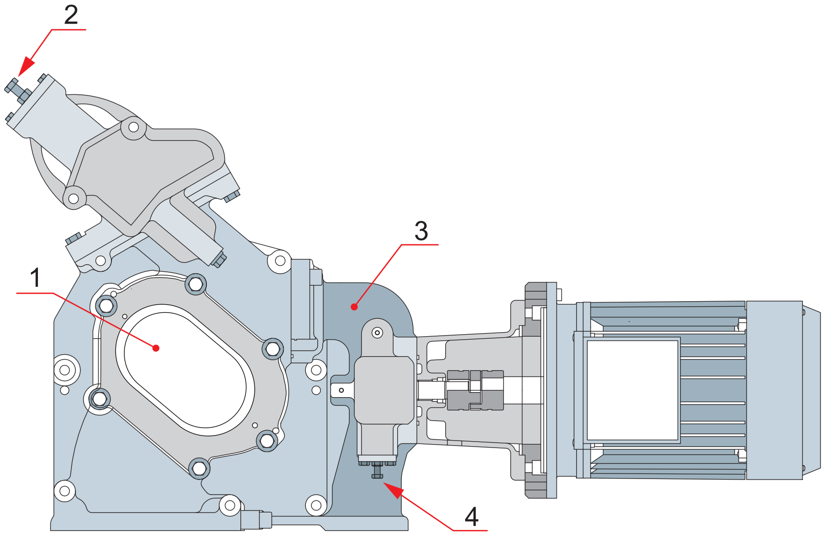
6 **To reassemble the parts, repeat the dismantling procedure in a reverse order.**
Tighten the screw (4) according to the turns calculated during dismantling, and tighten the locking nut (2).

NOTE
Make sure that no parts are jamming.

7 **Adjust the lubricating oil pressure according to** *section 18.3.2***.**

18.3.2 Adjusting oil pressures

v7



1 Main oil pump
2 Adjusting screw for lubricating oil pressure
3 Electric driven prelubricating pump
4 Adjusting screw for prelubricating oil pressure

Fig 18-12 Lubricating oil pump

The main oil pump (1) is a gear-type pump with an integrated pressure regulating valve installed on top of the pump. The electrically-driven prelubricating pump (3) is integrated into the main lubricating oil pump housing. The pumps are connected in parallel and both pumps are equipped with separate pressure adjusting valves.

NOTE

The oil pressure must be adjusted at nominal temperature.

- Adjust the lubricating oil pressure by using the screw (2).
- Adjust the prelubricating oil pressure by using the screw (4).

18.4 Prelubricating oil pump

v8

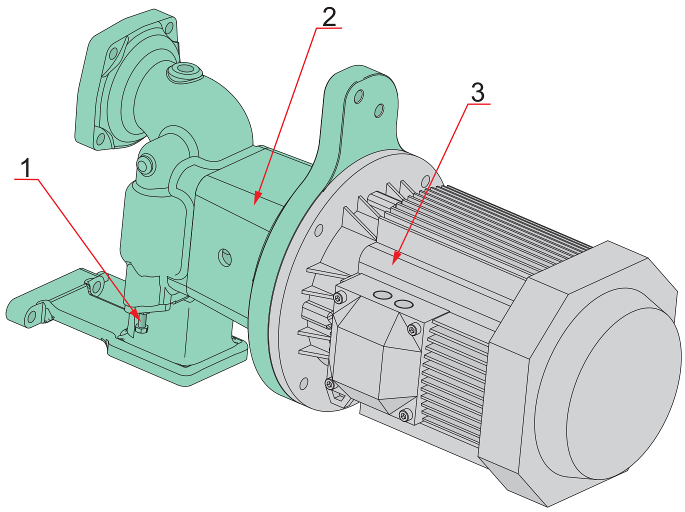
The gear-type prelubricating oil pump is driven by an electric motor. The pump is provided with an adjustable pressure control valve.

When running with very cold oil, adjust the pressure to the nominal value by loosening the adjusting screw to the end position so that the electric motor is not overloaded.

NOTE

Be careful when adjusting the pressure by loosening the adjusting screw as oil may come out.

The pump and the electric motor are both mounted on the pump drive house and connected to each other by a flexible coupling. To avoid reverse flow, a non-return valve is integrated into the main lubricating oil pump.



1 Pressure regulating valve
2 Prelubricating pump
3 Electric motor

Fig 18-13 Prelubricating oil pump

The pump is used for:

- Filling the engine lubricating oil system before starting, for example when the engine has been out of operation for a long time.
- Continuous prelubrication of a stopped engine through which heated heavy fuel is circulating.
- Continuous prelubrication of stopped engine(s) in a multi-engine installation when one of the engines is running.

CAUTION

Do not run the prelubricating oil pump when the engine is running. Running the pump and the engine simultaneously overheats and damages the pump.

18.4.1 Dismantling the prelubricating oil pump v5

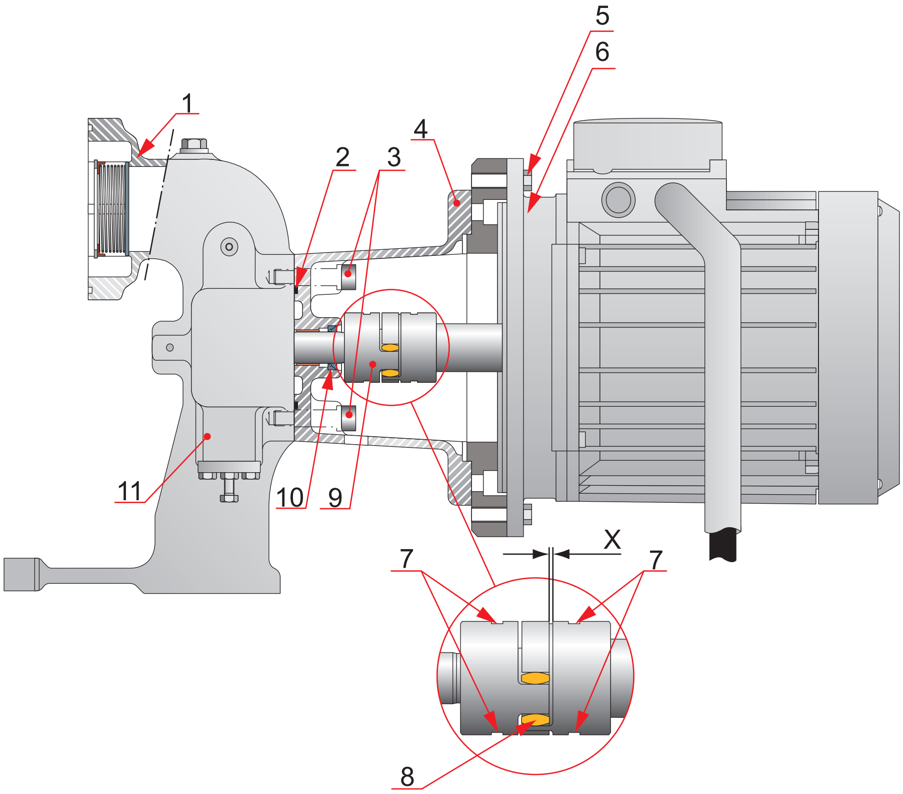
Prerequisites

Before you start:

- Disconnect the power from the electric motor.
- Disconnect the wires from the motor.

Procedure

1 **To remove the electric motor, loosen the electric motor screws (5).**
Use lifting straps to support the electric motor (6).



1 Non-return valve
2 O-ring
3 Bracket screws
4 Bracket
5 Electric motor screws
6 Electric motor
7 Coupling half screws
8 Flexible coupling rubber
9 Coupling halves
10 Shaft seal
11 Pressure regulating valve

X *2,5 mm*

Fig 18-14 Prelubricating oil pump

2 **To remove the coupling halves (9), loosen the coupling half screws (7).**

Before removing the coupling halves, mark their position on the pump and the electric motor shaft.

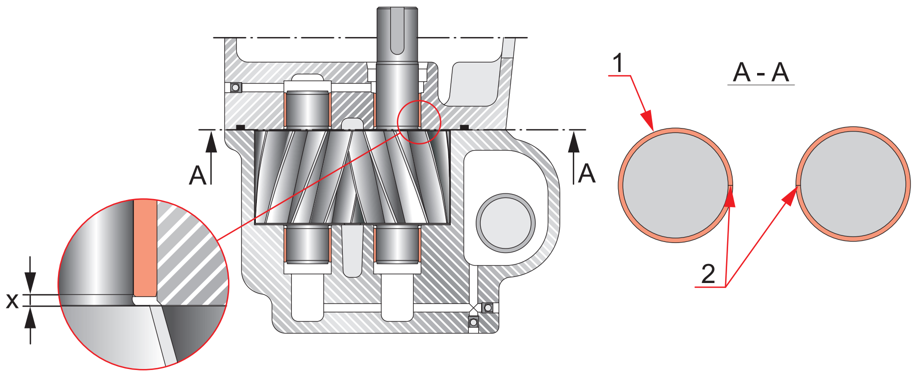
3 **To remove the bracket (4), loosen the bracket screws (3).**

4 **Withdraw the gear wheels by hand.**

5 **Remove the shaft seal and retaining ring (10) from the bracket (4).**

18.4.2 Inspecting the prelubricating oil pump

v8



1 Bearings
2 Butt joints

X. *2 mm*

Fig 18-15 Prelubricating oil pump bearing

Procedure

1 **Check all parts for wear and replace worn parts.**
See *Clearances and wear limits (at 20°C)* .

2 **Replace worn bearings (1).**

a **Remove the worn bearings from the housing with suitable mandrel or by machining.**

b **Freeze the new bearings.**

c **Mount the bearings so that the bearings are 2 mm below the cover and the housing level.**

NOTE
Position the bearing bushes so that the butt joints (2) point towards each other.

d **After mounting, check the bearing diameter.**
See *Clearances and wear limits (at 20°C)* .

18.4.3 Assembling the prelubricating oil pump

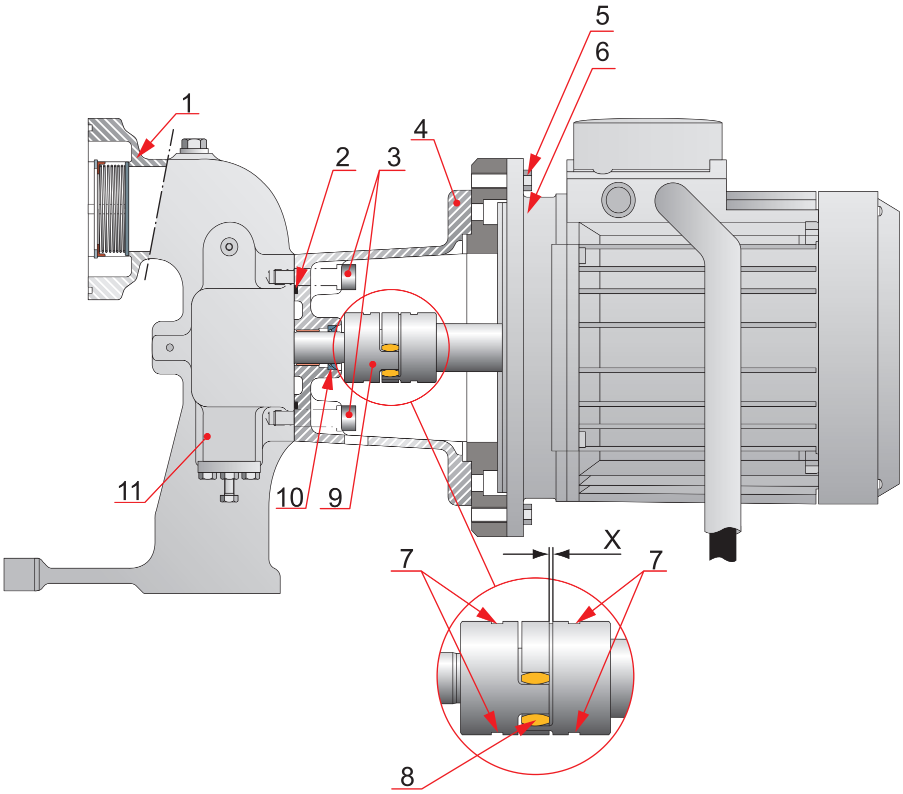
v4

Prerequisites

Before installing the gear wheels, clean and oil all contact surfaces.

Procedure

1 **Install the gear wheels.**



1 Non-return valve
2 O-ring
3 Bracket screws
4 Bracket
5 Electric motor screws
6 Electric motor
7 Coupling half screws
8 Flexible coupling rubber
9 Coupling halves
10 Shaft seal
11 Pressure control valve

X. *2.5 mm*

Fig 18-16 Prelubricating oil pump

2 **Mount a new shaft seal (10) to the bracket (4), and install the retaining ring.**
Lubricate with grease.

3 **Replace the O-ring (2).**

4 **Mount the bracket (4).**
Make sure that the O-ring stays in the groove.

5 **Tighten the bracket screws (3) to the right torque.**
See *Tightening torques for screws and nuts* .

6 **Check gearwheel axial clearance.**
See *Clearances and wear limits (at 20°C)* .

7 **Mount the coupling halves (9).**

a **Tighten the coupling half of the prelubricating oil pump end lightly by hand with the locking screw.**
Check that the coupling can be moved by hand.

b **Mount the coupling half of the electric motor end.**
Lock it to the mark made during the dismantling.

c **Place distance piece with thickness (X) between the coupling halves.**

NOTE

Check that the distance piece width (X) is 2.5 mm.

d **Mount the electric motor (6), tighten the screws (5), and remove it again.**

e **Tighten the prelubricating pump end coupling half with the locking screw.**

f **Remove the distance piece.**

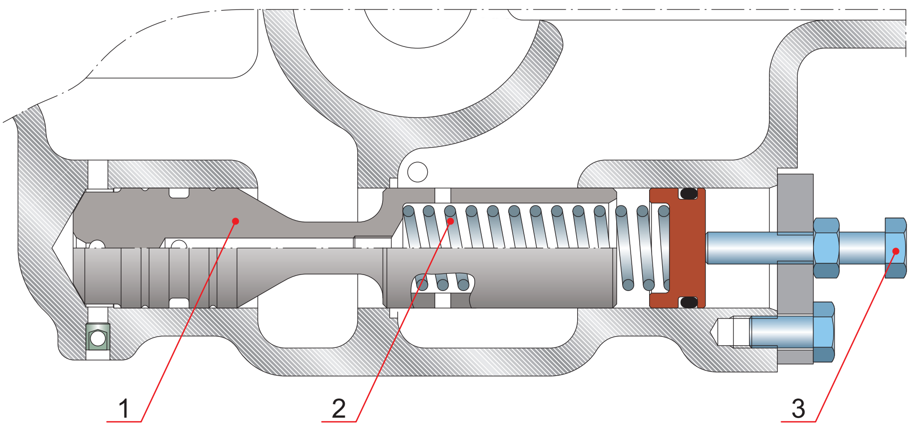
8 **Check that both coupling halves (9) are placed evenly on the shafts.**

9 **Mount the coupling rubber (8).**

10 **Mount the electric motor (6).**

11 **Tighten the screws (5).**

18.5 Prelubricating oil pressure regulating valve v7



1 Piston
2 Compression spring
3 Adjusting screw

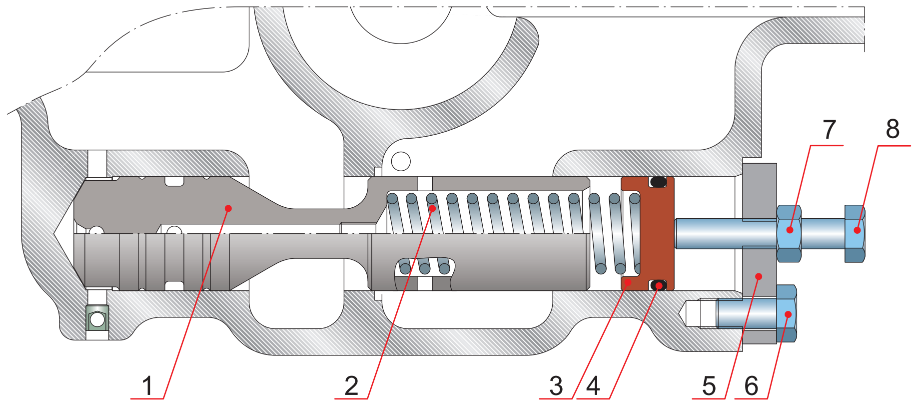
Fig 18-17 Pressure regulating valve

The pressure regulating valve controls the oil pressure before the engine by returning the surplus oil directly from the pressure side of the pump to the suction side.

This pressure actuates the regulating piston (1) and the spring (2) is tensioned to balance this force at the required pressure. By tensioning the spring adjusting screw (3), a higher oil pressure is obtained.

18.5.1 Dismantling the pressure regulating valve

v8



1	Piston	5	Cover
2	Compression spring	6	Screw
3	Spring retainer	7	Locking nut
4	O-ring	8	Adjusting screw

Fig 18-18 Pressure regulating valve

Procedure

1 **Open the locking nut (7) and loosen the adjusting screw (8).**
Record the number of turns.

> **CAUTION**
>
> The adjusting screw is spring-loaded.

2 **Open the screw (6).**

3 **Remove the cover (5).**

4 **Remove the spring retainer (3) and compression spring (2).**

5 **Remove the piston (1).**

18.5.2 Inspecting the pressure regulating valve of the prelubricating pump

v5

Procedure

1 **Check all parts for wear and replace worn or damaged parts with new ones.**

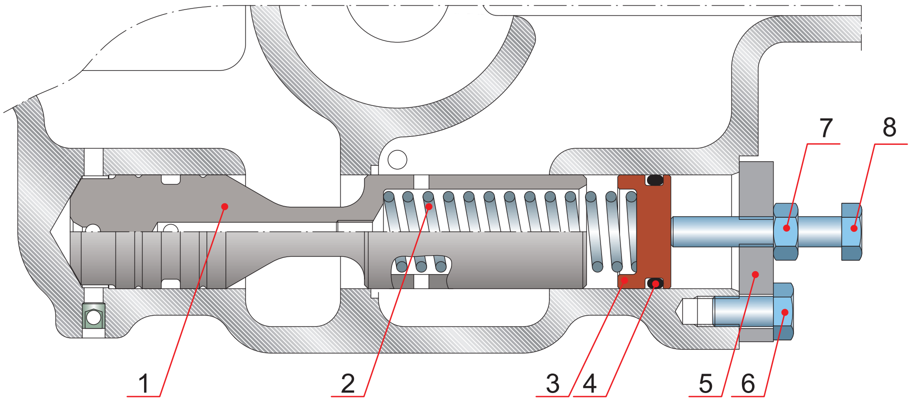
2 **Clean and lubricate the valve carefully.**

3 **Check that no parts are jamming while reassembling.**

18.5.3 Assembling the pressure regulating valve v5

Procedure

1 **Mount the piston (1).**



1 Piston
2 Compression spring
3 Spring retainer
4 O-ring
5 Cover
6 Screw
7 Locking nut
8 Adjusting screw

Fig 18-19 Pressure regulating valve

2 **Renew the O-ring (4) of the spring retainer (3).**

3 **Mount the compression spring (2) and the spring retainer (3).**

4 **Mount the cover (5).**

5 **Adjust the screw (8) according to the recorded turns, and tighten the locking nut (7).**

6 **Adjust the prelubricating oil pressure according to the main data.**

18.6 Lubricating oil cooler v2

The tube-type oil cooler is integrated in the lubricating oil module housing. The tube stack is inserted in a jacket and fixed at one end. To allow expansion, the other end is movable in a longitudinal direction. Both ends are provided with O-rings. The lubricating oil flows outside the tubes and the cooling water flows inside the tubes.

The oil cooler tube stack is made of copper-nickel and the water boxes of cast iron.

18.6.1 Maintaining the lubricating oil cooler v4

- **Clean and pressure test the lubricating oil cooler according to the maintenance schedule or if the lubricating oil temperature tends to raise abnormally.**

  See the nominal temperatures in the main operating data.

- **When cleaning the cooler, check for corrosion and test with hydraulic pressure.**

CAUTION
If the tubes are leaking, replace the tube stack with a new one.

- **To clean the oil and the water side, remove and dismantle the lubricating oil cooler.**

18.6.2 Dismantling the lubricating oil cooler

v2

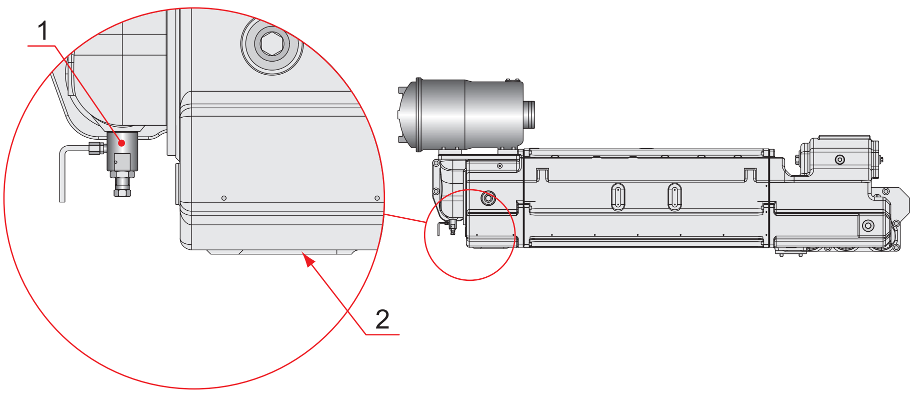
Procedure

1 **Drain the lubricating oil cooler.**

CAUTION
Beware of lubricating oil and water left inside the cooler.

a **Stop the prelubricating oil pump.**

b **Drain the oil side by opening the sample valve (1), and then remove the plug (2) to drain the rest of the oil.**



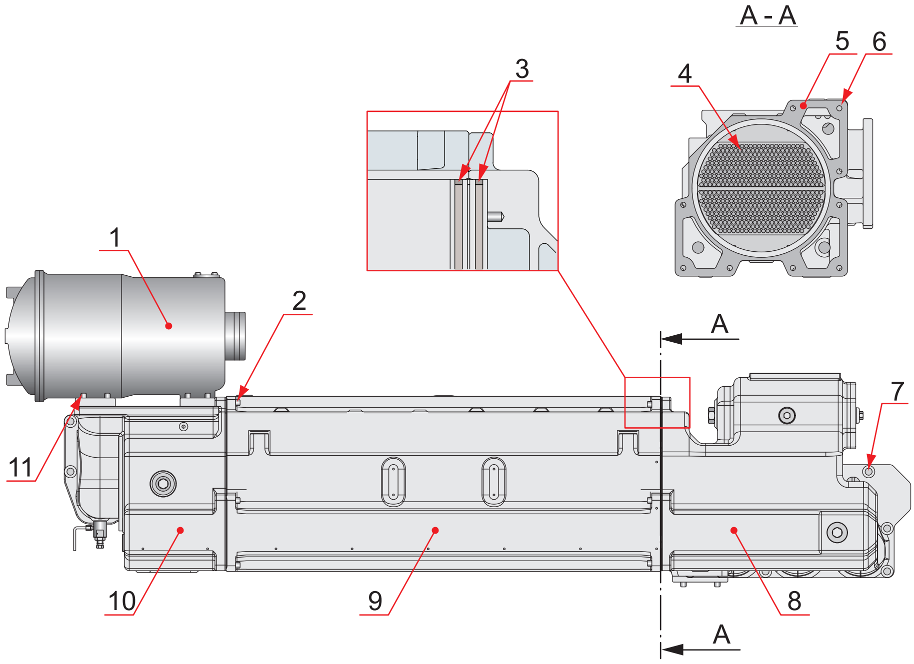
1 Sample valve
2 Plug

Fig 18-20 Draining the oil side

c **Drain the LT water side from the engine.**

d **Remove all pipe connections.**

2 **Remove the LT water thermostatic valve housing.**



1 Automatic back-flushing filter
2 Tube stack housing fastening bolt
3 O-rings
4 Tube stack
5 Gasket
6 LT housing fastening bolt
7 LT housing fastening bolt
8 LT thermostatic valve housing
9 Tube stack housing
10 Lubricating oil thermostatic valve side
11 Filter housing fastening bolt

Fig 18-21 Dismantling the lubricating oil cooler

a **Fit eye bolts on the LT water thermostatic valve housing (8), and support it with a lifting strap and a crane.**

b **Remove the LT housing fastening bolts (6) and (7).**

c **Detach the LT water thermostatic valve (8).**

3 **Remove the tube stack housing from the engine.**

a **Fit eye bolts on the tube stack housing (9), and support it with a lifting strap and a crane.**

NOTE

Use the old gasket plate to keep the tube stack in place during lifting.

b **Remove the tube stack housing fastening bolts (2).**

c **Detach the tube stack housing.**

4 **Remove the tube stack from its housing.**

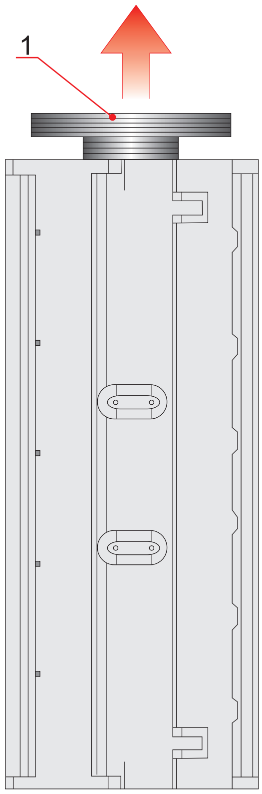


Fig 18-22 Removing the tube stack

a **Draw alignment marks on the tube stack and the housing.**

b **Remove the outer O-rings on both sides.**

c **Place the tube stack in a vertical position.**

d **Fit M10 eye bolts to the tube stack and lift it up with a crane.**

5 **If you need to maintain the automatic back-flushing filter, remove it from the engine.**

a **Support the automatic back-flushing filter (1) with a lifting tool or strap and a crane.**

b **Remove the filter housing bolts (11).**

c **Detach the filter from the lubricating oil module.**

18.6.3 Assembling the lubricating oil cooler v1

Prerequisites

Before assembling:

- Clean and check the lubricating oil cooler.
- Inspect all the sealing surfaces for damage and recondition them, if necessary.

Procedure

1 **Insert the tube stack into the housing.**

a **Place the housing in a vertical position.**

b **Fit M10 eye bolts to the tube stack and lift it up with a crane.**

c **Insert the tube stack into the housing from the lubricating oil thermostatic valve side, according to the alignment marks.**

Drop the stack into the housing, until only the lubricating thermostatic valve side O-ring grooves are visible.

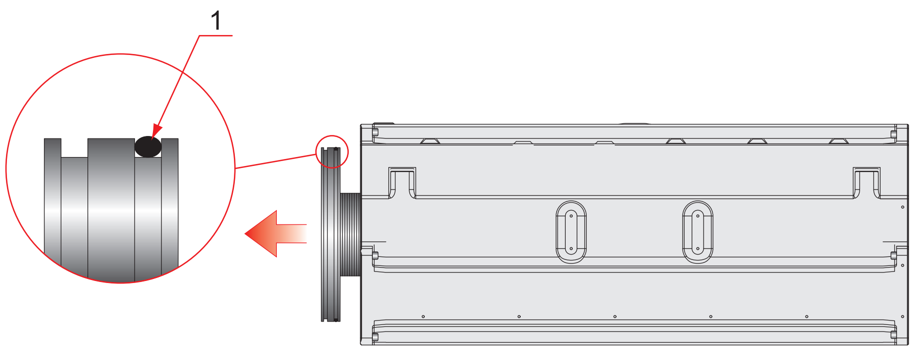
2 **Fit the tube stack O-rings.**

a **Place the tube stack housing in horizontal position.**

CAUTION

Make sure that the tube stack does not fall out from the housing and damage the core.

b **Insert a new inner O-ring on the lubricating oil thermostatic valve side and lubricate it with grease.**



1 Inner O-ring

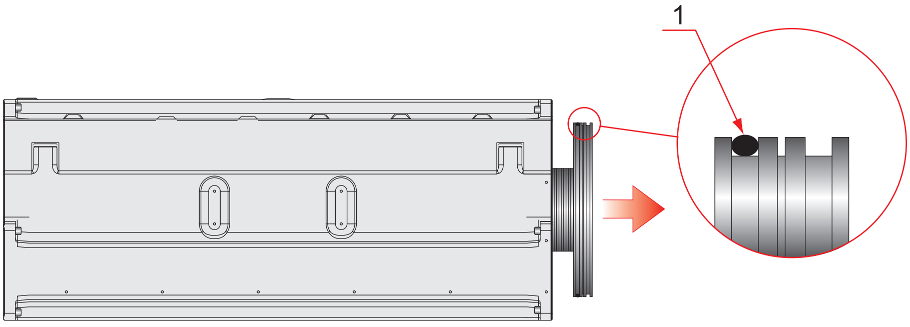
Fig 18-23 Inserting lubricating oil thermostatic valve side inner O-ring

c **Push the tube stack towards LT thermostatic valve side until the O-ring grooves on the LT water side are visible.**

NOTE

Make sure that the marks in the tube stack and the housing are aligned.

d **Mount a new inner O-ring on the LT side and lubricate it with grease.**



1 Inner O-ring

Fig 18-24 Inserting the LT water side inner O-ring

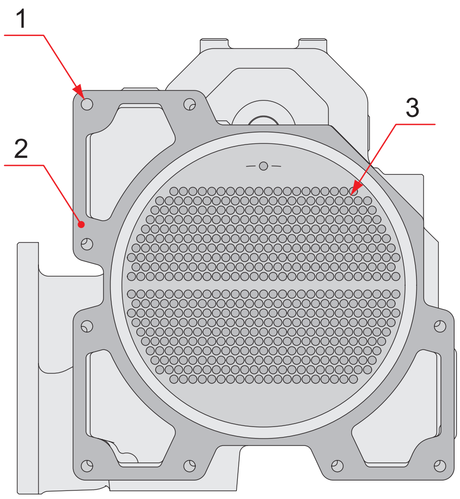
e **Push the tube stack towards the lubricating oil thermostatic valve side until the outer O-ring grooves are visible at both ends.**

f **Mount the outer O-rings and lubricate them with grease.**

3 **Mount the tube stack housing on the engine.**

a **Fit eye bolts to the tube stack housing and support it with a lifting strap and a crane.**

b **Fit new gaskets on the lubricating oil thermostatic valve side and apply sealing compound on the contact surfaces.**



1 Fastening bolt
2 Gasket
3 Tube stack

Fig 18-25 Lubricating oil thermostatic valve side

c **Attach the tube stack housing to the lubricating oil thermostatic valve housing and tighten the housing fastening bolts.**

4 **Mount the LT water thermostatic valve housing.**

a **Fit eye bolts to the LT water thermostatic valve housing and support it with a lifting strap and a crane.**

b **Fit new LT thermostatic valve housing gaskets and O-rings.**

Apply sealing compound on the contact surfaces.

c **Attach the LT water thermostatic valve housing and tighten the fastening bolts.**

5 **If you have removed the automatic back-flushing filter assembly, mount it on top of the lubricating oil thermostatic valve housing.**

Tighten the filter housing bolts.

6 **Mount all pipe connections.**

7 **Fit the drain plug and close the sample valve.**

18.6.4 Lubricating oil cooler cleaning v3

Oil side

Although uncommon, deposits can build up in the lubricating oil cooler's oil side. Fouling can influence the cooler efficiency strongly.

The outside of the tube stack cannot be cleaned mechanically. The deposits can be removed by blowing steam through the tube stack.

If the deposits in the oil side are considerable and cannot be removed with steam, use a chemical solution:

- Alkaline degreasing agents: They are suitable for normal degreasing and not suitable for heavy grease, sludge or oil coke. They require high temperatures.

WARNING

Pour the alkaline agent slowly into hot water, not the opposite.

CAUTION

Rinse with water after cleaning with alkaline agents.

- Hydrocarbon solvents: They include the whole range from light petroleum solutions to chlorinated hydrocarbons, for example, thrichlorethylene.

WARNING

Handle hydrocarbon solvents carefully. They are volatile, toxic and narcotic.

- Solvent emulsions: They are the only agents that dissolve heavy deposits such as oil coke.

Water side

CAUTION
Do not damage the cooler protective layer while cleaning. Use the special tool for cleaning.

If there are hard deposits on the water side of the cooler, such as calcium carbonate, you can use commercial chemical cleaning agents.

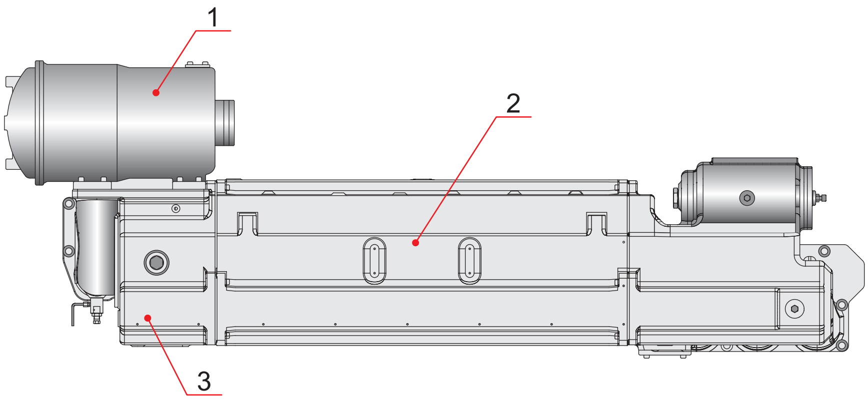
CAUTION
After treatment rinse or neutralise the heat exchanger with a solution.

NOTE
For detailed information about cleaning, see the cooler manufacturer's instructions.

18.7 Oil thermostatic valve

v7

The oil thermostatic valve maintains the lubricating inlet oil temperature at a constant level. The thermostatic elements are located inside the thermostatic valve housing (3) in the lubricating oil module, together with the lubricating oil filter (1) and the cooler (2).



1 Lubricating oil filter
2 Lubricating oil cooler housing
3 Thermostatic valve housing

Fig 18-26 Lubricating oil module

The thermostatic valve is a three-way valve with integrated thermal elements.

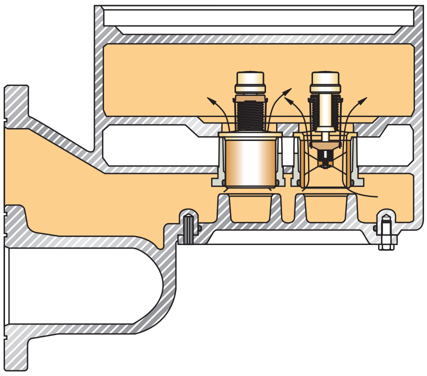


Fig 18-27 **Thermostatic valve, closed position**

When the oil temperature exceeds the nominal value, the expansion of the thermostatic elements moves the valve unit towards the holder, thus allowing the oil to pass through the cooler. This movement is continuous and maintains the mixed oil at the right temperature.

When the oil temperature is below the nominal value, the thermostatic valve is closed, and the oil bypasses the cooler. Cold oil in the cooler does not mix with the oil in engine circulation.

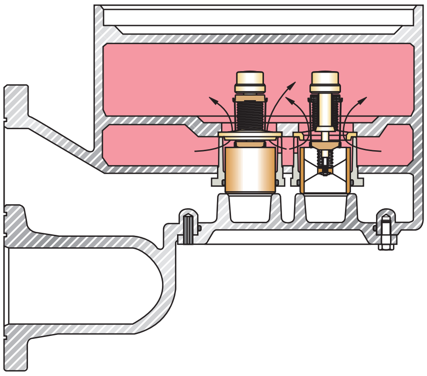


Fig 18-28 **Thermostatic valve, open position**

18.7.1 Removing the thermostatic element

v9

Procedure

1 **Drain the oil from the cooler.**

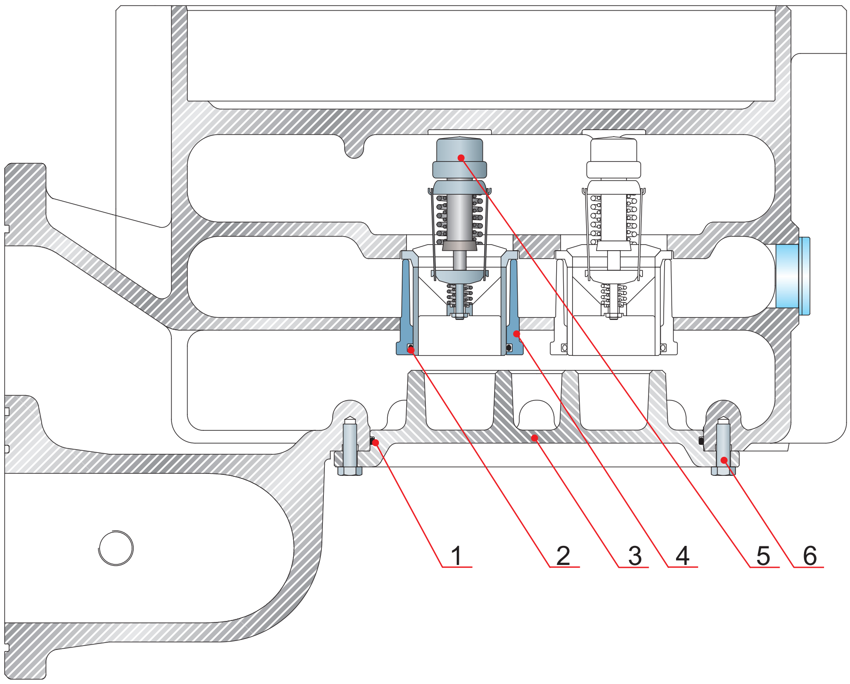
a **Drain the oil side by opening the sample valve.**

See *Fig 18-20*.

b **Remove the plug to drain the rest of the oil.**

c **When the cooler is empty, install the drain plug with a new sealing ring.**

2 **Remove the thermostatic element cover (3).**



1 Cover O-ring
2 Element holder O-ring
3 Cover
4 Thermostatic element holder
5 Thermostatic element
6 Cover fastening screw

Fig 18-29 Removing the thermostatic element

3 **Remove the thermostatic element holder screws.**

4 **Remove the thermostatic element holder .**

Use extractor tools 800122 and 800029 for the element holder, if necessary.

5 **Remove the thermostatic element from the holder (4).**

18.7.2 Inspecting the thermostatic element v5

Normally, the thermostatic valve requires no maintenance. The reason for a very low or very high oil temperature may be a defective thermostat or leaking O-rings. However, in most cases, a dirty cooler causes high temperature.

Procedure

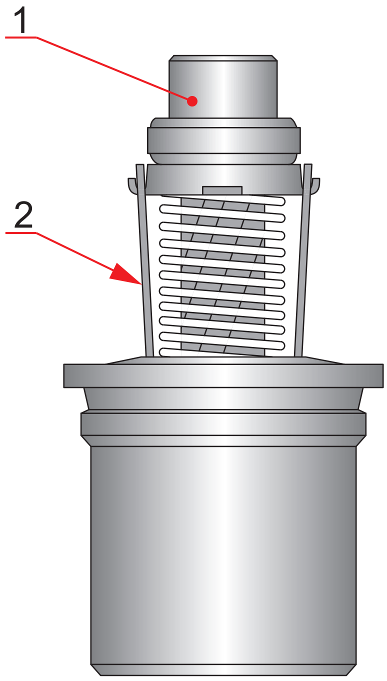
1 **Check the thermostatic element working range.**

a **Heat the element slowly in water.**

b **Check at which temperatures the element starts opening and is half open.**

You can find the values on the thermostatic element. The lower value is the opening temperature, the higher value is for the half open valve.

The nominal set point is the thermostatic element half open value.



1 Opening set point (°C)
2 Nominal set point (°F)

Fig 18-30 Thermostatic element set points

2 **Inspect the element for erosion marks.**

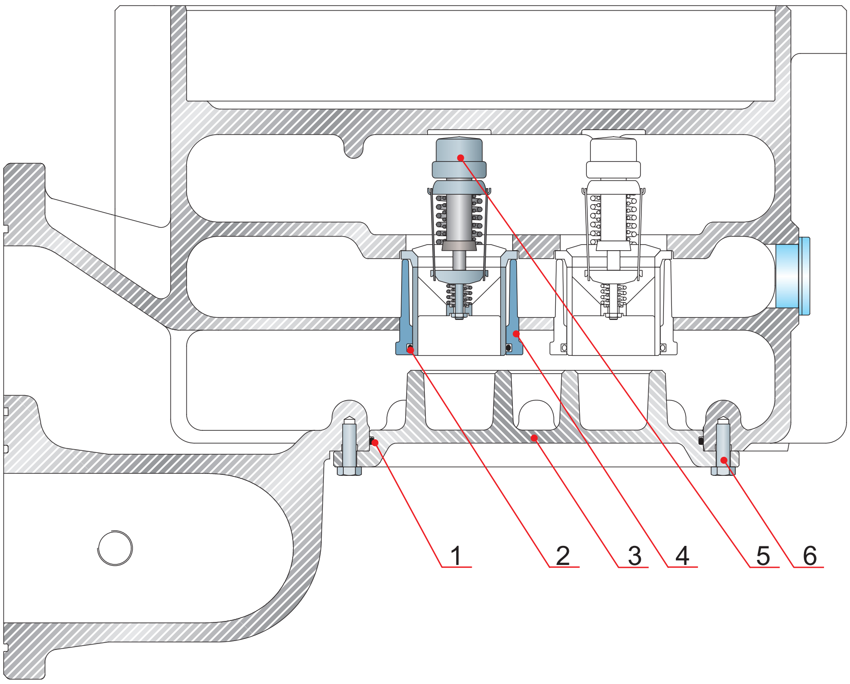
3 **If the element is defective or out of range, replace it.**

18.7.3 Mounting the thermostatic element

v6

Procedure

1 **Mount the O-rings (2)(1) to the holder (4).**
Lubricate the O-rings with clean engine oil.



1 Cover O-ring
2 Element holder O-ring
3 Cover
4 Thermostatic element holder
5 Thermostatic element
6 Cover fastening screws

Fig 18-31 Mounting the thermostatic element

2 **Install the thermostatic element (5) to the holder (4).**

3 **Mount the holder to the lubricating oil module.**

4 **Tighten the holder screws .**

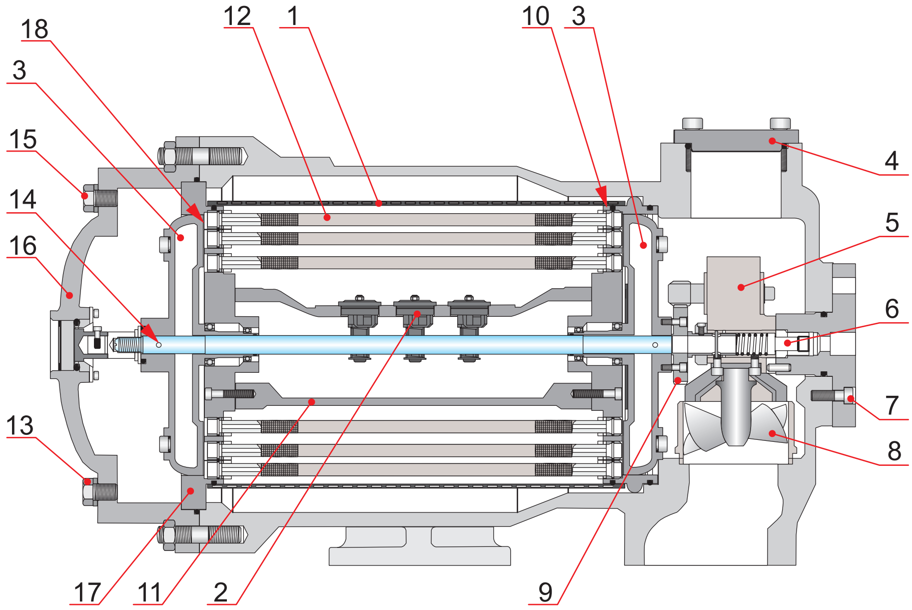
18.8 Lubricating oil automatic filter

v10

The lubricating oil filter is a full-flow filter, that is, the entire oil flow passes through it.

Filtration phase

The oil flows through the inlet flange and turbine (8) to the right end of the filter candles (12); a partial stream of about 50% is passed through the central connection tube (11) to the left end of the filter candles. This means that the oil flows through the filter candles at both ends from inside outwards and most of the dirt particles are retained in the inside of the candles. The filtered oil now passes through the protective filter (1) to the filter outlet.



1 Protective filter	10 Bottom sieve plate
2 Overflow valves	11 Central connection tube
3 Flushing arm	12 Filter candles
4 Flange	13 Plug
5 Worm gear unit	14 Flushing shaft
6 Flush bushing	15 Plug
7 Head cap screw	16 Cover
8 Turbine	17 Top sieve plate
9 Gear	18 Cover plate

Fig 18-32 Lubricating oil automatic filter

Back-flushing phase

The flow energy drives the turbine (8) installed in the inlet flange. The high speed of the turbine is reduced by the worm gear unit (5) and gear (9) to the lower speed required for turning the flushing arm(s) (3).

The individual filter candles (12) are connected successively to the centrifugal filter by means of continuously rotating flushing arms (3) through the flush bushing (6).

The lower pressure in the interior of the filter candles during the back-flushing operation (connected with the centrifugal filter) and the higher pressure (operating pressure) outside the filter candles produce a counter-flow through the mesh from the clean filter side through the dirty filter side to the centrifugal filter.

Function of the overflow valves

If the filter candles (first filter stage) do not clean the oil adequately, the overflow valves (2) are opened at a differential pressure of 2 bar upwards. The oil is now filtered only through the protective filter (1) (second filter stage).

However, before this situation arises, the installed differential pressure indicator emits a differential pressure warning. The cause must now be localized and remedied.

If this warning is not heeded, an alarm is emitted by the second contact of the differential pressure indicator.

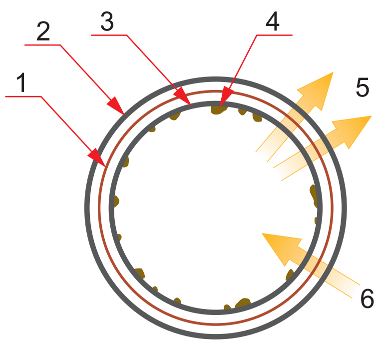
CAUTION

The filter may only be operated in this emergency condition for a short time (opened overflow valves and differential pressure warning). Prolonged operation in this mode can result in damage to downstream components.

The overflow valves are closed under normal operating conditions, even during startup at lower fluid temperatures.

Condition of the filter

The filter mesh is located in between the inner and outer support meshes. The condition of the filter mesh cannot be visually judged without destroying the support mesh.



1 Filter mesh
2 Outer support mesh
3 Inner support mesh (dirty side)
4 Dirt particles
5 Oil flow direction, operating mode
6 Oil flow direction, back-flushing mode

Fig 18-33 Filter candle construction

Replacing the filter candles

Filter candles must always be replaced with new ones if:

- Low quality rags have been used during cleaning of the oil system.

  Fibres from bad quality rags get tangled between the supporting meshes and filter mesh and cannot be removed by cleaning the candles.

- There has been a component seizure or breakdown.

  Especially a bronze bearing failure causes a large amount of particles that clog the candles and punch holes into the filter mesh.

- The protective filter is dirty.

  There are ruptures or holes in the filter mesh.
  If the differential pressure over the filter exceeds 2 bar the safety valve opens thus by-passing the filter candles.

- According to chapter 04 Maintenance schedule or after four years in service at the latest.

18.8.1 Maintaining the lubricating oil automatic filter v12

Prerequisites

To maintain trouble-free operation, inspect and maintain the automatic filter at regular intervals. In spite of constant back-flushing, the mesh may be clogged over time, depending on the lubricating oil quality and separation.

Procedure

1 **Check the filter and the connections for leaks.**

2 **Inspect all filter candles visually according to the maintenance schedule.**

NOTE

If a higher differential pressure occurs, check all the filter candles (12, *Fig 18-32*) and the protective filter (1). If necessary, clean the candles or replace them with new ones.

A highly contaminated protective filter is a sign of prolonged operation with defective or clogged filter candles and thus opened overflow valves.

3 **Check the ease of movement of the worm gear unit (5), and the turbine (8) including the gear (9) with flushing arm (3).**

See *Fig 18-32*.

a **Remove the flange (4).**

b **Check the ease of movement with a suitable spanner on the hexagon of the worm gear unit.**

c **Replace all O-rings and seals, and tighten the flange (4).**

18.8.2 Removing the lubricating oil filter candles v8

Procedure

1 **Drain the filter, open the plugs (15), (13) and discharge the oil.**

See *section 18.8*.

NOTE

Do not refill the system with drained oil.

2 **Remove the automatic filter from the engine.**

Protect the openings. See .*section 18.6.2*.

3 **Remove the cover (16) by opening the cover nuts.**

See *section 18.8*.

4 **Lift out the entire filter element including flushing arms (3) and gear (9) out of the housing with a suitable tool.**

NOTE

Make sure that the exposed gear (9) is not damaged.

5 **Remove the top flushing arm (3) by opening the screws.**

6 **Remove the cover plate (18) by opening the screws.**

7 **Remove the top sieve plate (17) by opening the screws.**

8 **Remove the filter candles (12) and protective filter (1).**

18.8.3 Cleaning the filter candles with a cleaning device v5

CAUTION

The cleaning of the protective filter with the cleaning lance of the high-pressure cleaning unit must only be carried from outside in. The distance to the stainless steel mesh must be approximately 10–20 cm and the angle to the mesh surface approximately 90°.

Clean the candles with warm (maximum 60° C) high pressure water of maximum 60 bar after soaking in approved chemicals. Otherwise the mesh may be damaged.

NOTE

To get an optimal cleaning effect, use a high-pressure cleaning unit (part No. 471345), cleaner (part No. 471346), and cleaning device.

Procedure

1 **Place the filter candles in a suitable cleaner or diesel oil.**

NOTE

The maximum soaking time is 24 hours.

2 **Take the filter candles out of the cleaner, and attach them to the cleaning device.**

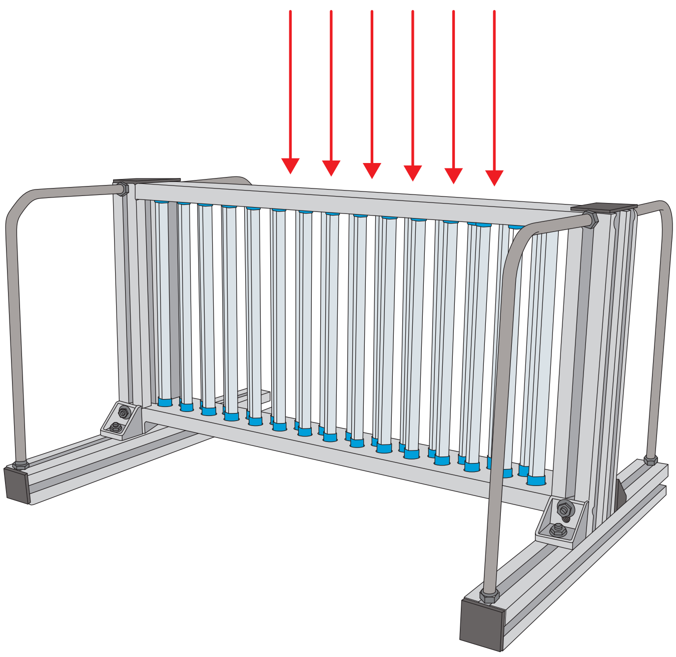


Fig 18-34 Mounting the filter candles to the cleaning device

If cleaning device is not available, see *Fig 18-37* for washing filter candles without a cleaning device.

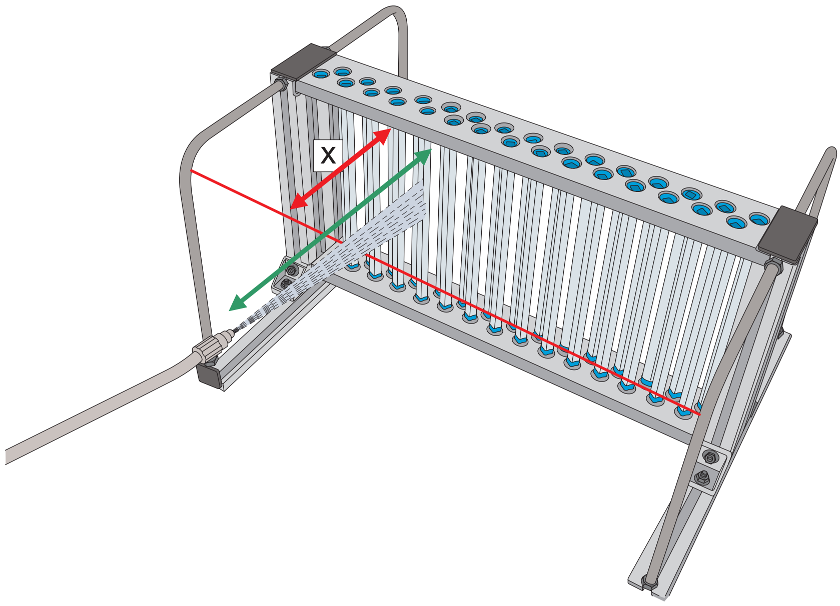
3 **Start the high pressure cleaning lance but not in direction of the filter candles.**

4 **Lead the high pressure jet up and down every single candle for at least five times.**

Use warm water.

NOTE

The minimum distance between the water nozzle and the candle as indicated by piping frame is 20 cm.



X = minimum distance 20 cm and maximum pressure 60 bar

Fig 18-35 Cleaning with high pressure

5 **Repeat the procedure from the other side.**

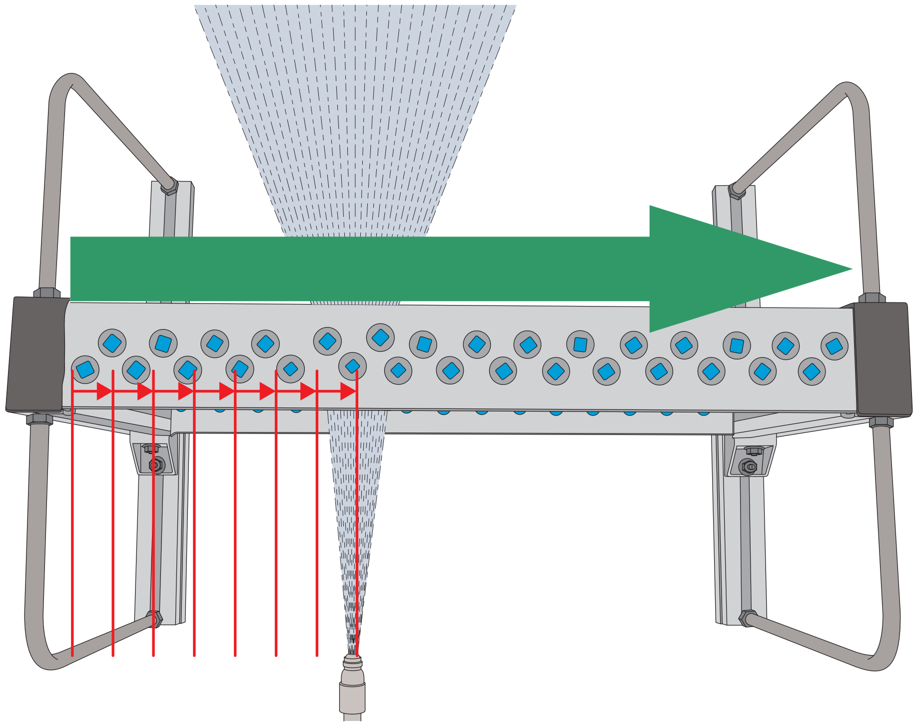


Fig 18-36 Cleaning procedure

6 **Clean the protective filter.**
See *section 18.8.5*.

7 **Dry the filter candles with compressed air gun.**

8 **Check and replace the worn candles.**

9 **Dismount the candles from the device, and mount them in the filter or store them in a dry and dust-free place.**

18.8.4 Cleaning the filter candles without a cleaning device v4

CAUTION
The cleaning of the protective filter with the cleaning lance of the high-pressure cleaning unit must only be carried from outside in. The distance to the stainless steel mesh must be approximately 10–20 cm and the angle to the mesh surface approximately 90°.

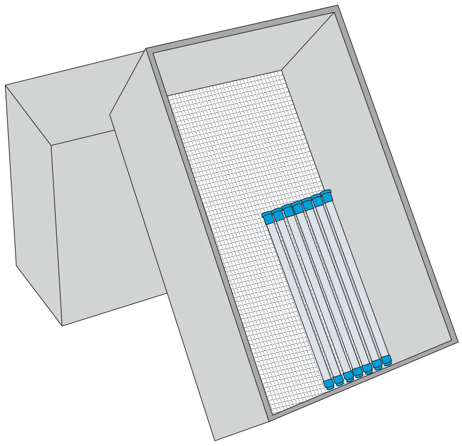


Fig 18-37 Cleaning the filter candles without a cleaning device

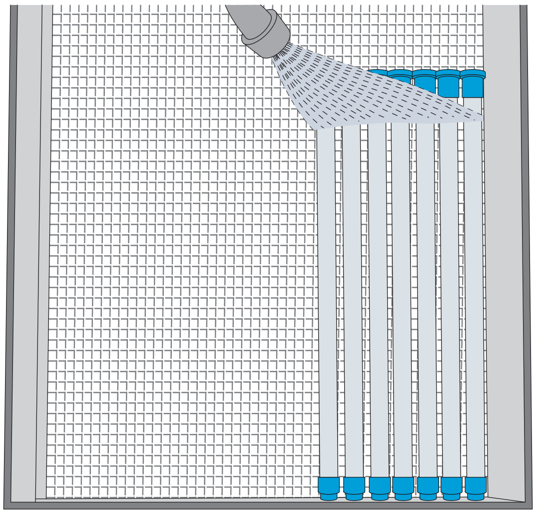
Procedure

1 **Place the filter candles in a suitable cleaner or diesel oil.**

NOTE
The maximum soaking time is 24 hours.

2 **After immersing, clean the filter candles from the outside inwards using a high-pressure cleaning unit.**

CAUTION
Use a pressure of maximum 60 bar, and make sure that the distance between the cleaning nozzle and the filter candle is at least 20 centimeters. Otherwise the mesh may be damaged.



Minimum distance 20 cm and maximum pressure 60 bar

Fig 18-38 Cleaning the filter candles

3 **Turn the candles and repeat the cleaning procedure, clean the candles from the outside inwards.**

4 **Check and replace worn candles.**

5 **Dry the filter candles with air.**

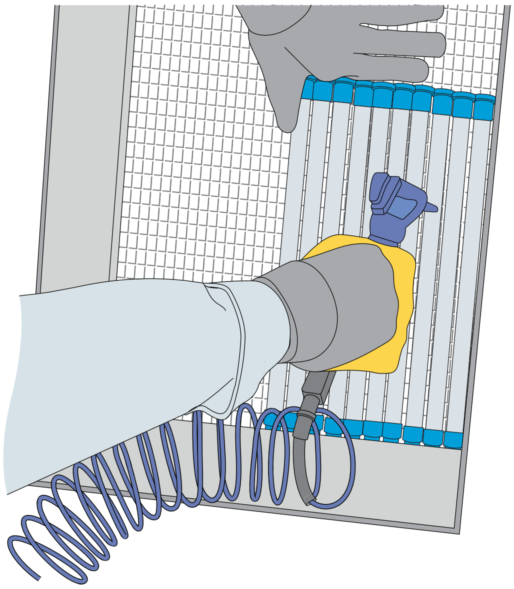


Fig 18-39 Drying the filter candles

18.8.5 Cleaning the protective filter v2

Procedure

1 **Place the protective filter in a suitable cleaning agent or diesel oil.**

2 **Remove loose particles that float on top of the cleaning agent during soaking.**

3 **Clean the protective filter all over from the outside to the inside by using a high-pressure cleaner.**

4 **Rinse out the protective filter in fresh cleaning agent.**

5 **Allow the protective filter to dry or blow with compressed air.**

6 **Check the protective filter.**
Replace, if damaged.

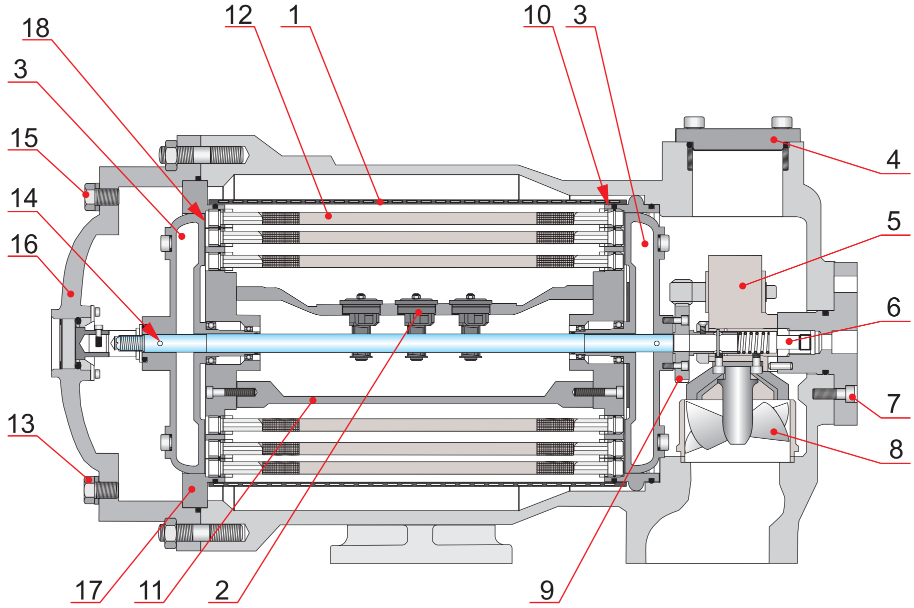
7 **Clean all the other components of the candle insert.**

8 **Check the seals for damage.**
Replace, if necessary.

18.8.6 Mounting the lubricating oil filter candles v8

Procedure

1 **Insert new O-rings.**



1 Protective filter
2 Overflow valves
3 Flushing arm
4 Flange
5 Worm gear unit
6 Flush bushing
7 Head cap screw
8 Turbine
9 Gear
10 Bottom sieve plate
11 Central connection tube
12 Filter candles
13 Plug
14 Flushing shaft
15 Plug
16 Cover
17 Top sieve plate
18 Cover plate

Fig 18-40 Lubricating oil automatic filter

2 **Mount the protective filter (1) and the top sieve plate (17).**

Tighten the screws.

NOTE

Note the position of the cover plate guiding pin.

3 **Before installing the filter candles, inspect them visually, and replace damaged candles with new ones.**

NOTE

Do not use defective filter candles again.

4 **Mount the filter candle in its position with the chamfered end towards the gear wheel end.**

a **Push the filter candles through the top sieve plate (17).**

b **Mount the cover plate (18).**

c **Mount the top flushing arm (3).**

d **Before installing the entire filter element, check the ease of motion of the flushing arms.**

e **Make sure that the flushing arms (3) do not come in contact with the bottom sieve plate (10) and the cover plate (18).**

5 **Insert new O-rings.**

6 **Push the entire filter element into the housing.**

By slightly turning the flushing shaft (14), the gear (9) is forced into the drive pinion of the gear unit (5).

7 **Mount the cover (16), and tighten the nuts.**

8 **Mount the plugs (15), (13) with new washers.**

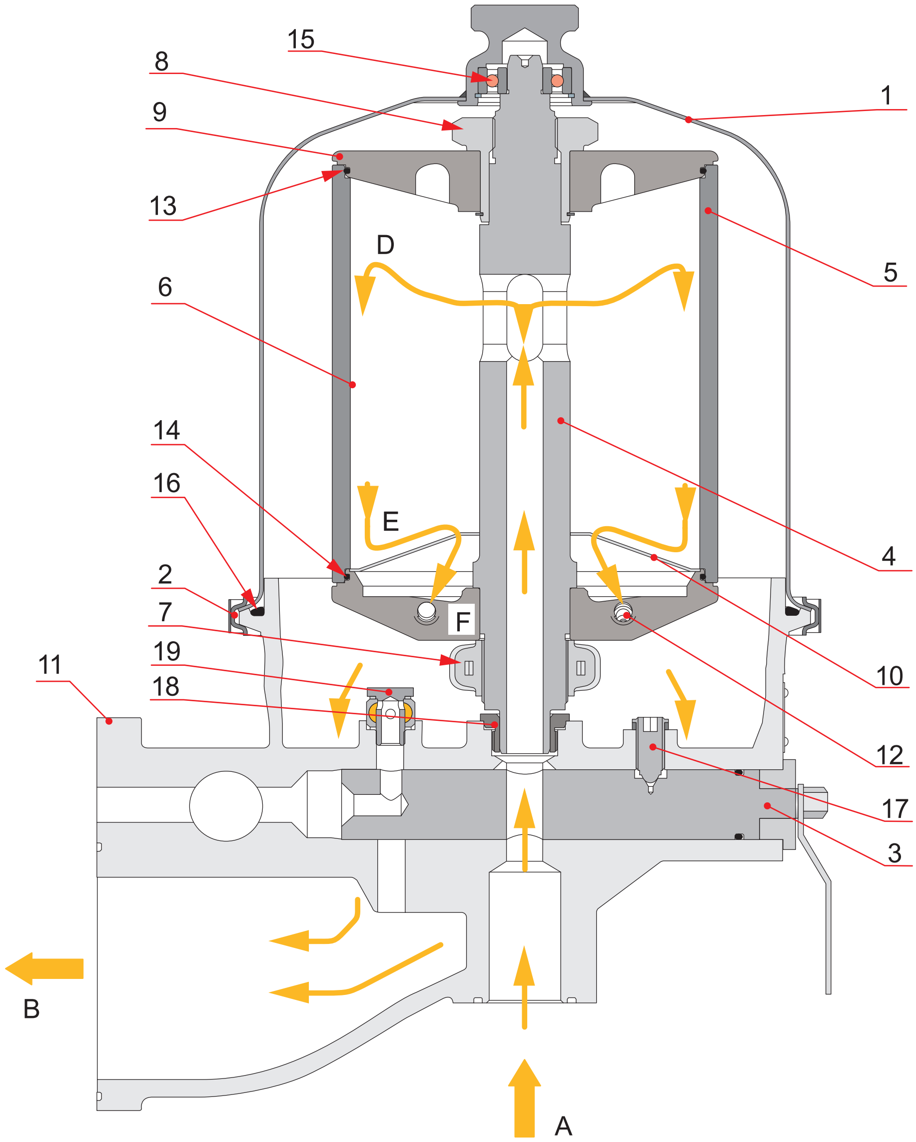
9 **Mount the lubricating oil automatic filter to the engine.**

18.9 Centrifugal filter

v13

The centrifugal-type bypass filter complements the automatic filter.

The flushed oil from the automatic filter is lead to connection (A). The oil flows through the shaft spindle (4) to the upper part of the rotor tube (5). After filtering, the clean oil is led back to the oil sump (B) through the nozzles (12) which rotates the centrifugal filter.



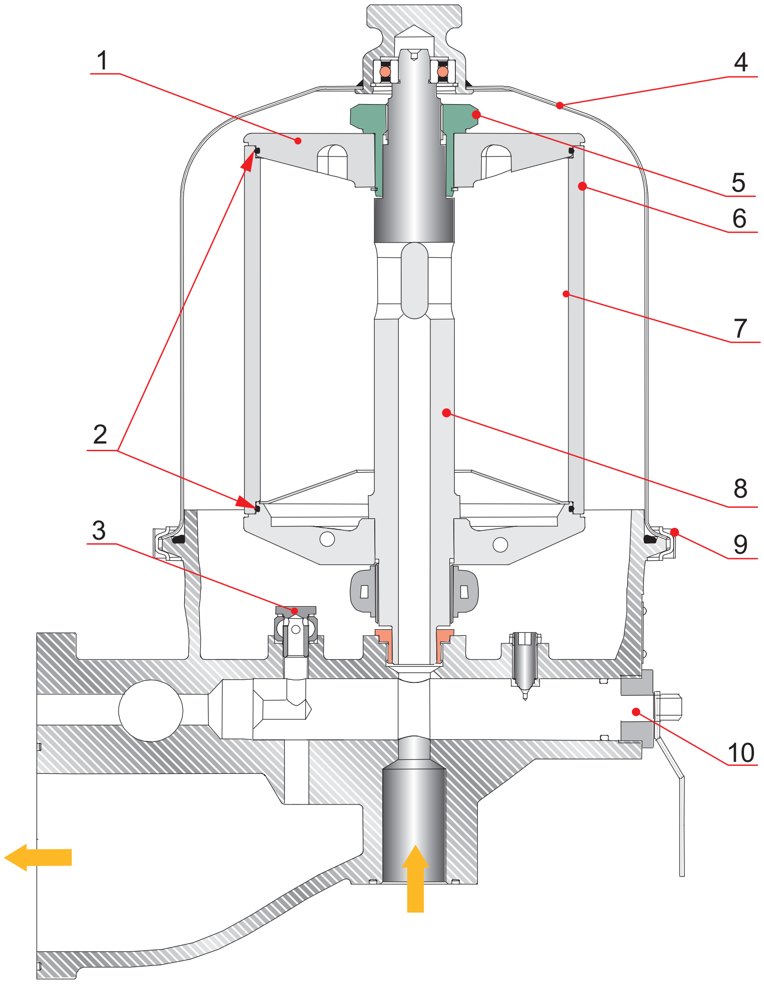
1	Filter cover	11	Housing
2	Cover clamp	12	Nozzle for back-flush oil
3	Cut-off valve	13	O-ring
4	Spindle	14	O-ring
5	Rotor tube	15	Ball bearing
6	Paper insert	16	O-ring
7	Turbine wheel	17	Locating screw
8	Rotor cover nut	18	Journal bearing
9	Rotor cover	19	Plug
10	Cone		

A. *Back-flush oil inlet* B. *Oil to crankcase* D. *Cleaning chamber* E. *Outlet chamber* F. *Outlet hole*

Fig 18-41 Centrifugal filter

18.9.1 Dismantling the centrifugal filter

v9



1 Rotor cover	6 Rotor tube
2 O-rings	7 Paper insert
3 Plug	8 Spindle
4 Filter body cover	9 Cover clamp
5 Rotor cover nut	10 Cut off valve

Fig 18-42 Centrifugal filter

Procedure

1 **Shut off the filter by closing the cut off valve (10).**

2 **Wait for at least one minute until the centrifugal filter stops rotating and the filter is empty.**

3 **Open the filter cover clamp (9).**

4 **Lift out the filter body cover (4).**

5 **Remove the rotor assembly.**

a **Hold the rotor body and open the rotor cover nut (5).**

b **Lift out the rotor cover (1).**

c **Remove the rotor tube (6) from the spindle (8).**

6 **Measure the thickness of the sludge to estimate future cleaning intervals.**

7 **Remove the sludge from the inside of the rotor cover and body by means of a wooden spatula or a suitably shaped piece of wood, and wipe clean.**

If a paper insert has previously been fitted, remove this insert containing the sludge from the rotor and discard.

8 **Clean out the nozzles with brass wire to ensure free passage of oil.**

NOTE
Ensure that the bore of the spindle is clear of sludge buildup.

9 **Examine spindle journals to make sure that they are free of damage or excessive wear.**

10 **Renew the O-rings.**

11 **Inspect the bearings for wear.**

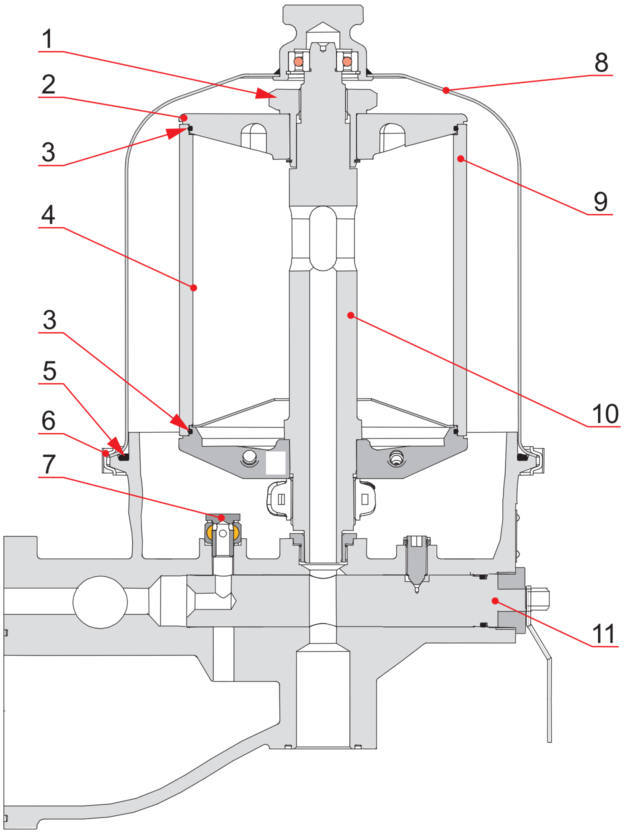
Replace, if necessary.

18.9.2 Assembling the centrifugal filter v8

Procedure

1 **Install new O-rings (3) in the rotor cover (2) and spindle (10).**

Lubricate them with oil.



1 Rotor cover nut
2 Rotor cover
3 O-ring
4 Paper insert
5 O-ring
6 Cover clamp
7 Plug
8 Filter body cover
9 Rotor tube
10 Spindle
11 Cut-off valve

Fig 18-43 Centrifugal filter

2 **Mount the rotor tube (9) to the spindle (10).**

3 **Install new paper insert (4) to the rotor tube (9).**

4 **Mount the rotor cover (2).**

5 **Tighten the rotor cover nut (1) to the stated torque, see chapter 07.**

CAUTION

Do not overtighten the rotor top nut. Overtightening can lead to rotor imbalance that decreases filter performance and can damage the bearings.

6 **Install the complete rotor unit.**

7 **Install a new O-ring (5) and the filter body cover (8).**

Tighten the cover clamp (6) to the stated torque, see chapter 07.

NOTE

Ensure the cover clamp is properly tightened before taking the centrifugal filter in operation.

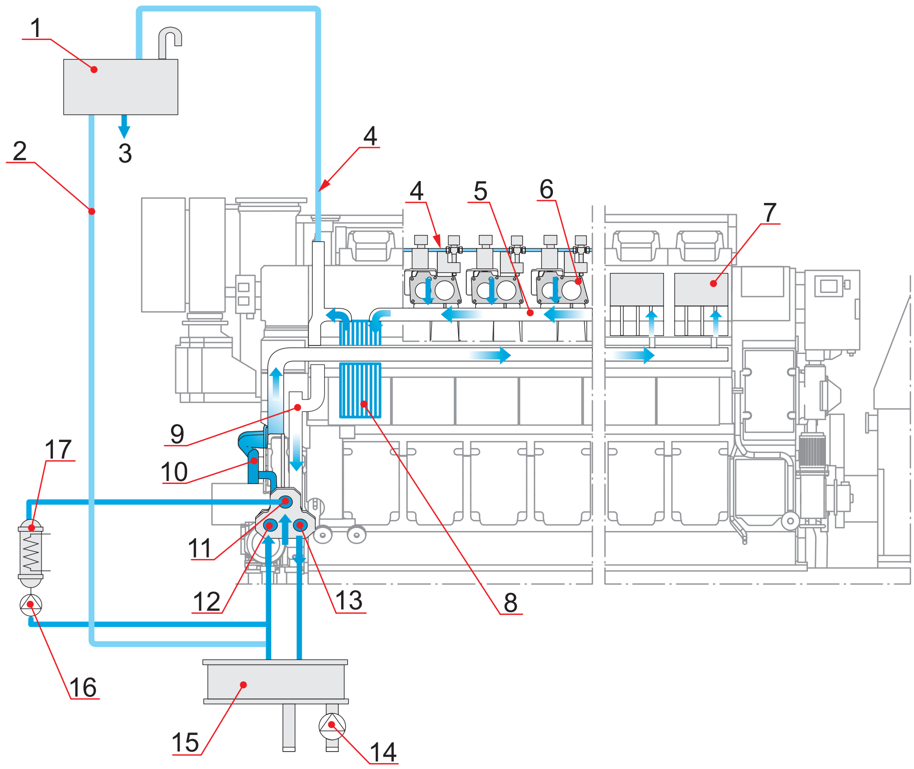
8 **Open the cut-off valve (11).**

9 **Check all the joints for leaks and any excessive vibrations while the centrifuge is running.**

19. Cooling Water System

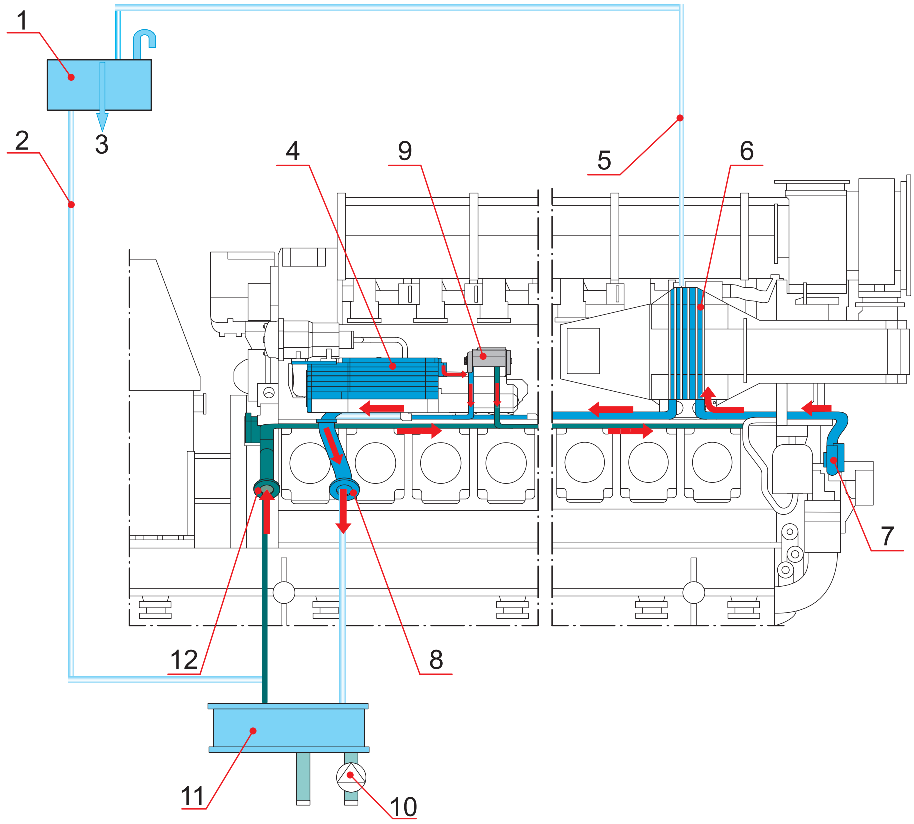
The engine is cooled by a closed-circuit cooling water system, divided into a high-temperature (HT) circuit and a low-temperature (LT) circuit. The cooling water is cooled in an external cooler.

Both cooling water circuits are provided with either engine-mounted or externally-mounted water pumps and thermostatic valves.



1 Expansion tank	10 HT water pump
2 Make-up line	11 Water from preheater to HT circuit
3 Over flow	12 HT water inlet
4 Vent pipe	13 HT water outlet
5 HT water return pipe	14 Water pump
6 Multiduct	15 Cooler
7 Cylinder head	16 Preheating water pump
8 Charge air cooler (HT side)	17 Preheater
9 Thermostatic valve for HT water (option)	

Fig 19-1 HT cooling water system circuit



1 Expansion tank
2 Make-up line
3 Over flow
4 Lubricating oil cooler
5 Vent pipe
6 Charge air cooler
7 LT water pump
8 LT water outlet
9 Thermostatic valve for LT water (option)
10 Water pump
11 Cooler
12 LT water inlet

Fig 19-2 LT cooling water system circuit

19.1 HT circuit

v8

The HT circuit water cools the cylinders and cylinder heads.

The HT-water pump circulates the water through the HT circuit. The cooling water is first circulated to the distributing duct, cast in the engine block. From the distributing ducts the water flows to the cylinder water spaces and further on through connection pieces to the cylinder heads. Here the water is led along the flame plate, around the centre sleeve for the injection valve and the exhaust valve seats, efficiently cooling these components. See *Fig 19-1*.

From the cylinder head the waterflow continues through the multiduct to the collecting duct and finally to the temperature control valve, that maintains the right water temperature level.

In installations with two stage charge air coolers, the HT -water is also circulated through the charge air cooler before it is led to the thermostatic valve.

The external HT system can vary from one installation to another.

19.2 Venting and pressure control of HT-circuit v4

For venting the cooling system, venting pipes from the multiducts are connected to a box. From this box the vent pipe leads to the expansion tank which is connected to the inlet pipe of the HT and LT water pumps. 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 by a pump or pressurized expansion vessel. See *Fig 19-1*.

19.3 LT circuit v4

The LT circuit cools the charge air cooler and the lubricating oil cooler. The LT water pump that circulates the water is of a similar design as the HT pump. The circuit temperature is controlled and maintained at the right level by the thermostatic valve. The necessary cooling is gained from the cooler. The LT system outside the engine can vary from one installation to another.

For venting the cooling system, venting pipe from the charge air cooler is connected to ventilation pipe that leads to the expansion tank. See *Fig 19-2*.

19.4 Preheating the cooling water system v5

For preheating the circuit, the preheating water pump and preheater are connected to the HT circuit before the engine. The non-return valves in the circuit force the water to flow in the right direction. See *Fig 19-1*.

Before start, the HT circuit is heated up to 50-70°C by a separate heater.

This is of utmost importance when starting and idling with heavy fuel.

19.5 Monitoring the cooling water system v14

The cooling water temperatures mentioned in *section 01.2* should not be exceeded.

The HT and LT pressures (after the pumps) are displayed on the display units. The pressures depend on the speed and the installation. The guidance values are in *section 01.2*.

The HT water system is equipped with two temperature sensors for alarm and depending on installation, if the temperature exceeds certain limit, shuts down the engine.

Engines may also be equipped with pressure switches for start of stand-by pumps. For further information, see chapter 23 Instrumentation and Automation.

19.6 Maintaining the cooling water system v5

The installation - including expansion, venting, preheating, pressurizing - should be carried out strictly according to the instructions of the engine manufacturer to obtain correct and trouble free service.

WARNING

Depressurize and drain the cooling system before carrying out any maintenance or repair work.

WARNING

Risk of injury due to spraying of hot pressurized liquids. Wear the correct protective equipment during any maintenance or repair work.

The cooling water should be treated according to the recommendations in chapter 02., section Cooling Water 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.

Remember to close the drain and open the cooling water connections to refill the engine cooling water system before the engine is started again.

19.6.1 Cleaning the cooling water system

v5

Prerequisites

In completely closed systems the fouling is minimal if the cooling water is treated according to the instructions in chapter 02, section Cooling Water. Depending on the cooling water quality and the efficiency of the treatment, the cooling water spaces foul more or less over the course of time. Deposits on cylinder liner water spaces, cylinder heads and cooler stacks must be removed as they disturb the heat transfer to the cooling water and thus cause serious damage.

The need to clean must be examined, especially during the first year of operation. This is done by inspecting cooling water spaces and checking for fouling and deposits.

The deposits can be of the various types and of different consistencies. It can be removed mechanically and/or chemically as described below. More detailed instructions for cleaning of coolers, see chapter 18.

Procedure

1 **Mechanical cleaning**

A great deal of the deposits consist of loose sludge and solid particles which can be brushed and rinsed off with water.

In places where accessibility is good, for example cylinder liners, mechanical cleaning of considerably harder deposits is efficient.

In some cases it is advisable to combine chemical cleaning with subsequent mechanical cleaning as the deposits may have dissolved during the chemical treatment without having come loose.

2 **Chemical cleaning**

Narrow water spaces (such as cylinder heads, coolers) can be cleaned chemically. At times, degreasing of the water spaces may be necessary if the deposits seem to be greasy, see chapter 18.

Deposits consisting of primarily limestone can be easily removed when treated with an acid solution. On the other hand, 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 the area is accessible).

The cleaning agents should contain additives (inhibitors) to prevent corrosion of the metal surfaces. See the list of approved cooling water additives and treatment systems, (mentioned in the end of chapter 02). 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 carbonate solution (washing soda) of 5 % to neutralize possible acid residuals.

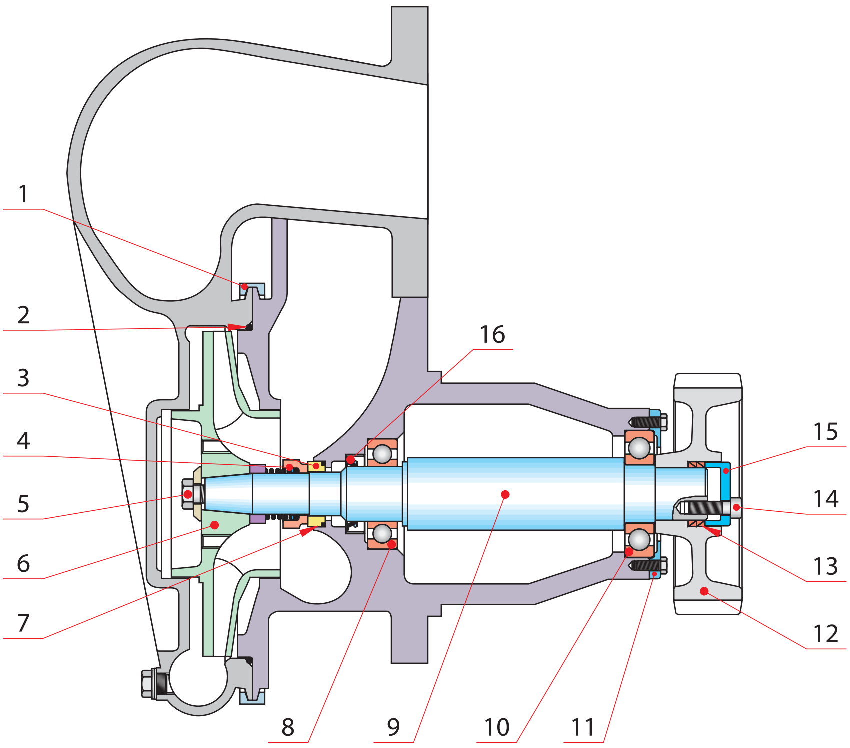
19.7 Engine driven cooling water pump v4

The water pump is a centrifugal pump and is driven by the gear mechanism at the free end of the engine. The shaft is made of acid resistant steel, the impeller (6) and the remaining parts of cast iron, see *Fig 19-3*.

The shaft is mounted in two ball bearings (8) and (10), which are lubricated by pressurized oil entering through the opening in the bearing housing. The shaft seal (16) prevents the oil from leaking out and, at the same time, dirt and leak water from entering.

The gear wheel (12) is fastened to the shaft by a friction ring pair (13). When the screws (14) 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 (4) rotates along with the shaft and seals against it with the O-ring. The spring presses the rotating ring against a fixed ring (3) which seals against the housing with the O-ring (7). Possible leak-off water from the sealing can flow out through a telltale hole at the bottom of the pump.



1 Cover clamp
2 O-ring
3 Fixed ring
4 Shaft sealing
5 Screw
6 Impeller
7 O-ring
8 Ball bearing
9 Shaft
10 Ball bearing
11 Bearing retainer
12 Drive gear
13 Friction rings
14 Screw
15 Pressure plate
16 Seal

Fig 19-3 Cooling water pump

19.7.1 Maintaining the water pump

v5

Prerequisites

Normal maintenance operations, like removing the impeller or replacing the mechanical seal, can be done without removing the complete pump from the engine.

Check the pump at intervals according to the maintenance schedule in chapter 04, or immediately if any water or oil leakage occurs.

Any water or oil leakage can be seen through the telltale hole . Check every now and then that the telltale hole is open.

NOTE

A small amount of water leakage (a few drops per hour) can be considered normal.

19.7.1.1 Dismantling and assembling the impeller

v5

Prerequisites

Before dismantling or removing the water pump:

1 Drain the water from the cooling water system and collect it for re-use.

2 Remove the drain plug to drain and empty the pump casing.

CAUTION

The LT and HT impellers may have different diameters. Do not mix up the impellers.

NOTE

Always use a crane or other lifting device.

Procedure

1 **Remove the volute casing by loosening the clamp (1) and the fastening screws.**

2 **Loosen the impeller fastening screw (5).**

3 **Pull off the impeller using the extractor 837055.**

4 **When reassembling the impeller, tighten the screw to torque, see *07.1*.**

5 **Check that the O-ring (2) and non-return valve O-rings between pump and engine pump cover are intact and in position when reinstalling the volute casing.**
Check that the volute casing is in position.

6 **Mount the clamp and tighten the screws.**

19.7.1.2 Dismantling and assembling the mechanical shaft seal v4

Procedure

1 **Remove the impeller.**

See *19.7.1.1*

2 **Carefully dismantle all seal parts.**

Sealing rings are very fragile.

3 **Take care not to damage sealing surfaces as a slight scratch may disturb the sealing function.**

4 **Replace the complete seal if it is leaking, or if sealing faces are corroded, uneven or worn.**

Avoid touching the sealing faces with fingers.

5 **Reassemble the details in correct order and install the impeller.**

See *19.7.1.1*. Ensure that the washer between the spring and the O-ring is in place.

19.7.1.3 Replacing the bearings and oil seal ring v7

Procedure

1 **Remove the pump from the engine.**

2 **Dismantle the impeller and mechanical seal.**

3 **Loosen the screws (14) and remove the pressure plate (15).**

See *Fig 19-6*.

4 **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 friction rings (13) come loose together with the gear wheel.

CAUTION
Using an extractor may damage the shaft (axial scratches).

5 **Loosen the bearing retainer (11) by opening the screws and drive out the shaft and bearing.**

6 **Check the seal (16) and the bearings for wear and damage.**

If the seal is leaking, knock it out using a suitable brass piece.

7 **Remove the bearings by pressing its inner ring with a suitable pipe.**

8 **Inspect the shaft for wear and damage.**

9 **Oil the new seal and insert it by pressing against the shoulder.**

10 **Oil the collar and press the bearing in by its inner ring with a suitable pipe.**

See *Fig 19-4* A.

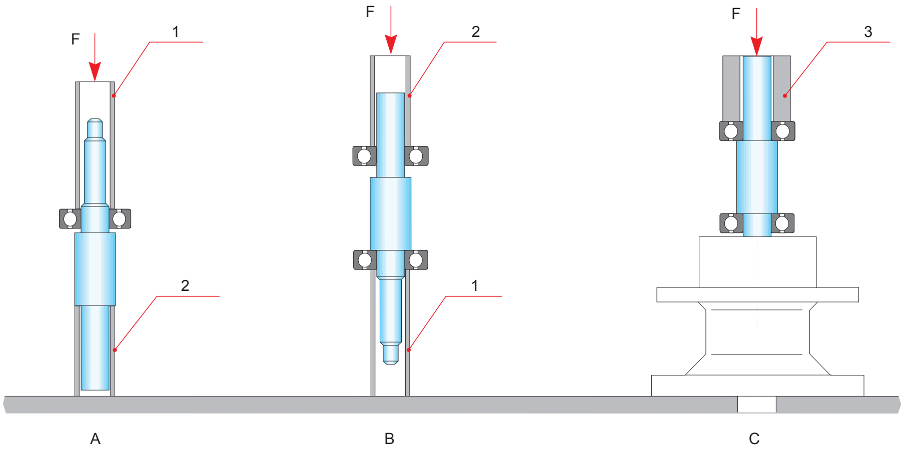
11 **Turn the shaft according to *Fig 19-4* B.**

12 **Oil the collar and press the bearing in by its inner ring with a suitable pipe.**

See *Fig 19-4* B.

13 **Turn the housing according to *Fig 19-4* C and lubricate the outer surfaces of the bearings.**

Use a suitable pipe to press both the inner and outer ring of the bearing into the shaft housing.



1 Pipe 1
2 Pipe 2
3 Pipe 3

Fig 19-4 Mounting of bearings

14 **Fit the bearing retainer (11) and tighten the screws.**

15 **Before reinstalling the gear wheel, all contact surfaces should be cleaned.**

16 **Reinstall the gear wheel and the friction ring pair (13).**

CAUTION
Re-install the friction ring pair as in *Fig 19-6*. The friction ring pair should fall easily in place and must not jam.

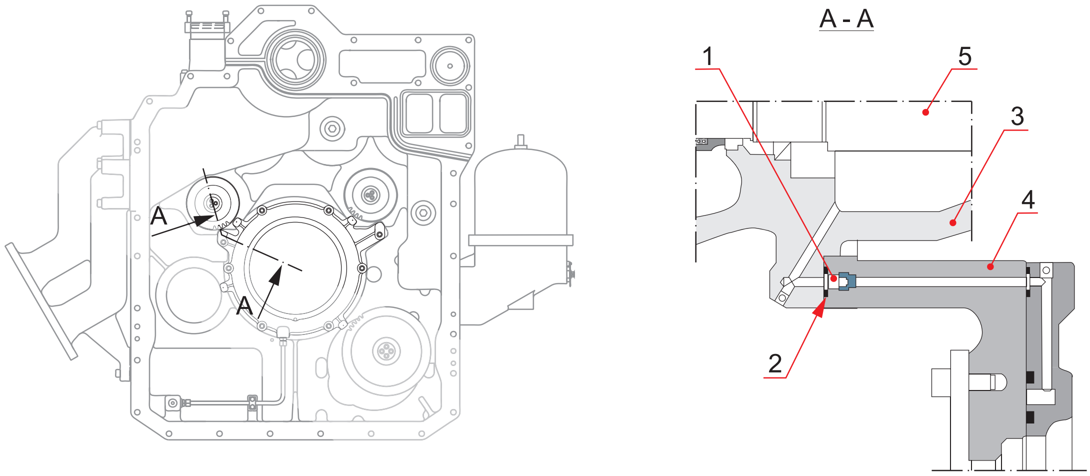
17 **Re-install the pressure plate (15).**

18 **Tighten the screws a little and check that the gear wheel is in the right position.**

19 **Tighten the screws to torque according to *07.1*.**

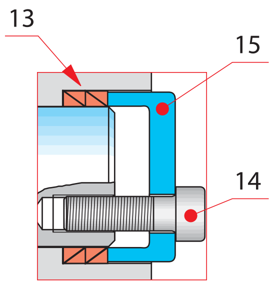
20 **Mount the pump on the engine.**

CAUTION
Make sure that the oil supply bore is open (see *Fig 19-5*) and that no sealing compound blocks the hole at mounting of the pump on the engine. Blocked oil supply causes failure to the bearings and oil seal ring.



1 Oil supply bore
2 O-ring
3 Bearing housing
4 Pump cover
5 Shaft

Fig 19-5 Oil supply bore



13.*Friction rings* 14.*Screw* 15.*Pressure plate*

Fig 19-6 Mounting of gear wheel to water pump

21 **Check the backlash of the gear wheel (12) after mounting. See *06.1*.**

19.8 Temperature control system

v3

Temperature control valves can either be mounted in the external system or engine mounted. For externally mounted thermostatic valves see supplier's operation and maintenance manual.

The HT circuit is provided also with a fixed thermostatic valve mounted inside the upper part of pump cover to maintain the HT outlet water temperature.

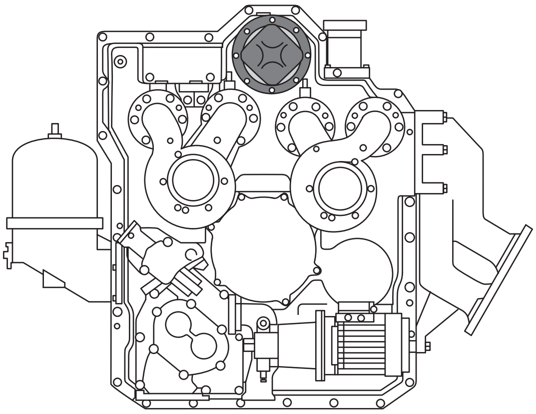


Fig 19-7 HT circuit temperature control system

19.8.1 HT thermostatic valve

v5

The HT thermostatic valve is integrated into the pump cover at the free end of the engine.

The HT thermostatic valve is a three-way valve which controls the direction of the water flow. When the engine is started up and is cold, the HT thermostatic valve allows the water to be by-passed back into the pump, thus providing the quickest warm-up period possible. After warm up, the correct amount of water is by-passed and mixed with the cold water (returning from the heat exchanger or other cooling device) to produce the desired HT water outlet temperature. If required, the HT thermostatic valve shuts off the by-pass line for maximum cooling. When the engine is cold, the three-way action of the valve maintains a constant flow of water through the pump and engine at all times.

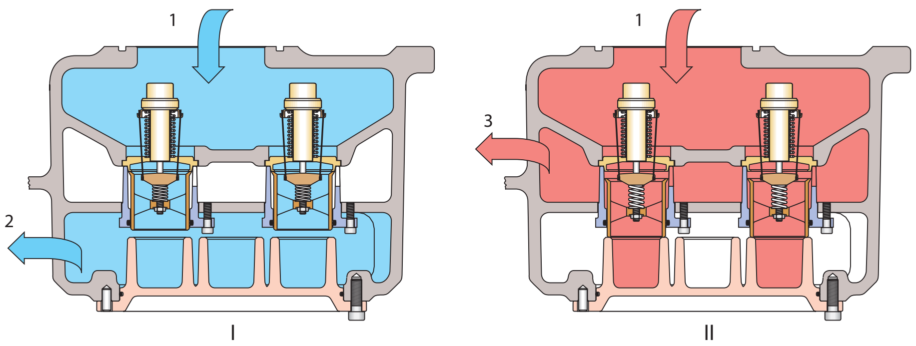
The HT thermostatic valve requires no adjustments. The temperature is permanently set at the factory. The temperature can be changed only by changing the temperature element assemblies, which is easily accomplished by unscrewing the cover. The HT valve is entirely self-contained, and there are no external bulbs or lines that could be damaged or broken. There are no packing glands to tighten and no parts to oil.

For wax-type elements, the power creating medium is the wax in the element. This remains in a semi-solid form and is highly sensitive to temperature changes. The expansion of the element contents is utilised to move the valve to the cooling position. Maximum expansion takes place during the melting period of approximately two minutes over a temperature change of approximately 8.5°C.

The HT thermostatic valve is provided with four elements.

Since the water flow is diverted either through the by-pass or the heat exchanger, thermostat failure does not affect the pressure.

When the elements are heated, this force is transmitted to the piston thus moving the sliding valve to the by-pass closed position. When the elements are cooled, this force is opposed by a high spring force, which moves the sliding valve to the heat exchanger closed position. The high force available on heating is the basis of the fail safe feature. Failure of the element would cause the engine to run cold.



I *Cold engine* II *Warm engine*

1.*From engine* 2.*Bypass* 3.*To cooler*

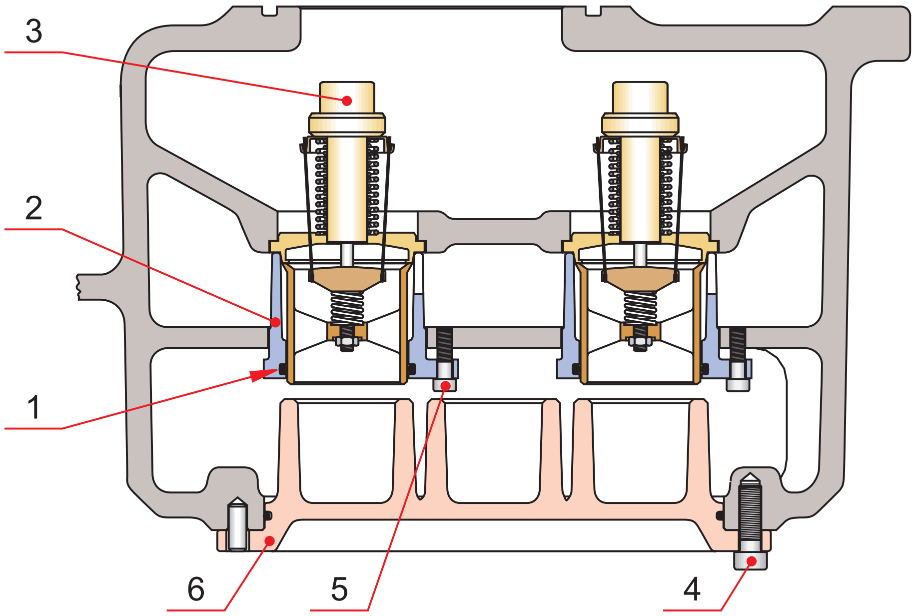
Fig 19-8 Water flow in HT thermostatic valve

19.8.1.1 Maintaining the HT thermostatic valve

v7

Prerequisites

Inspect the valve according to the maintenance schedule. Very low or very high temperature is a sign of a defective thermostat. Leaking O-rings may also be a reason, but in most cases, it is a dirty cooler.



1 O-ring
2 Element holder
3 Thermostat element
4 Screw
5 Screw
6 Cover

Fig 19-9 Thermostatic valve

Procedure

1 **Drain the cooling water circuit.**

2 **Remove the cover (6) by opening the screws (4), see *Fig 19-9*.**

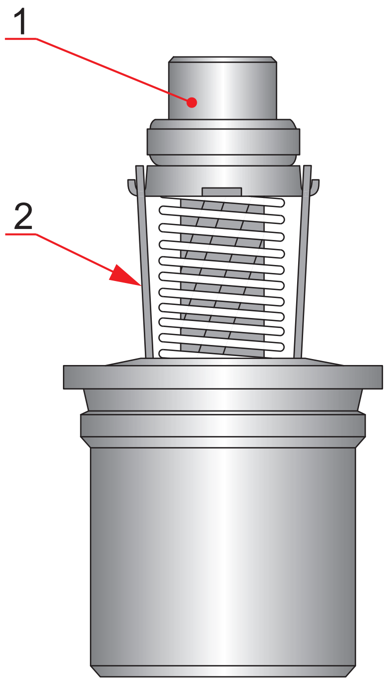
3 **Open the screws (5) and remove thermostat elements (3) with element holders (2).**

Use extractor tools 800122 and 800029 for element holder if necessary.

4 **Check the element by heating it slowly in water.**

Note the temperature at which the element starts opening and the temperature at which it is fully open. The lower value for the water temperature is the opening temperature, the higher for the fully open valve. The nominal values can be found on the thermostatic element, see *section 01.1*.

NOTE	
i	Thermostatic elements are marked with opening set point in degrees Celsius [°C] and nominal set point in degrees Fahrenheit [°F].



1 Opening set point (°C)
2 Nominal set point (°F)

Fig 19-10 Maintaining the HT thermostatic valve

5 **Change defective elements. Renew the O-rings.**

6 **Re-assemble the valve in reverse order.**

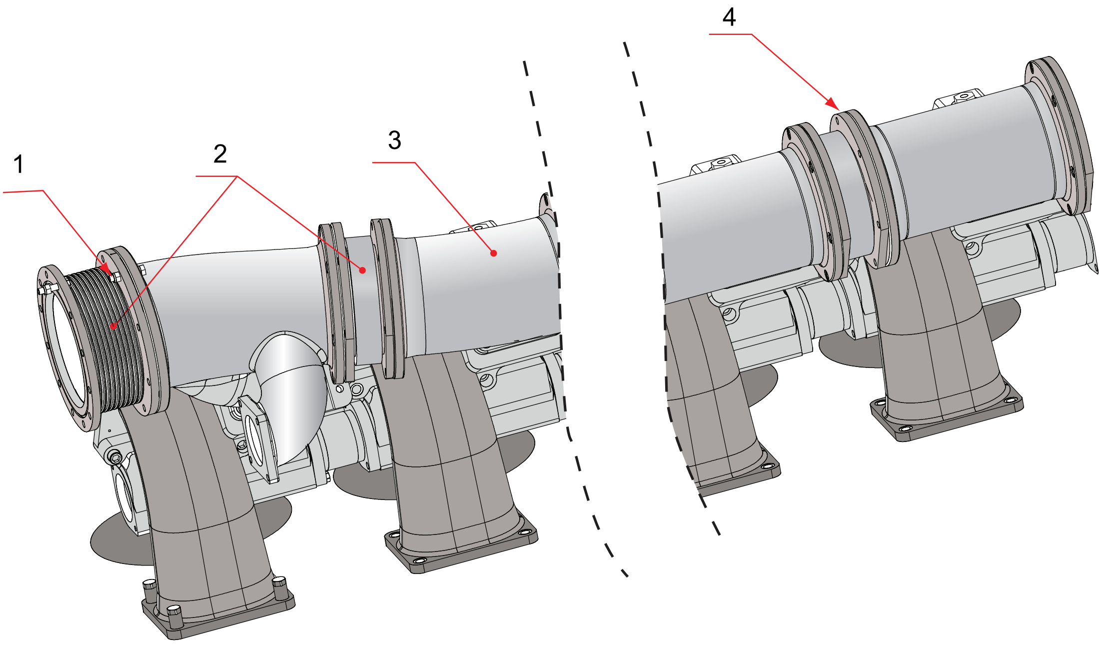
20. Exhaust system

The "SPEX" exhaust system is a combination of pulse system and constant pressure system retaining the kinetic energy of exhaust gases in a simple constant pressure type exhaust pipe.

Exhaust gases from cylinders are led into common exhaust manifold which is connected to the turbocharger.

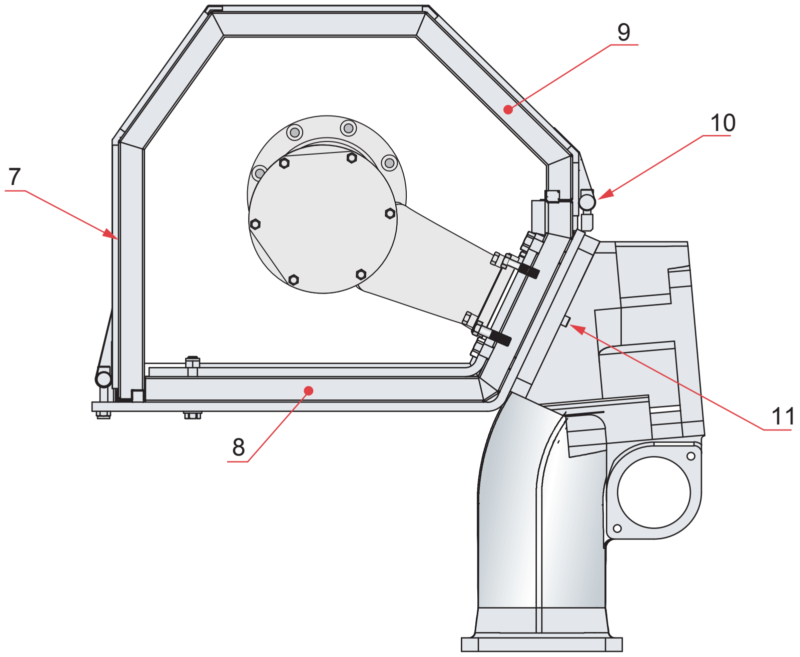
Pipe sections are provided with bellows on each end to avoid thermal deformation.

The complete exhaust system is enclosed by an insulation box built up of sandwich steel sheets.



1 Screw
2 Bellows
3 Exhaust pipe
4 Sealing ring

Fig 20-1 "SPEX" Exhaust system, L-engine



7. Cover profile
8. Lower protecting pane
9. Upper protecting pane
10. Screw
11. Screw

Fig 20-2 Insulation box, L-engine

20.1 Changing expansion bellows

v9

Procedure

1 **Remove the necessary parts of the insulation box.**

WARNING
The surface of the insulation box is hot.

2 **Open the flange screws (1) of the expansion bellows (2) in question and remove the bellows.**

See *Fig 20-1*.

3 **Check that the exhaust pipe flanges are parallel and positioned on the same centre line to avoid lateral forces on the bellows.**

4 **Mount the new expansion bellow with new seal rings and tighten the screws.**

5 **Check the correct tightening torque for the flange connections, see *section 07.1*.**

CAUTION

Do not keep the wrench against the bellows when tightening, otherwise the bellows can be deformed.

6 **Check for possible leaks.**

7 **Mount all parts of the insulation box.**

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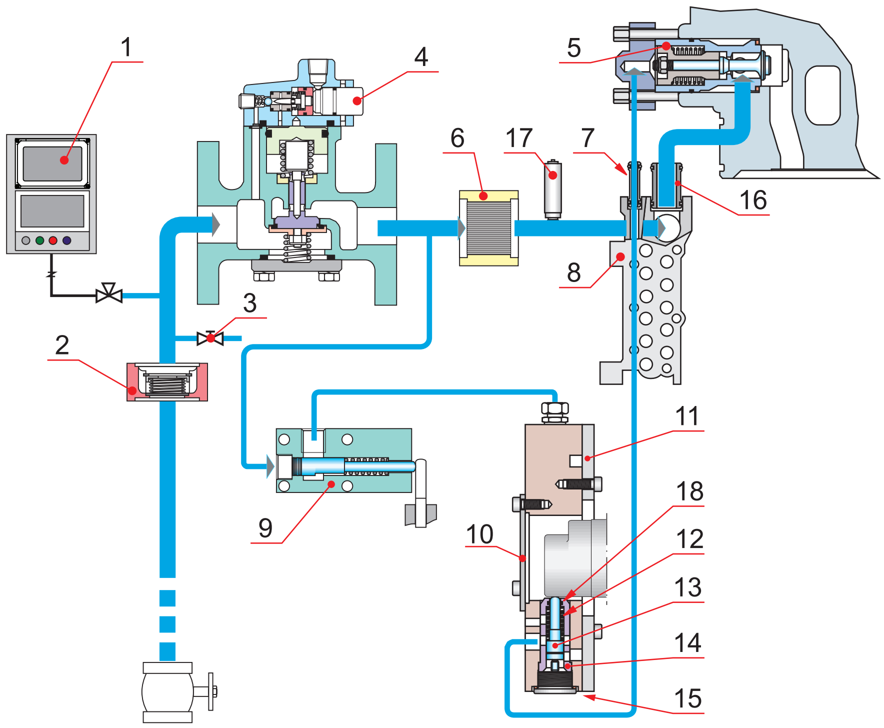
21. Starting air system

The engine is started with compressed air that flows into the cylinders through the starting valves. The maximum pressure of the compressed air is 30 bar and the minimum pressure required to start the engine is 15 bar. The pressure before the main starting valve (4) is indicated on the local display (1).

The inlet air pipe from the starting air receiver is provided with a non-return valve (2) and a drain valve (3) before the main starting valve (4). The main starting valve is a pneumatically controlled valve with an integrated throttle valve. A solenoid valve controls the operating air to the starting valve.



1 Local display	10 Cover
2 Non-return valve	11 Plate
3 Drain valve	12 Spring
4 Main starting valve	13 Control piston
5 Starting valve	14 Liner
6 Flame arrester	15 Plug
7 Connection piece	16 Connection piece
8 Air block	17 Safety valve
9 Blocking valve	18 O-ring

Fig 21-1 Starting air system

When the main starting valve opens, a part of the starting air passes through the flame arrester (6) and the air block (8) to the starting valves (5) in the cylinder heads. Another part of the starting air passes to the starting air distributor , which guides the control air to the starting valves. The starting valves open and admit starting air to flow to the cylinders for suitable periods. The starting air system is equipped with a safety valve (17), which protects the system and the components in possible fault situations. Starting air to the distributor is led from the main line before the safety valve and flame arrester.

As a precaution the engine cannot be started when the turning gear is engaged. The starting air to the distributor is led through a blocking valve (9) that is mechanically blocked when the turning gear is engaged, thus preventing start.

WARNING

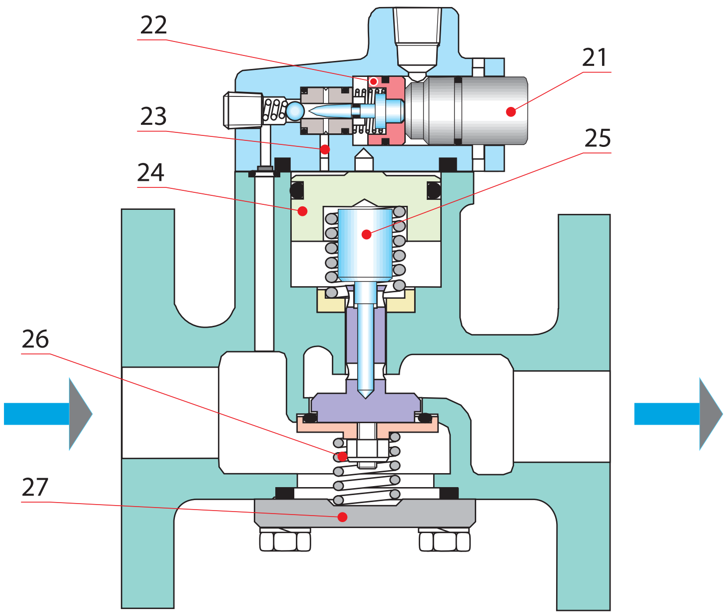
Before any maintenance steps are taken, make sure that the starting air shut-off valve located before the starting valve is closed and the engine starting air system is drained.

21.1 Main starting valve

v3

Inlet pressure is led through drilling to a small pilot valve with a pilot piston (22). This valve can be manually operated by the push button (21) or pneumatically operated by a solenoid valve for remote or automatic start. When opening the valve, the air flows through drilling (23) to the power piston (24), which exerts its thrust through a valve stem (25) directly on to the main valve and opens this against the load provided by a return spring (26) 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.



21.*Push button* 22.*Pilot piston* 23.*Drilling* 24.*Power piston* 25.*Valve stem* 26.*Spring* 27.*Flange*

Fig 21-2 Main starting valve

21.1.1 Maintenance of Main Starting Valve

v2

Procedure

1 **Remove the main starting valve**

from the engine.

2 **Remove the hexagon socket head screws**

and remove the pilot valve assembly.

3 **Remove the pilot valve piston (22).**

4 **Clean the pilot valve**

of any dirt which may block the small air passages and holes.

5 **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.

6 **Remove the power piston (24)**

and check the O-ring. Ensure that the small vent hole to atmosphere in the cylinder under the piston is clear.

7 **When reassembling the valve**

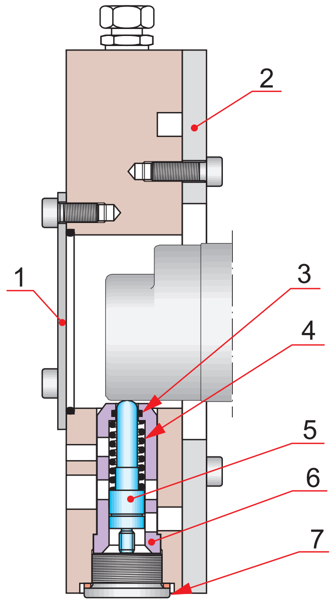
ensure that the air passage hole in the upper body flange lines up with the hole in the lower body.

8 **Remove the flange (27),**

spring (26) and main valve seat complete with the valve stem (25). Examine O-rings as in step 5 above.

21.2 Starting air distributor

v6



1 Cover
2 Plate
3 O-ring
4 Spring
5 Control piston
6 Liner
7 Plug

Fig 21-3 Starting air distributor

The starting air distributor is of the piston type with precision-machined interchangeable liners (6). The liners as well as the pistons are of corrosion-resistant materials. The distributor pistons are controlled by a cam at the camshaft end. When the main starting valve opens, the control pistons (5) are pressed against the cam, whereby the control piston for the engine cylinder that is in the starting position, admits control air to the power piston of the starting valve. The starting valve opens and allows pressure air to pass into the engine cylinder.

The procedure is 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 (4) 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.

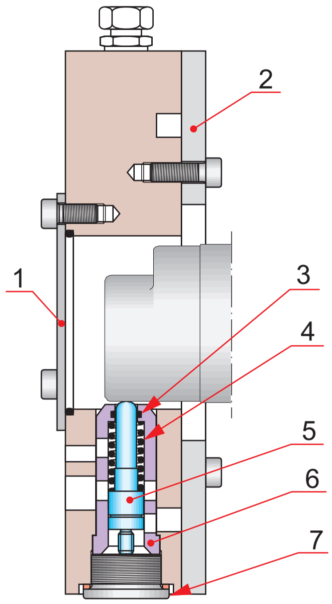
21.2.1 Maintaining the starting air distributor v7

Prerequisites

If the starting air distributor has to be opened for checking and cleaning, remove the complete distributor from the engine. However, individual pistons can be checked without removing the distributor.

Procedure

1 **Remove the distributor.**



1 Cover
2 Plate
3 O-ring
4 Spring
5 Control piston
6 Liner
7 Plug

Fig 21-4 Starting air distributor

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

b **Loosen all pipes from the distributor.**

c **Remove the fastening screws and lift the distributor.**

2 **Remove the plugs (7).**

The pistons (5) forced out as it is spring-loaded (4). If the piston is stuck, use M8 thread at the end of the piston to get it out.

NOTE

Take care not to damage the sliding surfaces of the piston and liners.

NOTE

Do not change the place of the piston although they are precision-machined to be interchangeable. Utilize the numbers stamped at the control air connection on the cylinders to identify the right cylinder.

3 **Remove the plate (2) and clean the slot under the plate.**

4 **Remove the liner if it is worn out.**

a **Heat the distributor to a maximum of 200°C.**

b **Press the liner out.**

5 **Clean the parts and check for wear.**

6 **Clean the bore carefully to avoid liner deformation and sticking of piston.**

Replace the O-ring (3).

7 **Mount the new liner manually.**

a **Apply Loctite 242 on the outside surface of liner.**

b **Mount the liner into the housing.**

Check that the openings in the liner and housing correspond to each other.

8 **Check that there is no Loctite on the inside sliding surfaces.**

9 **Renew the O-rings inside the liners.**

10 **Apply Molykote Paste G to the piston sliding surfaces before re-assembly.**

NOTE

Wipe off surplus paste and check that the pistons do not stick.

11 **Apply silicon sealant to the intermediate plate (2). Tighten the fastening screws.**

NOTE

Do not use too much sealant as it may get into the system when tightening the fastening screws.

12 **Mount the distributor and check that the pistons are working properly.**

Connect compressed air (6 bar) to the distributor inlet, turn the crankshaft and check that all pistons follow the cam profile.

WARNING

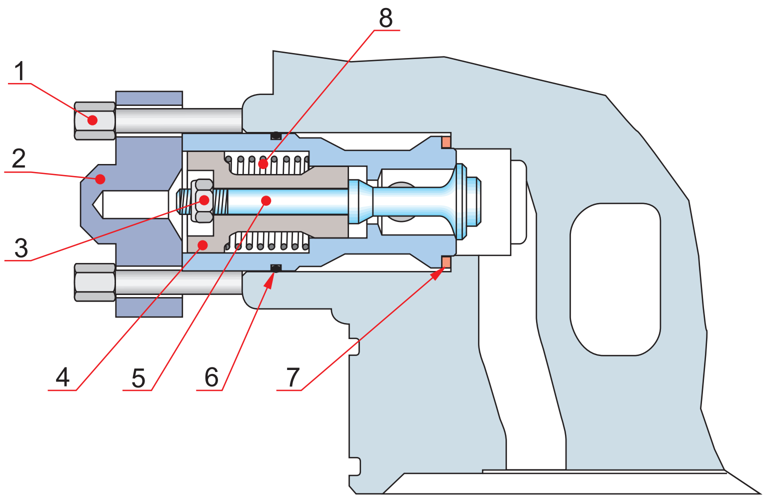
Do the testing with control air pipes and starting air pipe disconnected, otherwise the engine may start.

13 **Connect the pipes and cover (1) with new O-rings.**

21.3 Starting valve

v3

The valve consists of a valve spindle (5) with a spring-loaded operating piston (4) mounted in a separate housing.



1 Nut
2 Cover
3 Nut
4 Piston
5 Spindle
6 O-ring
7 Sealing ring
8 Spring

Fig 21-5 Starting valve

21.3.1 Maintaining the starting valve

v7

Check and clean the valve in connection with cylinder head overhauls.

Procedure

1 **Remove the fastening nuts (1) and pull out the valve cover (2), see *Fig 21-5*.**

2 **Pull out the starting valve.**

3 **Open the self-locking nut (3).**
Remove the spring (8) and the spindle (5).

4 **Clean all the parts.**

5 **Check sealing faces of the valve and valve seat.**
If necessary, lap the valve by hand. See instructions for the engine valves in chapter 12, section: Exhaust and Inlet Valves and seat rings. Keep the piston on the valve spindle to get guiding.

6 **Replace the nut (3) with a new one.**

7 **After reassembling the valve, check that the valve spindle moves easily along with the piston and closes completely.**

8 **Check that the O-ring (6) of the valve housing are intact.**
Lubricate with oil.

9 **Check that the steel sealing (7) is intact and in position, when mounting the valve into the cylinder head.**

10 **Tighten the valve to torque stated in chapter 07, section: Tightening Torques for Screws and Nuts.**

NOTE
Make sure that all pipe clamps and brackets are re-mounted after starting air system maintenance.

21.4 Starting air vessel and piping v5

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 safety valve are mounted.

Drain the starting air vessel from condensate through the drain valve before starting.

Keep the piping between the air vessels and the engines free from dirt, oil and condensate.

Inspect the starting air vessels for corrosion and leaks, and clean them regularly. At the same time, inspect the valves of the starting air vessels. Overtightening damages the seats and makes them leaky. Replace leaky and worn valves, including safety valves. Test the safety valves by applying pressure.

21.5 Pneumatic system v11

The engine is equipped with a pneumatic system to control the following functions by means of solenoid valves:

- engine start: CV321
- engine stop: CV153-1

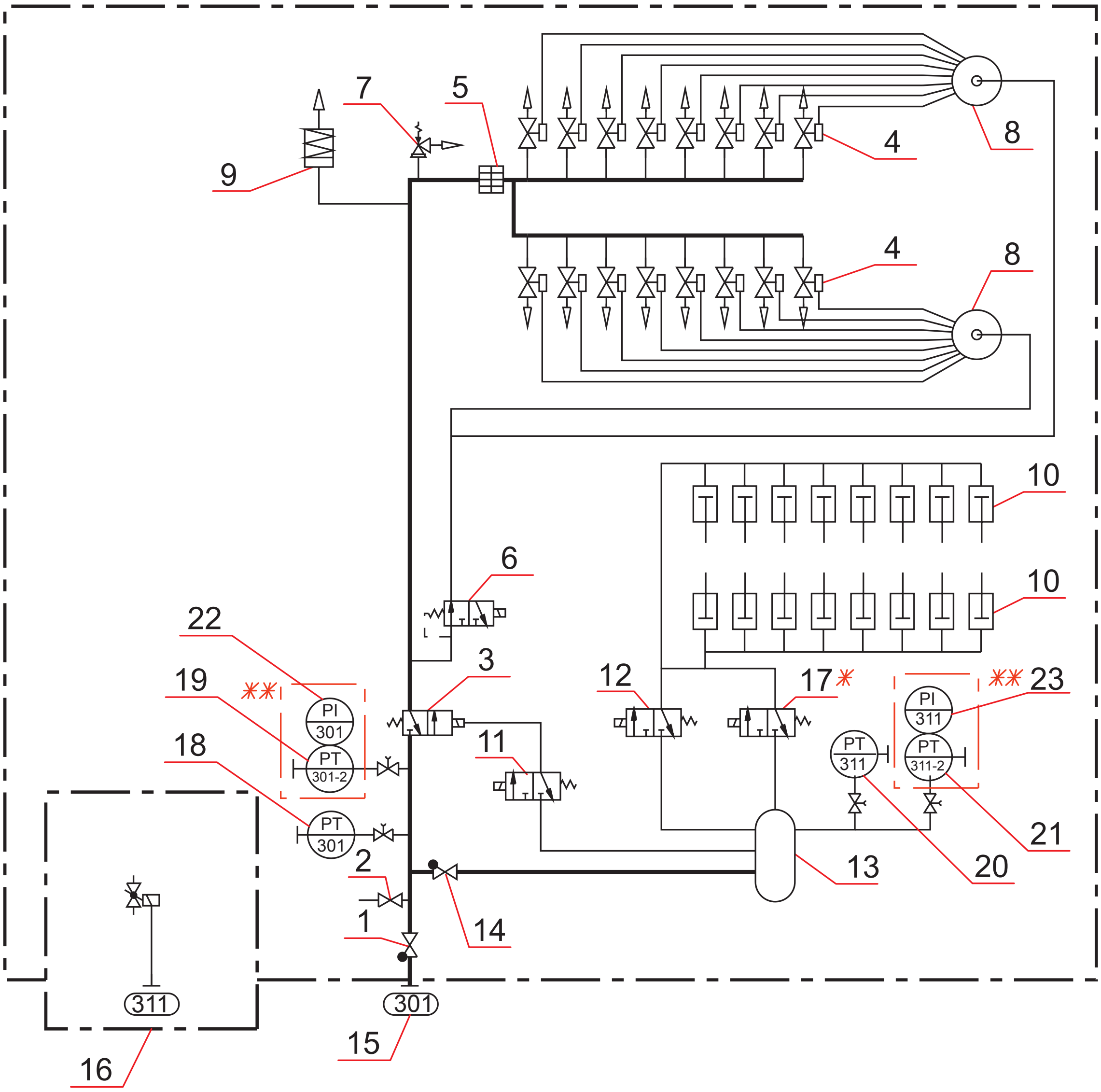
The system includes an air container (13) and a non-return valve (14) to ensure the pressure in the system is maintained.

The main starting valve (3) is actuated by the solenoid valve (11).

Fig 21-7 shows the solenoid valve. The valve is equipped with a push button and can be operated manually.

The pneumatic overspeed trip devices (10), described in detail in chapter 22 *Control mechanism*, are controlled by the solenoid valves (12)(17) which are actuated by the electric signal from the speed monitoring system, whereby the engine stops.

The push button of the solenoid valve can be used as a local mechanical stop.



1 Non return valve
2 Drain valve
3 Main starting valve
4 Starting valve
5 Flame arrester
6 Blocking valve
7 Safety valve
8 Starting air distributor
9 Starting booster
10 Pneumatic cylinder for overspeed trip device
11 Solenoid valve
12 Solenoid valve
13 Air container
14 Non return valve
15 Starting air inlet **301**
16 Instrument air to Wastegate valve (only if Wastegate arrangement) **311**
17 Solenoid valve, CV153-1
18 Starting air pressure **PT301**
19 Starting air pressure **PT301-2**
20 Control air pressure **PT311**
21 Control air pressure **PT311-2**
22 Starting air pressure **PI301**
23 Control air pressure **PI311**

**Only if UNIC or Marine-BASIC* ***Only if UNIC C1 or Marine-BASIC*

Fig 21-6 Pneumatic system

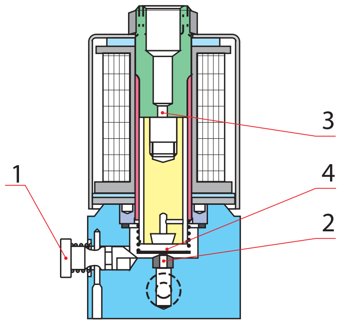
21.5.1 Maintenance of pneumatic system v3

The system is built up of high-class components. Usually it requires no other maintenance than function check and draining of condensed water from the air container using the draining plug.

21.5.2 Maintenance of pneumatic components v7

In case of disturbance in the electric function of the valve, test the valve by pushing the button (1), see *Fig 21-7*. If there is 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.



1 Button
2 Bore
3 Bore
4 Gasket

Fig 21-7 Solenoid valve

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22. Control Mechanism

22.1 Overview of control mechanism

v5

During normal operation the engine speed is controlled by a governor which regulates the injected fuel quantity to correspond with the load and engine speed.

The regulation movement is transferred to the control shaft (10) through an adjustable link rod (2), see *Fig 22-2*.

The movement from the control shaft to the injection pump fuel racks (15) is transferred through the regulating lever (6) and the torsion spring (7). The torsion spring (5) enables the control shaft and consequently, the other fuel racks to be moved to a stop position, even if one of the fuel racks has jammed. In the same way the torsion spring (7) 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 (16). When the stop lever is moved to stop position, the lever (17) actuates the lever (9) forcing the regulating shaft to stop position.

The engine is provided with an electro-pneumatic device with tripping speed about 15 % 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 direct on the fuel rack. The electro-pneumatic device can also be tripped manually, see *section 22.6*.

When starting, the governor will automatically limit the movement of the regulating shaft to a suitable value.

The speed governor is provided with a stop solenoid which is connected to the engine automation system.

22.2 Maintaining the control mechanism

v5

WARNING
Special attention should be paid to the function of the system, as a defect in the system may result in a disastrous overspeed of the engine or in the engine not being able to take load.

Procedure

1 **The system should work with minimal friction.**

Regularly clean and lubricate racks, bearings and ball joints with lubricating oil or with grease, if grease nipple is installed.

2 **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.

3 **Check regularly (according to the recommendations in chapter 04) the adjustment of the system; stop position, overspeed trip devices and starting fuel limiter, see sections *22.3.1*, *22.3.2* and *22.3.3*.**

4 **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.**

22.3 Check and adjustment

22.3.1 Stop lever stop position

v4

Prerequisites

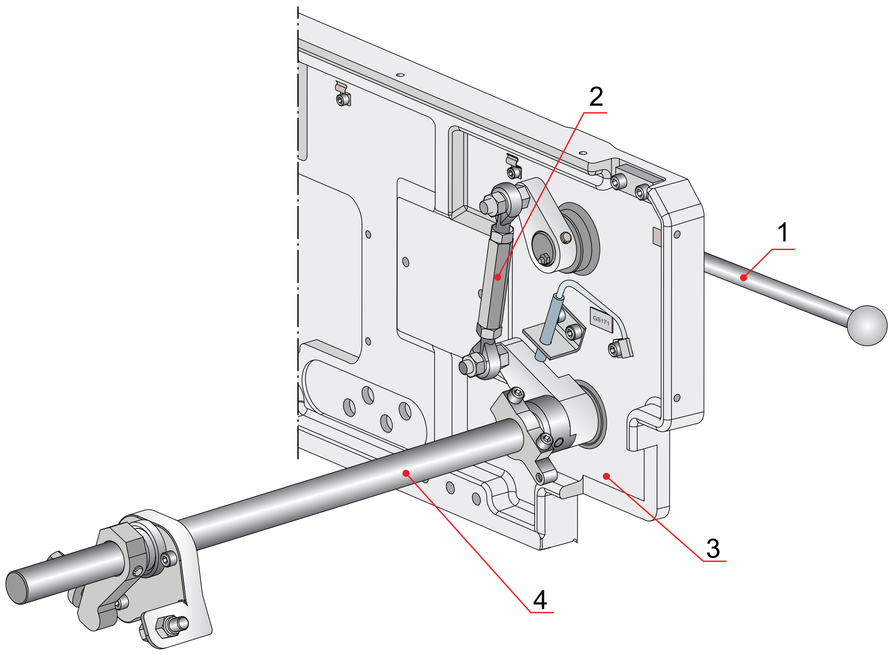
NOTE

Before adjustment, make sure that the fuel rack in every injection pump moves freely.

Procedure

1 **Check:**

- Set the terminal shaft lever in the maximum fuel position and the stop lever in the stop position.
- Check that the fuel rack position of all injection pumps is maximum 5 mm.



1 Stop lever
2 Adjustable link rod
3 End cover
4 Control shaft

Fig 22-1 Stop lever stop position

2 **Adjustment:**

- Set the stop lever in the stop position and check that the lever (9) contacts the dog (18) properly. See *Fig 22-2*.
- A small resistance will be felt due to the governor. Make sure that the resistance is not too big, because this will twist the shaft unnecessarily. This can be adjusted with the adjustable link rod.
- Adjust the fuel rack position to 5 mm by adjusting the screws (14).

22.3.2 Governor stop position

v6

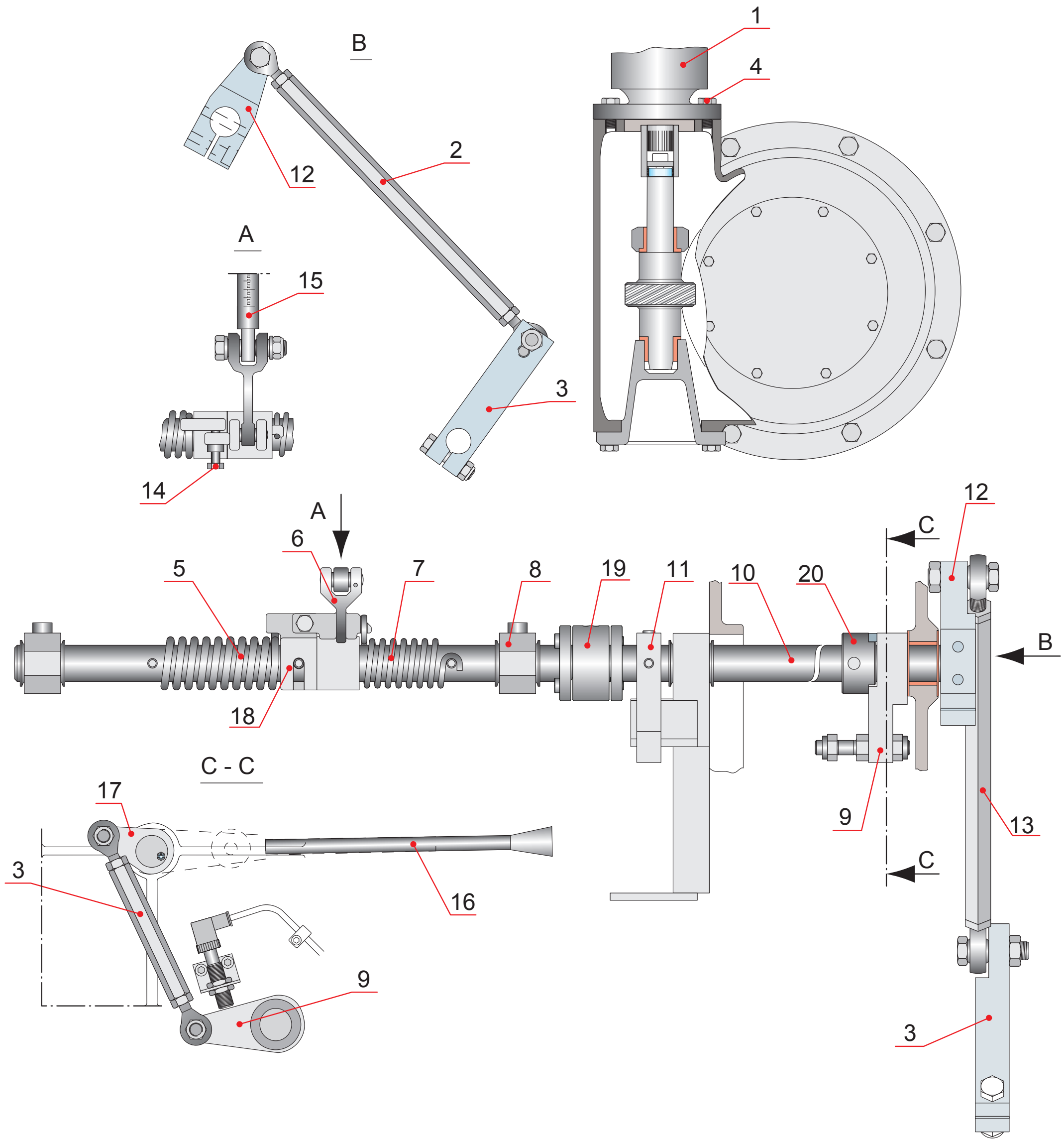
Procedure

1 **Check:**

- Move the stop lever into work position.
- Set the governor terminal shaft lever in the stop position.
- Check that the fuel rack positions are 2 mm.

2 **Adjustment:**

- If the fuel rack positions are unequal, adjust first according to *section 22.3.1*.
- Adjust the link rod (2), so that the fuel rack position of 2 mm is obtained, see *Fig 22-4*.
- If changing the governor, see *section 22.4*.

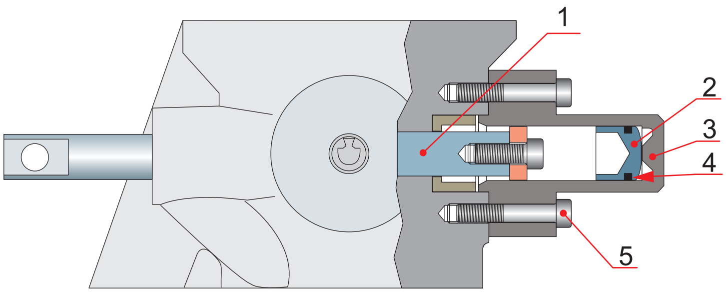


1 Governor
2 Adjustable link rod
3 Lever for governor
4 Screw
5 Torsion spring
6 Regulating lever
7 Torsion spring
8 Bearing housing
9 Lever
10 Control shaft
11 Load limiter
12 Lever
13 Adjustable link rod
14 Screw
15 Fuel rack
16 Stop lever
17 Lever
18 Dog
19 Connection piece
20 Dog

Fig 22-2 Control mechanism

22.3.3 Stop position of electro-pneumatic overspeed trip device

v3



1 Fuel rack
2 Piston
3 Cylinder
4 Slide ring
5 Screw

Fig 22-3 Electro-pneumatic overspeed trip device

Procedure

1 **Check of stop position**

- Set the stop lever in the work position and the terminal shaft lever in the maximum fuel position.
- Press the STOP button on the engine. The stop sequence is activated for approximately 1 min. **Note! The starting air supply should be open.**
- Check that the fuel rack (1) position is less than 5 mm.

2 **Adjustment of stop position**

- The electro-pneumatic overspeed trip device requires no adjustment.
- If a fuel rack (1) position of less than 5 mm cannot be obtained, check for wear.

22.4 Speed governor

v3

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

v3

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 serrated coupling sleeve is secured with a screw and friction rings.

The governor and the drive unit can be removed and mounted as a single unit or alternatively 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.

Check according to the maintenance schedule:

- Radial and axial clearances of bearings
- Gear clearance
- Oil drillings and nozzle to be open
- Serrated coupling sleeve to be firmly fastened to the shaft
- Serrations of coupling sleeve and governor drive shaft for wear
- Friction rings

Change worn parts. For more information, see chapter 04 Maintenance Schedule.

22.4.2 Removing the governor

v5

Procedure

1. **Drain the oil from the governor.**
2. **Loosen the terminal shaft levers, governor electrical connection and necessary pipe connections.**
3. **Mount an eye bolt to the top of the governor and attach a lifting sling between the crane and the eye bolt.**
4. **Open the governor fastening screws and lift the governor.**

22.4.3 Mounting the governor

v6

Prerequisites

If you are mounting the same governor, check the settings, see *section 22.3.2*.

When mounting a new governor, proceed as follows:

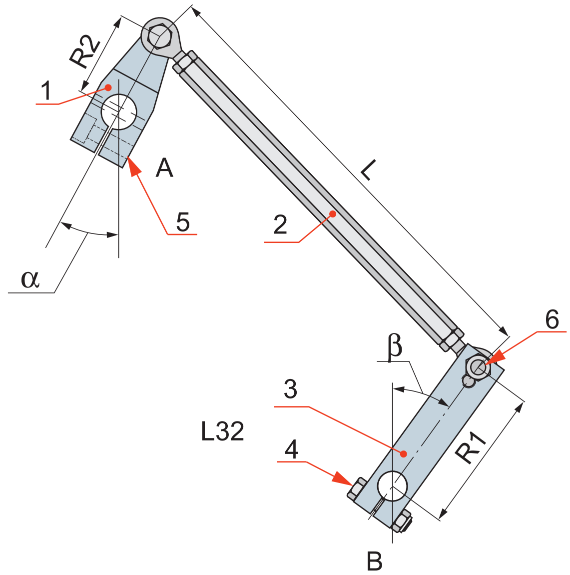
Procedure

1. **Install a new gasket and mount the governor.**
2. **Tighten the screws and remove the lifting sling and eye bolt.**
3. **Turn the governor shaft lever to the stop position (0).**
   Turn the shaft in counter-clockwise direction as seen from the driving end.
4. **Mount the governor shaft lever to the angle β, and tighten the fastening bolt.**
5. **Set the fuel pumps to 0 position.**
6. **Install the lever in the control shaft to the angle α and tighten the fastening bolt.**
   This is required only if the lever has been removed from the control shaft.
7. **Turn the governor indicator to the position 1.5 and turn the control shaft so that the fuel pump shows 5 mm.**
8. **Adjust the link lever length (L) and install and lock the length adjustment.**
9. **Mount the governor electrical and pipe connections.**
10. **Fill the governor and booster unit with clean oil, see *section 22.5*.**

NOTE

Dismantle and clean the booster unit each time the governor oil is changed.

11 **Check the lever setting once again.**



1 Lever for control shaft
2 Adjustable link rod
3 Lever for governor
4 Bolt
5 Screw
6 Ball joint

A. Control shaft
B. Governor shaft

Fig 22-4 Governor shaft settings

Table 22-1 Governor basic settings for L-engine

Booster mounted with 30˚ angle from end surface of engine block								
Engine type	Governor type	L (mm)	R1 (mm)	R2 (mm)	α (˚)	β (˚)	Rack h (mm)	Governor indicator
L32	PG-58	360±20	124	73	27	29±3.5	0 [1] 5 [2]	0 [1] 1.5 [2]

[1] When assembling levers
[2] When assembling adjustable link rod

NOTE

The adjustable link rod measurement (L) is meant for guidance only.

22.5 Booster unit

v3

The external booster for actuator (starting booster) increases the oil pressure inside the actuator during the start, which speeds up the start and conserves starting air.

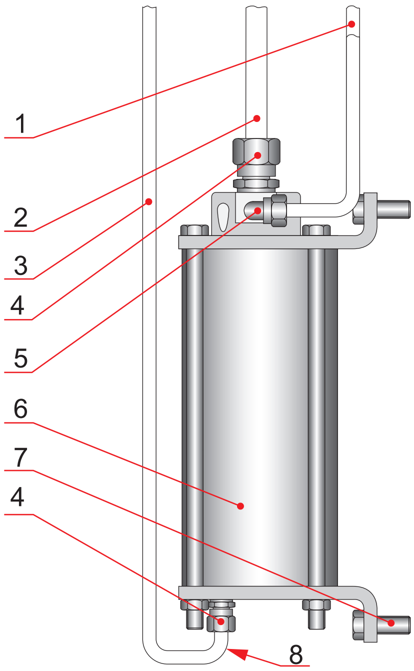
The booster unit is positioned lower than the actuator to prevent the air from getting trapped in the booster and the oil lines. The unit comprises a servo mechanism, and the piping connects it to the actuator.

Starting air activates the booster at the moment the engine starts. Instantly after the air fills the starting air header on the engine, the booster supplies pressurized oil to the actuators. Due to the instant oil pressure built up to the level required, the actuator's gear pump moves the linkage to the injection pumps. The response time of the actuator power piston and the fuel rack decreases.

When the booster is inactive, the springs hold the piston(s) at the one end of the cylinder. The cylinder is filled with oil supplied from a line from the actuator's sump.

When the booster is activated, the starting air at the bottom of the piston pressurizes the oil. The oil is forced through the ports and piping into the actuator's oil system. The check valves control the direction of the oil flow, preventing reverse flow during start.

For more information, see the installation-specific documents.



1 Oil pipe to governor
2 Oil pipe from governor
3 Air pipe
4 Male stud
5 Angle union
6 Booster servomotor
7 Screw
8 Air inlet

Fig 22-5 Booster unit

Single-cylinder booster

Single-cylinder (low-volume) boosters have two oil outlets: one is unrestricted and the other has a built-in orifice-type restriction.

- Outlet 1 (unrestricted) is connected directly to the governor's oil pressure system.
- Outlet 2 (restricted) can be used to pressurize the speed setting servo that compresses the speeder spring of governors equipped with any shutdown feature.

A single-cylinder booster also has two air inlets: one restricted and one unrestricted. Using the restricted air inlet results in slower movement of the fuel rack.

22.5.1 Overhauling the booster

v3

Procedure

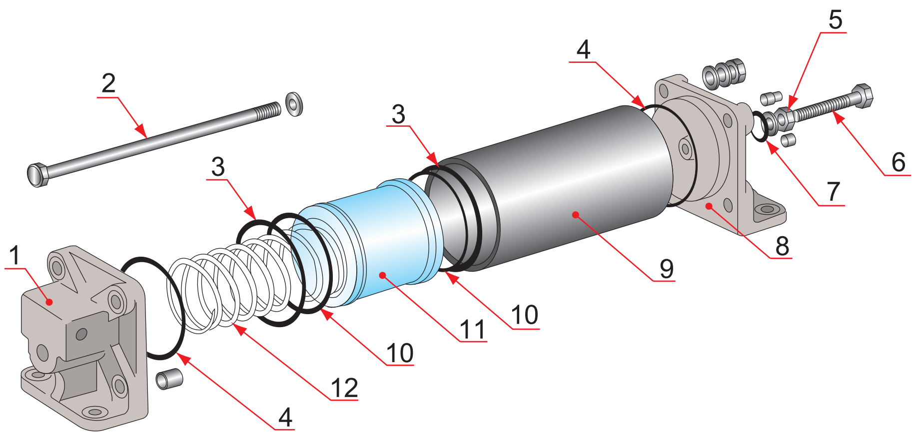
1 **Drain the oil from the governor.**

2 **Dismantle all required pipes and remove the booster from the engine.**

3 **Dismantle the booster according to figure.**

WARNING

Be careful when dismantling the booster, as there is a loaded spring.



1	Top cover	7	Washer
2	Screw	8	Bottom cover
3	O-rings	9	Cylinder
4	Slide rings	10	O-rings
5	Securing nut	11	Piston
6	Stroke limiting screw	12	Spring

Fig 22-6 Booster servomotor

4 **Check the actuator, piston, cylinder and spring for wear.**

5 **Replace worn parts, if necessary.**

O-rings, slide rings, backup rings, seals, and washer are included in the spare part kit (depending on the engine type). See also the manufacturer's instructions.

6 **Mount the booster in reverse order to dismantling.**

7 **Turn the stroke limiting screw (6) until it touches the piston and then half a turn more. Secure the screw with the nut (5).**

8 **Mount the booster unit and connect the oil pipes to the governor.**

9 **Fill the governor with oil.**

10 **Fill the booster unit by using an air gun, for example, to supply the air to the booster air connection. See *section 22.5*.**

Repeat this procedure until the booster is full of oil. Add oil to the governor, if needed.

22.6 Electro-pneumatic overspeed trip device v8

The overspeed trip device is electronically controlled. Air of maximum 30 bar is used as operating medium. The tripping speed is 15 % above the nominal speed.

The three-way solenoid valve gets the stop signal for overspeed from the engine automation system, see *section 21.5*.

When the solenoid valve opens, air is fed to the three-way valve, which conveys pressure air to the cylinders, one for each injection pump, see *section 21.5*. The piston of the air cylinder actuates on the fuel rack moving it to stop position.

The stop signal is energized long enough to stop the engine completely. When de-energized, the air is evacuated through the three-way valve.

The solenoid valve can also be operated manually.

22.6.1 Check of tripping speed v6

The tripping speed can be checked in two ways:

- simulating the engine speed signal by using a signal generator
- running the engine and increasing the engine speed.

Increasing the engine speed

Check the tripping speed at idle by increasing the engine speed above the nominal speed by slowly turning the control shaft in direction towards the engine with a suitable wrench fitted on the lever (1), see *Fig 22-4*. When the nominal speed is reached and exceeded, the governor begins to decrease the fuel setting, that is, the control shaft must be forced against the governor.

The tripping speed should be 15 % above the nominal speed, see chapter 06., section *06.1*.

WARNING

Do not increase the engine speed above 920 RPM in any circumstances. In genset applications, check the overspeed limits of the generator.

CAUTION

Pay special attention when checking the tripping speed. Carelessness can result in a disastrous overspeeding of the engine.

22.6.2 Maintaining the three-way solenoid valve v3

- **If the solenoid is out of order, replace it with a new one.**
- **If the valve does not move, clean all channels. Check the valve piston.**
- **If air is leaking to the cylinders, change the sealings.**

22.6.3 Maintenance of the electro-pneumatic cylinder on the injection pump

22.6.3.1 Removing the electro-pneumatic overspeed trip device v4

Procedure

1 **Remove the electro-pneumatic valve from the injection pump.**

2 **Remove the piston (2) by tapping the cylinder (3) against a piece of wood. See *Fig 22-7*.**

If the piston is stuck, press it out by connecting a grease gun with a suitable adapter to the air supply of the cylinder.

WARNING
If compressed air is used, the piston may be ejected with such a force that it may cause injuries or damage.

22.6.3.2 Maintaining the cylinder and piston v2

Procedure

1 **Check for wear.**

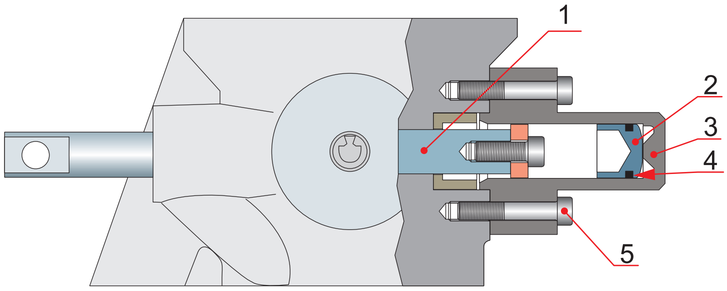
2 **Check the tightness of the piston, see *Fig 22-7*.**

Replace sealings by new ones. Take care not to deform the teflon ring outside the O-ring.

3 **Lubricate the sealings and piston with lubricating oil.**

4 **Check that the piston does not stick.**

22.6.3.3 Mounting the electro-pneumatic overspeed trip device v4



1 Fuel rack
2 Piston
3 Cylinder
4 Slide ring
5 Screw

Fig 22-7 Electro-pneumatic overspeed trip device

Procedure

1 **Ensure that there are no sharp corners or dents on the piston (2) or in the cylinder (3).**

Smoothen if necessary. Apply a suitable grease and take care not to damage the seal ring when mounting the piston (2) to the cylinder (3).

2 **Mount the cylinder (3) to the back side of the injection pump and tighten the screws (5).**

3 **Mount the air pipe and tighten to the stated torgue. See chapter 07, Tightening Torques and Use of Hydraulic Tools.**

4 **Check the stop position, see** *section 22.3.3***.**

5 **Check the tripping speed, see** *section 22.6.1***.**

23. Instrumentation and Automation

23.1 UNIC automation system

v10

The UNIC automation system is an embedded engine management system. The system has a modular design. Some parts and functions in the configuration are optional depending on application. The system is specifically designed to handle the demanding environment of marine engines. Special attention has been paid to temperature and vibration endurance in this rugged design. This compact system can be directly mounted on the engine as there are no dispersed external cabinets or panels. The engine can therefore be delivered fully tested from factory. The number of inputs and outputs are determined to optimally suit this application. The galvanic signal isolation is also made to match these needs.

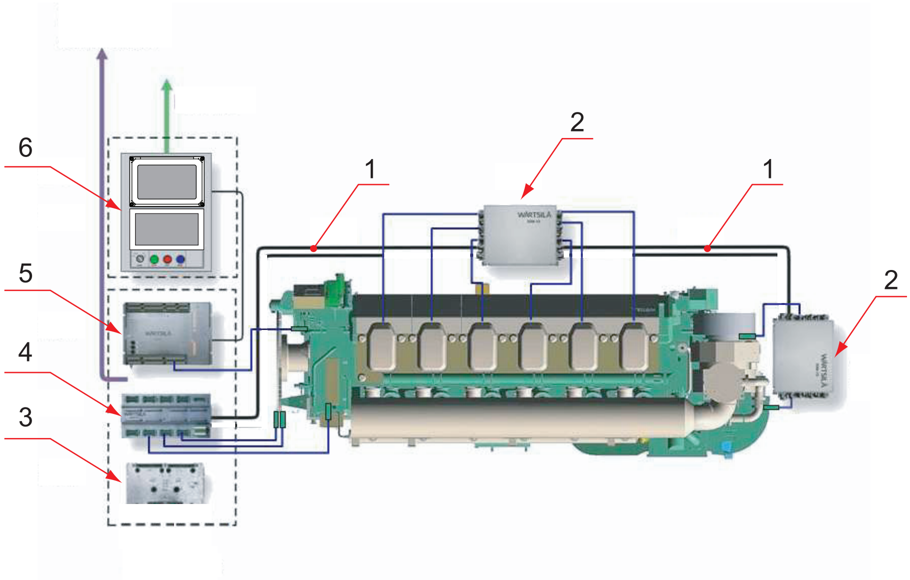
There are three different versions of the UNIC automation system namely: UNIC C1, C2 and C3. The type of automation system used depends on the automation level.

UNIC C2 Automation System

This engine is equipped with a UNIC C2 automation system.

The UNIC C2 system handles all tasks relating to start/stop management, engine safety and engine speed/load control, and the system utilizes modern bus technologies for safe transmission of sensor and other signals.

All the sensors are connected to the UNIC system. Information from the engine is displayed on the WIP-1* and LDU. The WIP-1* shows all the important measurements and the LDU displays other sensor data like engine modes, possible failures, and an event log.



1 Controller area network
2 Input / output module
3 Power distribution module
4 Main control module
5 Engine safety module
6 Local control panel.

Fig 23-1 Overview of UNIC C2 system

The UNIC automation system consists of the following major parts:

- **Local Control Panel (LCP):** Contains push buttons for local engine control, as well as two graphical displays.
- **Main Control Module (MCM):** Handles all the start/stop management and speed/load control functions of the engine. This module is an optional for engines having mechanical governors.
- **Engine Safety Module (ESM):** Handles fundamental engine safety, and is the interface to the shutdown devices and some local instruments.
- **Power Distribution Module (PDM):** Handles fusing, power distribution, earth fault monitoring and EMC filtration in the system. It provides two fully redundant 24 VDC supplies to all modules, sensors and control devices. Common rail engines also have two redundant 110 VDC supplies for the injector drivers.
- **Input / output (Module) IOM:** Handles measurements and limited control functions in a specific area on the engine where the sensors/devices are located. Communicates with other IOM's and the MCM over CAN. The number of modules varies according to cylinder number, engine type and application.

The system performs the following major tasks and functions:

- Provides a local interface to the operator, including a local display indicating all important engine measurements, an hour counter and a local control panel.
- Handles the fundamental engine safety (alarms, shutdowns, emergency stops, load reductions) including fully hardwired shutdowns for engine overspeed (redundant), lube oil pressure, cooling water temperature and external shutdowns.
- A high performance electronic speed/load controller with various operating modes (optional).
- Engine start/stop management, including start block handling and slow-turning (where used), load reduction, waste-gate control (where used) and LT/HT-thermostat control (where used)

23.2 Mechanical design

v10

The UNIC system is designed to meet very high targets on reliability. This includes special measures for redundancy, fault tolerance as well as mechanical and electrical design.

UNIC sensors and actuators are designed to be reliable, easy to service and to calibrate. Flying lead design is introduced (wherever possible) to avoid failure prone connectors.

Fig 23-2 Sensor with flying lead design

Only screened dedicated Teflon insulated cables for the demanding engine environment are used on the engines. These well protected point-to-point cables provide the most reliable solution, as they ensure good protection against electrical disturbances, high mechanical strength as well as good protection against chemicals and temperature.

Modules are interconnected with a special multi-bus cable, including power supply (24V), engine speed, engine phase (where needed), CAN-bus, all doubled for redundancy reasons.

Electronic modules which are distributed on the engine, are mounted in specially designed WTB terminal boxes. These enclosures are used to facilitate all interconnections on the engine, i.e. they are acting as an interface between the control modules and their peripheral devices.

Fig 23-3 Enclosure used for module interconnections and cabling

The WTB boxes are equipped with cable glands for all out-going cables. They meet demands of a service friendly cabling system, as the design facilitates measurements of different signals and the exchange of an electronic module or a cable, in case of failure. They also meet high demands of ingress protection, and there is a window on the cover plate for viewing of the module's LED's.

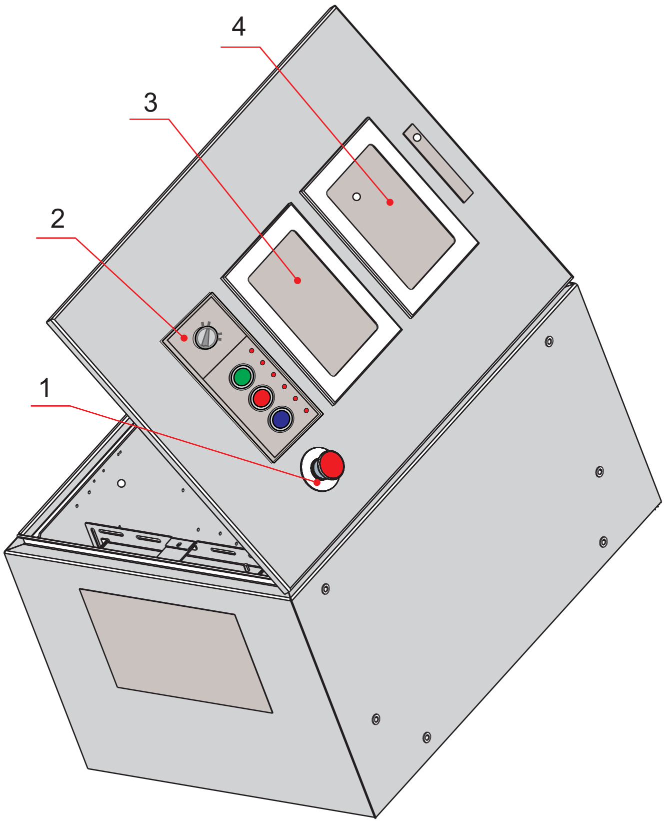
23.3 Parts of the UNIC System

23.3.1 Local control panel

v19

The Local control panel (LCP) is a resilient electrical cabinet mounted on the front side of the engine. This panel is the local interface to start and stop the engine, and also to view engine measurements. The LCP consists of:

- Local display unit (LDU) with a number of submenus
- WIP-1* display
- Control panel with switches and buttons (WCP)
- Emergency stop button



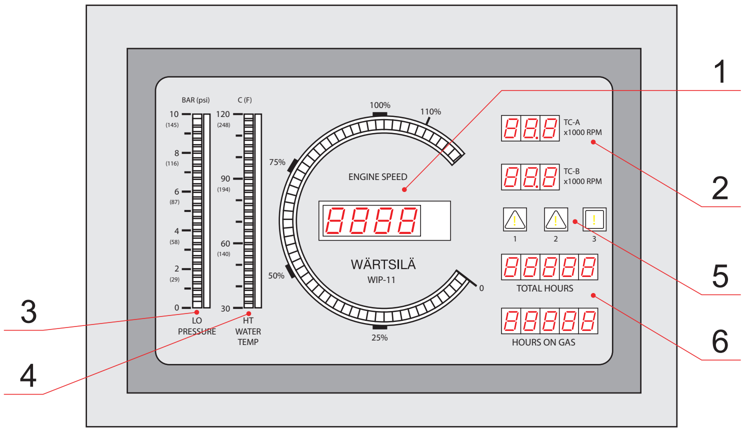
1 Emergency stop button
2 WCP
3 LDU
4 WIP-1*

Fig 23-4 Connecting box of UNIC C2

23.3.1.1 WIP-1* display

v4

WIP-1* is a display unit that comprises a number of system-independent measurements. These measurements and readings constitute the most important local information on the engine.



1 Engine speed
2 Turbocharger speed
3 Lube oil pressure
4 HT water temperature
5 System failure indication
6 Hour counters

Fig 23-5 WIP-1* display

The WIP-1* display has indications of:

- Engine speed: a graphical relative scale of 0...120 % of nominal speed, with a numerical four-digit indication in the centre
- Turbocharger speed: a numerical three-digit indication
- Two hour counters, both five-digit numerical indications, one total and one for gas operation (optional). The accumulated running hours are stored in a non-volatile memory and do not disappear in case of a power failure.
- Bar graph indications for:
  - Lube oil pressure
  - HT water temperature

Normal values are represented with green colour in the bar graphs left of the measurement value, while abnormal values first turn yellow, then red.

In case of a sensor failure or sensor signal wire break, the lowest LED element in the bar-graph flashes. In case the sensor or the wiring provides an over-current, the highest LED element flashes.

On WIP-1*, there are two triangle symbols and one square symbol with ! signs inside. The symbol on the left is used for WIP failure indication. If the light in this symbol is on, it indicates a failure in the WIP module. The binary output *NS881 Engine control system, minor alarm* is activated in this situation.

NOTE

The two other symbols with a ! sign are not used in this UNIC system application.

23.3.1.2 Local display unit v1

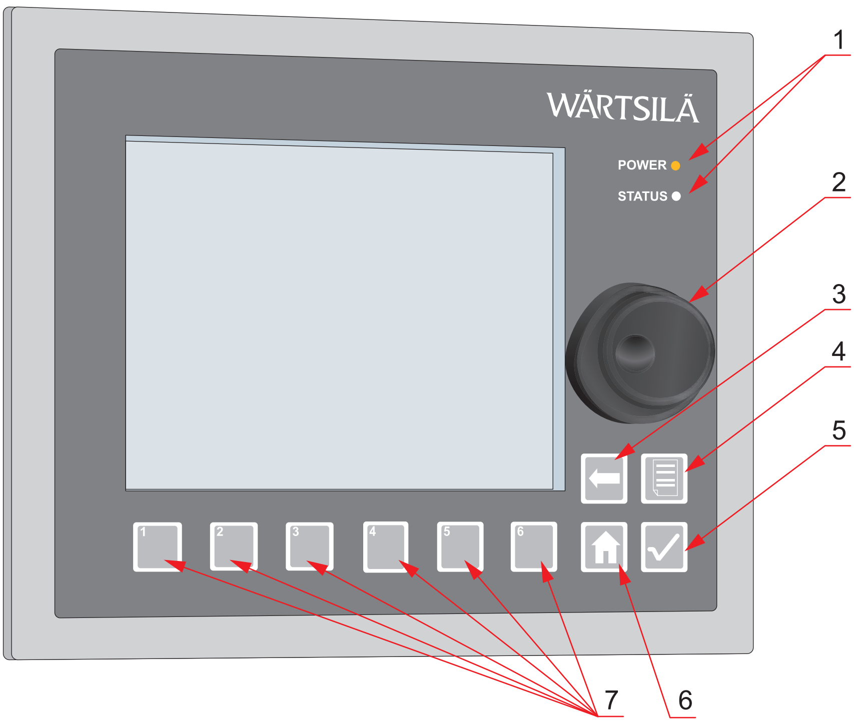
The local display unit (LDU) is located on the engine and replaces the traditional analog instruments. It has a key pad for activation of various pages, and a graphic display. A power indicating LED is also located on the front panel for indicating the status of the power supplies. When the LED is steadily on, it indicates that both power supplies are working. If the LED is flashing it indicates that one of the power supplies is missing. The LDU is connected to the MCM which transfers the application data over CAN to the display. The same information is externally sent out over Modbus TCP through this module.

Typical information shown on the LDU pages includes:

- General system layout
- Logical name of sensor
- Readings
- Abnormal values (inverted)
- Bar graphs
- Various status information (for example, modes)

NOTE

The display shown below is an example. The display panels can vary depending on application.



1 Main page
2 Alarm list page
3 Escape/back
4 Accept/Enter
5 Rotary knob
6 Dynamic function
7 LED

Fig 23-6 Local display unit

The LDU has two LEDs at the top right-hand corner:

- Power supply LED:
  - If both the supplies are ok, power LED glows green.
  - If one supply is missing/failed, power LED glows yellow.
  - If both the power supplies are missing/failed, power LED is off.
- Status LED: According to application

At the rear, there are two ethernet LEDs and three CAN LEDs:

- Ethernet (Modbus TCP) LED: If it is connected, ethernet LED glows green, otherwise off.
- CAN LED:
  - If the CAN is ok, LED glows yellow.
  - If it is a warning, LED glows orange.
  - If CAN bus is off, LED glows red.

23.3.1.3 Switches and buttons

v16

Below a description of the switches and buttons used in the LCP.

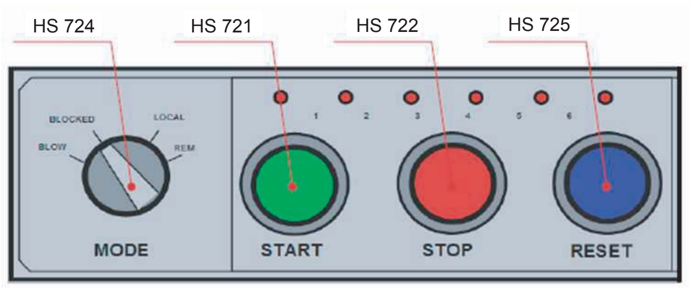


Fig 23-7 Control buttons and switches on the LCP

NOTE

On power plant engines, this control panel only comprises an emergency stop button.

- **HS724 Engine mode selector switch**

This mode selector switch has the following four positions:

- **Local**: Local control of engine start and stop enabled.
- **Remote**: Remote control of engine start and stop enabled.
- **Blocked**: Starting is electrically blocked (both local- and remote start).
- **Blow**: When the selector is in this position, it is possible to perform a "blow" (an engine rotation check with indicator cocks open) when pressing the local start button. The engine will not start (fuel shaft limited to zero), only the starting air valve will be activated while pressing the start button in this situation.
- **HS721 Start button** By pressing this button, the engine will be started locally. A lamp in the button will turn on (green colour), when the engine is ready for start.

NOTE

In case the mode selector HS724 is in remote, blocked or blow position, the local start signal is disabled.

- **HS722 Stop button** By pressing this button, the engine will be stopped locally.

NOTE

In case the mode selector **HS724** is in remote position, the local stop signal is disabled. A re-start after a manually activated stop, will not require a reset.

- **HS725 Shutdown reset button** In case an automatic shutdown or emergency stop has occurred, the shutdown circuit will latch. When the engine has stopped, a reset of this circuit can be performed by pressing this button. When a reset is necessary, blue light will turn on in the button.

NOTE

Before a reset and a re-start is performed, the reason for the automatic protective action must carefully be checked.

- **HS723 Emergency stop button** (not visible in *Fig 23-7*) By pressing this button, the engine will instantly shut down. The signal from the button goes directly to the Engine Safety Module (ESM) which activates the el. pneumatic stop solenoids, and also informs the MCM to enter shutdown mode i.e. to set the fuel shaft to zero position. The push button position is latching, and it needs to be turned to release. The emergency stop function in ESM & MCM is also latching, and after the rotation speed has reached zero level, this latch can only be reset by pressing the reset button. The emergency stop button is mounted separately from the other buttons and switches.
- **HS801–1 Supply switch (24 V)** A switch in the main cabinet for disconnecting the 24 V DC supply from the engine external system to the main cabinet.

23.3.2 Main control module (MCM) v17

The MCM module is a versatile, configurable microprocessor based control- and data acquisition module. It has a variety of analogue and digital measuring channels, as well as a number of analogue and binary outputs. The module is designed for mounting directly on the engine. Engine mounting allows the engine to be delivered fully tested from factory, and also allowing a faster commissioning.

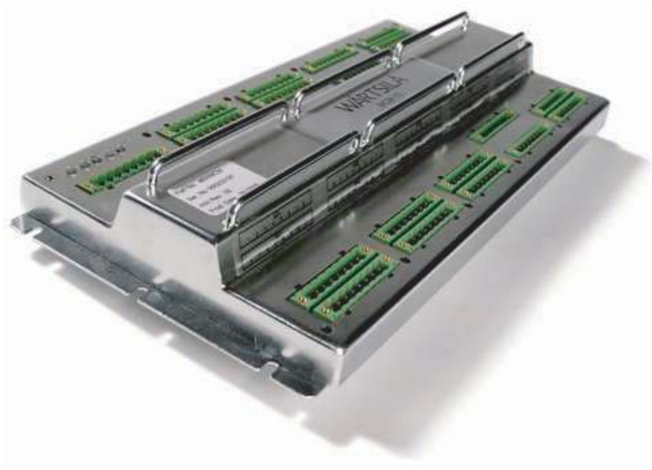


Fig 23-8 MCM module

The CPU used in MCM is a high-performance Motorola PowerPC MPC561 controller. The module itself contains diagnostic features on internal system integrity (like memory checksums, CPU watchdog, system temperature) as well as advanced I/O checks based on signal processing, like open/short circuit detection and sensor diagnostics. In addition, depending on application, also other application specific diagnostics is available. The max. current consumption of MCM (all outputs energised) is 2 A, while the idle comsumption is less than 200 mA.

There are four hardware controlled green LEDs in the MCM. In Table 1 below the functions behind these LEDs are explained:

Table 1.Usage of hardware controlled LEDs in MCM.

LED marking	Description
PWR1 24V	Indicates state of power supply 1 input.
PWR2 24V	Indicates state of power supply 2 input.
SYS 24V	Indicates state of power supply to module logics and microprocessor.
SENS 24V	Indicates state of power supply output used for module's I/O.

The MCM has one two-colour diagnostic LED (right-most in row, marked "DIAG"), which is used to indicate the execution state. The function behind this LED is given in Table 2.

Table 2: Usage of the software controlled two-colour LED in MCM.

Red	Yellow	Execution in	Description
OFF	OFF	Undefined (boot phase)	No software is running.
ON	OFF	Bootloader 1	Bootloader 1 is running and waiting for connection.
Flash	OFF	Bootloader 1	Bootloader 1 has established connection with tool.
OFF	ON	Bootloader 2	Bootloader 2 is running and is waiting for connection. Also in case of software lock-up.
Alt w/ yellow	Alt w/ red	Bootloader 2	Bootloader 2 cannot find application; waiting for connection.

Continued on next page

Red	Yellow	Execution in	Description
OFF	Flash	Bootloader 2	Bootloader 2 has established connection with tool. Application software running.

The MCM module handles the following main tasks in the UNIC system:

- Speed/load control
- Start/stop management
- Other strategic control

For processing of additional sensor signals, and for sending/receiving signals in the engine external hardware interface, a second MCM module is used.

23.3.2.1 Speed controller v6

The main task of the MCM module is acting as the speed controller for the engine. The speed controller functionality is fully embedded in the module, and optimised to suit Wärtsilä power plant engines as well as ship genset- and main engine applications. On engines equipped with the UNIC system, the module supports various sub-modes, needed for various types of applications, see *section 23.4.1.1*.

To meet high robustness demands (e.g. in case of to signal failures or other disturbance), the UNIC system will always be capable to operate in droop mode, if premises for other modes are not met. In order to meet high demands in terms of reliability, two speed sensors are simultaneously used by the controller. If one speed sensor fails, the operation will be uninterrupted.

Speed controller parameters are verified and if necessary changed at the test run facilities at the engine maker, i.e. parameters do normally not have to be changed at the installation. However, in case some changes are necessary, a separate service tool needs to be connected to the module. Downloaded settings are permanently stored in the module's flash memory, and are not lost at a power failure.

See *section 23.4.1.1*, for detailed information about the speed controller functionality.

23.3.2.2 Start/stop management v4

Another major task of MCM is acting together with ESM as an embedded management system, handling start blockings, the engine's slowturning (if used) start sequence and stop sequence. In these tasks, discrete signals are communicated between the MCM and the ESM modules, where ESM handles the fundamental engine safety while MCM handles the start management.

See *section 23.5*, for detailed information about the engine start- & stop sequences and *section 23.6* Sensors and safety handling, for details about engine safety.

23.3.2.3 Other strategic control (optional) v3

See *section 23.4* for details.

23.3.3 Engine safety module

v6

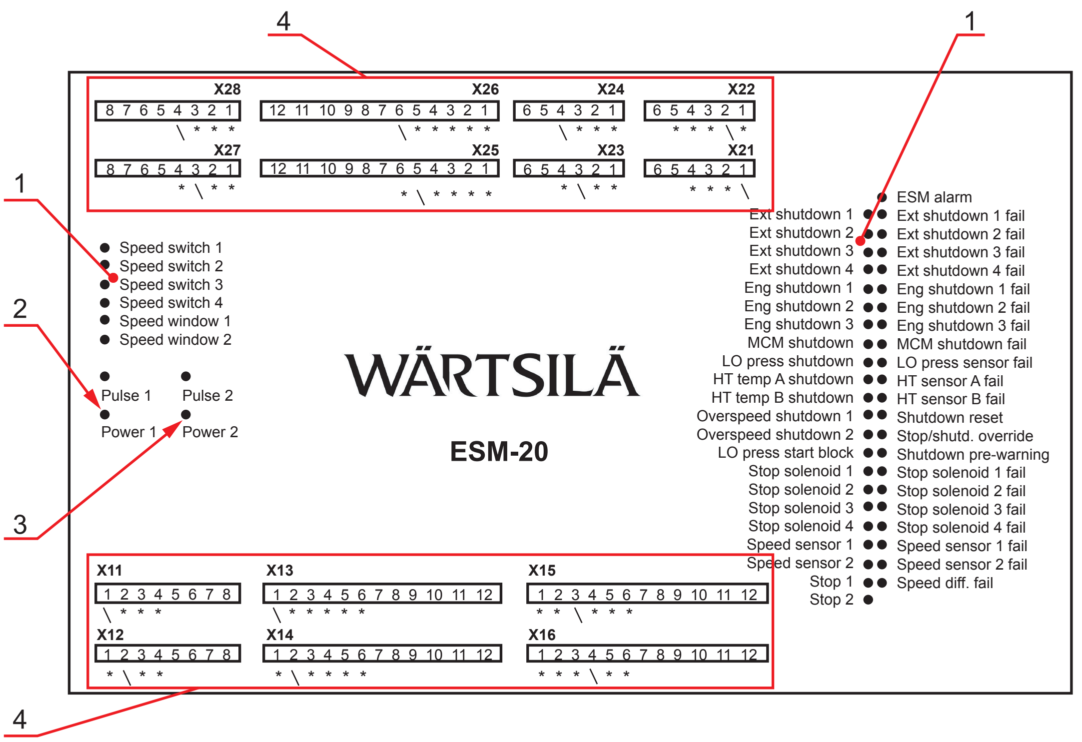
Fig 23-9 Engine safety module

The tasks of the engine safety module (ESM) include:

- Handling the fundamental engine safety and a number of speed measuring functions
- Acting as the interface to the engine shutdown devices

The ESM is located behind a window in the engine cabinet, which makes it possible to view all the status LEDs of the module without opening the cabinet door.

The ESM is preprogrammed. Its design is largely redundant, based on independently working microcontrollers.



1 LED indications for module function
2 Power 1 LED
3 Power 2 LED
4 Connectors (inputs/outputs)

Fig 23-10 Engine safety module front panel (ESM-20)

23.3.3.1 Engine safety module power supply v5

To ensure that the engine safety module (ESM) is functional in all situations, full redundancy is achieved by combining the double incoming power supplies to the module.

Supply failure detection

- Failure on any supply activates ESM alarm output
- Supply failures are detected on
  - Primary (power supply 1)
  - Secondary (power supply 2)
  - Internal power supply circuits (3 pcs)

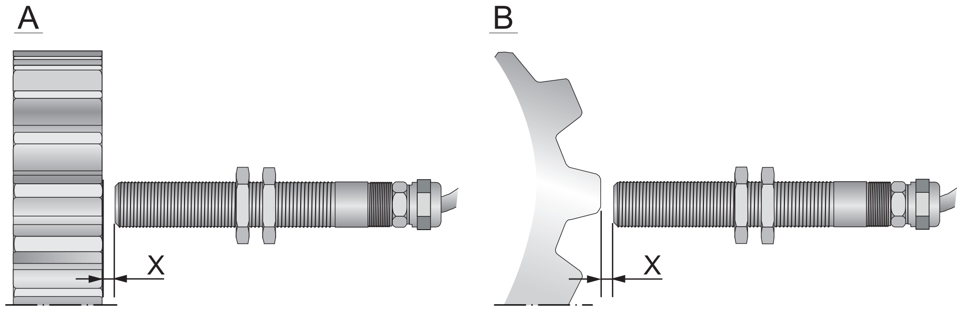
Fuse values

As all inputs and outputs are short circuit protected the electronic fuses in ESM-20 are only for protection of internal failures and breakdowns.

23.3.3.2 Engine safety module speed sensor v3

The rotational speed of the engine is measured with two speed sensors. Each speed sensor is supplied with a 24 V DC from the engines safety module (ESM). The output signal of the sensor is a pulse train with a frequency corresponding to the rotational speed of the engine.

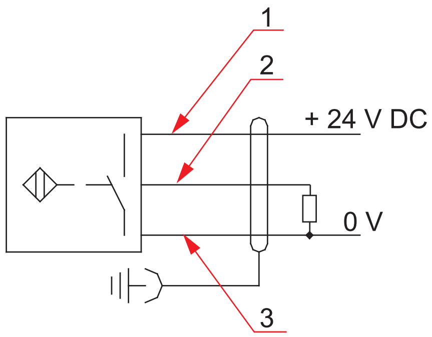
Mounting the speed sensor



A. Side of gear mounted alternative **B.** Front of gear mounted alternative

x. Sensing gap distance: 2–2.5 mm

Fig 23-11 Engine speed sensor



1 Black (24 V DC)
2 Brown (Signal)
3 Blue (0 V)

Fig 23-12 Sensor wiring diagram

WARNING
Do not run the engine while adjusting the sensor.

Procedure

1 **Turn the engine until the cog is in line with the sensor.**

2 **Adjust the sensor to the correct sensing distance.**

3 **Tighten the locking nut to the correct torque.**
See *Chapter 07 Tightening torques and use of hydraulic tools*.

CAUTION
Do not overtighten the locking nut.

23.3.3.3 Speed measuring and speed switches v6

The engine speed is measured with two independent speed sensors with separate supply circuits and separate sensor failure detection circuits. Inductive proximity PNP-type sensors are used.

The frequency from the speed sensors is measured by independent microcontrollers. The measured values are used to trig the internal overspeed trip circuits in the engine safety module (ESM).

Failure detection

- The frequencies of the two speed measuring channels are compared to each other. A speed differential failure is triggered when the difference between the speed signals is greater than 5%. Speed differential failure indication is disabled if rotational speed is smaller than speed switch 1. The higher speed value (if different) is used as an internal speed signal for controlling the analogue outputs and the speed switches.
- Short circuit detection
- Wire break detection
- Sensor failure and speed differential failure triggers ESM alarm output after two seconds delay if failure remains.

Speed outputs

- Engine speed output 1 (0–10 V DC or 4–20 mA depending on the ESM setting) is connected to external systems.
- Engine speed output 2 (4–20 mA) is used internally for local indication (in WIP-1*).

Overspeed shutdown

- The trigging point for the overspeed shutdowns 1 and 2 is by default 115% of the rated engine speed.
- Driver outputs stop solenoid 1 and stop solenoid 2 activates the two stop solenoids CV153-1 and CV153-2. Stop solenoid 2 is only activated in case of emergency stop or overspeed.

Status/control outputs

- IS181 Speed switch 1 is used as "engine running" information and is part of the external interface of the engine.
- IS182 Speed switch 2 has a configurable switching level and is also part of the external interface of the engine.
- All shutdown status outputs are open (closed at shutdown). Overspeed shutdown statuses are connected in parallel.

23.3.3.4 Shutdown reset v5

The *Shutdown reset* input on the engine safety module (ESM) is connected in parallel with the reset input of the main control module (MCM). Reset has to be pressed after all automatic shutdowns as all shutdowns are latching in the UNIC system. A reset releases this latch, and starting the engine is possible. Reset does not, however, override shutdown signals that are still active. The ESM reset input is disabled when rotational speed is more than 2% of rated speed.

The indicator LED on the ESM front panel is lit when the shutdown reset input on the ESM is activated and no shutdown is active.

23.3.3.5 Stop and shutdown signals

Lubricating oil pressure safety

A dedicated safety sensor *PTZ201 LO press, engine inlet* is connected to the engine safety module (ESM). The sensor is also connected to the WIP-1* module, where the measured lubricating oil pressure is displayed with a LED bar. If the lubricating oil pressure becomes too low, an engine shutdown is activated after a certain delay. Both the pressure limit and the delay are predefined in the ESM.

Sensor failure detection

- Sensor failure is indicated when the signal is out of range (<3.5 mA or >20.5 mA).
- ESM alarm output is activated after two seconds if sensor failure remains. It is looped with other signals in the common signal *NS881 Engine control system, minor alarm.*
- Shutdown is blocked.

Status outputs

- IS2011 Lubricating oil pressure shutdown status

HT water temperature safety

A dedicated safety sensor *TEZ402 HT water temperature* is connected to the engine safety module (ESM).The sensor is also connected to the WIP-1* module, where the measured HT water temperature is displayed with a LED bar. If the HT water temperature becomes too high, an engine shutdown is activated after a certain delay. Both the temperature limit and the delay are predefined in the ESM.

Sensor failure detection

- Sensor failure indicated when signal is out of range (<3.5 mA or >20.5 mA).
- ESM alarm output activated after two seconds if sensor failure remains.
- Shutdown is blocked.

Status output

- IS4011 HT water temp shutdown status

23.3.3.6 Other engine safety module inputs and outputs v6

Additional inputs

- **Stop 1** is activated by the local and remote stop signals via the main control module (MCM). The activation of this input keeps the primary electro-pneumatic stop solenoid and the governor stop solenoid energized, and the engine shuts down. This input is latching and is activated until a predefined delay has elapsed or until reset is pressed. A red LED shows that the *Stop 1* input is activated. An external status signal, binary output *Stop status* is activated in this situation.
- **Stop 2** is activated from the local control during an engine blow situation. The activation of this input keeps the primary electro-pneumatic stop solenoid and governor stop solenoid energized during the blow procedure to secure that the engine does not start. This input is non-latching, that is, no reset is necessary after a blow. A red LED shows that the *Stop 2* input is activated. The external status signal, binary output *Shutdown status* is not activated in this situation.
- **OS820/NS886 Main Controller shutdown** is activated by the MCM in case of an automatically generated shutdown. The activation of this input keeps the primary electro-pneumatic stop solenoid and the governor stop solenoid energized, and the engine shuts down. This input is latching, that is, a reset is required to release the shutdown. A signal interruption failure detection (using a 22 kΩ resistor) is provided between the two modules. LED indications for *OS820/NS886 Main Controller shutdown* (red) and *Main Controller shutdown signal failure* (yellow) are provided.

NOTE

NS886 Control system major failure is a separate signal, not the same as *OS820*.

- **OS7309 External shutdown 1** initiates a shutdown of the engine. This shutdown is a latching function. A signal interruption failure detection is provided between this engine safety module (ESM) module input and the external system.
- **OS7310 External shutdown 2** initiates a shutdown of the engine. This shutdown is a latching function. A signal interruption failure detection is provided between this engine safety module (ESM) module input and the external system. The input is optional. See installation specific drawings.
- **OS7311 External shutdown 3** initiates a shutdown of the engine. This shutdown is a latching function. A signal interruption failure detection is provided between this engine safety module (ESM) module input and the external system. The input is optional. See installation specific drawings.
- **OS7305 External shutdown 4** is connected to an external emergency stop signal. The signal is in parallel with the local *HS723 Emergency stop button*. The activation of this input keeps both electro-pneumatic stop solenoid and the governor stop solenoid energized, and the engine shuts down. A reset is required to release the shutdown because the input is latching. A signal interruption failure detection (using a 22 kΩ resistor in marine configurations) is provided between the module and the external emergency stop button. LED indications for *External shutdown 4* (red) and *External shutdown 4 failure* (yellow) are provided.

Inputs in the ESM used for possible optional engine shutdowns include:

- **OS7337 Engine shutdown 1** (Used for Oil mist detector shutdown)
- **OS7338 Engine shutdown 2** Normally inactive. Activation of input shuts down engine. (Used for Big end bearing temperature measurement system shutdown)
- **OS7339 Engine shutdown 3** Not in use

Additional outputs

- **IS7602 Stop/shutdown status 1** is activated when a the manual stop has been activated, or in case any ESM-initiated shutdown or an external shutdown input is activated. Signal connected to MCM and through an opto-relay to the external interface.
- **IS7309 External shutdown 1 status** is activated in case the *OS7309 External shutdown 1* input is activated. Signal connected to MCM.
- **IS7310 External shutdown 2 status** is activated in case the *OS7310 External shutdown 2* input is activated. Signal connected to MCM.
- **IS7311 External shutdown 3 status** is activated in case the *OS7311 External shutdown 3* input is activated. Signal connected to MCM.
- **IS7305 External shutdown 4** status output in ESM is activated in case the *OS7305 External shutdown 4* (emergency stop) input is activated.
- **IS7337 Engine shutdown 1 status** output in ESM that activates in case of activation of an optional shutdown. The ESM input *OS7337 Engine shutdown 1* is used for Oil Mist Detector shutdown. Signal connected to MCM.
- **IS7338 Engine shutdown 2 status** output in ESM that activates in case of activation of an optional shutdown. The ESM input *OS7338 Engine shutdown 2* is used for big end bearing temperature measurement system shutdown. Signal connected to MCM.
- **IS7339 Engine shutdown 3 status** output in ESM that activates in case of activation of an optional shutdown (see installation specific drawing, and use of ESM input *OS7339 Engine shutdown 3*). Signal connected to MCM.
- **IS7306 Stop/Shutdown override status** output in ESM is activated in case input *OS7306 Stop/shutdown* override to UNIC is activated. Overrides internal shutdowns in MCM.

23.3.3.7 Testing the pneumatic overspeed protection system v1

Prerequisites

Perform the test with the engine running in "CB open" mode (no engine load).

CAUTION

Monitor the engine speed continuously during the test. If the overspeed trip malfunctions or the engine speed is equal or higher than 120 % of the nominal speed, stop the engine immediately by pressing the emergency stop button.

Procedure

1 **Disconnect the primary overspeed sensor ST173 from the input X13–2 on the engine safety module (ESM).**

2 **Start up the engine and bring it up to nominal speed.**

3 **Increase the engine speed slowly (~1 rpm/second) up to 115 % of the nominal speed.**

4 **Verify that all overspeed protection actions are performed by the ESM when reaching overspeed (115 % of the nominal speed).**

NOTE

When performing the test for the first time, if the speed cannot be increased to the overspeed limits, an automation system parameter must be changed by a service engineer to enable the testing.

a **Check that the led *Overspeed shutdown 2* is switched on.**

This indicates that the engine is being stopped by the secondary overspeed sensor ST174.

b **Record the maximum measured value of the engine speed before the engine is stopped.**

Compare the measured value with the calculated value 115 % of the nominal speed to see if they are the same.

c **Verify that the alarm *IS1741 EMG Overspeed shutdown 1 status* is activated on the local display unit (LDU).**

d **Check that the stop solenoids *CV153.1* and *CV153.2* are energized.**

Use a screw driver or a metallic piece to sense if a magnetic force is produced by the energized stop solenoids.

5 **Reset the overspeed trip by pushing the reset button.**

6 **Reconnect the overspeed sensor ST173 to the input X13–2 on the ESM.**

7 **Disconnect the secondary overspeed sensor ST174 from the input X14–2 on the ESM.**

8 **Perform steps 2–4.**

In step 4a: Check that the led *Overspeed shutdown 1* is switched on by the primary overspeed sensor ST173.

9 **Reset the overspeed trip by pushing the reset button.**

Postrequisites

- Reconnect the overspeed sensors ST173 and ST174 to the ESM.

23.3.3.8 Replacing the engine safety module

v2

WARNING

The below information must be read before installing and taking the product into use. Neglecting to follow the instructions can cause personal injury and/or property damage.

NOTE

This product is programmed/adjusted before delivery. Although every effort has been made to ensure the accuracy of the programming/adjustment for the device according to the information available about installation, engine number, module etc, due to adjustments and/or re-engineering made by the end-customer or other parties at the installation this information might be outdated/ inaccurate.

NOTE

All electronic equipment is sensitive to ESD (Electro Static Discharge). All necessary measures to minimize or eliminate the risk of equipment being damaged by ESD must be taken.

NOTE

During the delivery from our warehouse to the end customer the product has passed stages which are out of control of Wärtsilä Finland Oy. During the transportation the program/settings might have changed due to careless handling, heat, exposed to radiation etc.

WARNING

Please take all necessary precautions when using the product for the first time after repair, re-programming or adjustment has been made to the Product. Whenever practically possible, always verify the functionality of the device before taking into operation.

WARNING

Do not use automatic start of the engine!

Procedure

1. **Verify the module settings with the settings sticker on the cover.**
2. **Switch off the power supplies.**

   The voltage is 24 V DC
3. **Open the terminal box cover.**
4. **Disconnect all the connectors from the module.**
5. **Remove the screws.**
6. **Remove the module.**
7. **Insert the new module into its place.**
8. **Mount the screws.**

9 **Connect the connectors to the new unit.**

CAUTION
Avoid overtightening the connectors.

10 **Close the terminal box cover.**

11 **Switch on the power supplies.**

23.3.4 Power distribution module (PDM) v21

The power supply of the engine is set up according to overview scheme below.

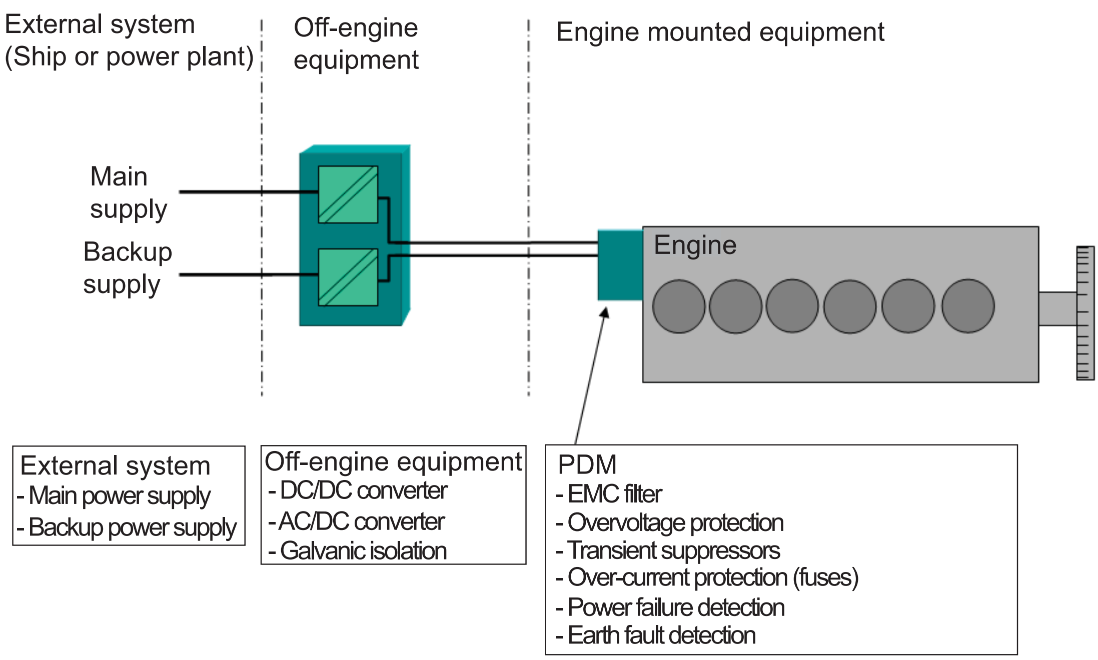


Fig 23-13 Power supply and distribution principle

The PDM's (Power Distribution Module's) purpose is used to distribute the power supply to all electronic equipment on the engine. The module handles filtering of the power supplies, protection against over-voltage and voltage transients and monitoring of earth faults. The whole power supply system is floating in respect to ground (PE) (providing that the both external supplies are isolated). PDM is supplied with two supplies which are redundant. Only the supply to the fuel rack speed actuator's driver is by-passing the PDM, all other consumers are connected through this module.

The following features are provided in PDM:

- Monitoring of voltages
- Short circuit protection
- EMC filter
- Over-voltage protection
- Transient suppressors

- Power failure detection
- Earth fault detection
- Reverse polarity protection

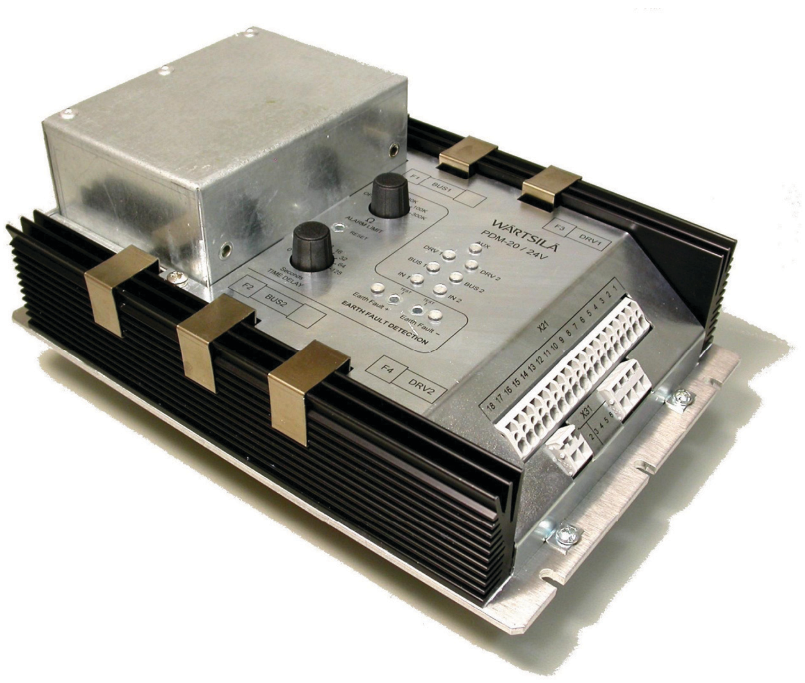
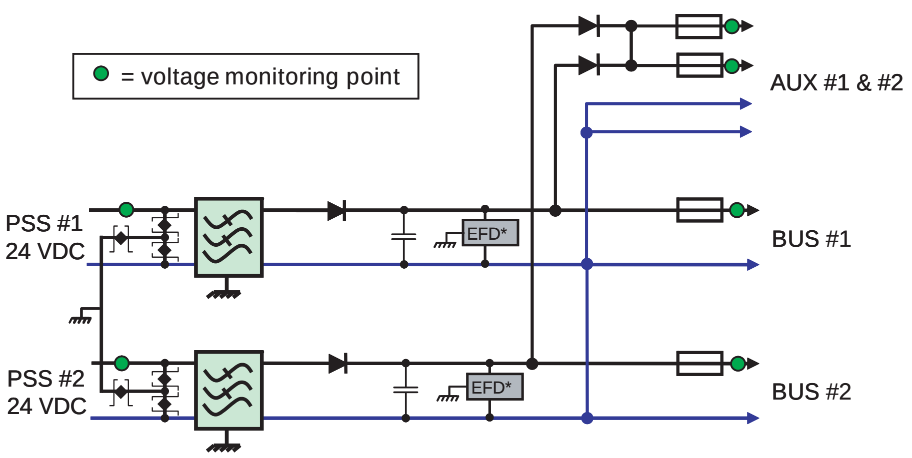


Fig 23-14 PDM module

Internally, the PDM is designed in the following principal way.



*) when EFD not handled by external supply

Fig 23-15 Principal internal design of PDM

LED indications are provided for the input supply voltages, for the fuses and for earth fault monitoring.

- Input voltages are monitored and if the supply voltage drops below 18VDC, the PDM alarm output is activated. The LED indication corresponding to the input with the low voltage is then turned off.
- Each fuse has an individual (green) LED. The LED will turn off if the fuse has blown. The fuses are located inside the PDM and the cover must be removed in order to access them.
- An earth fault is indicated with LED indications, positive line failure and negative line failure separately. The earth fault detection alarm level is adjustable between 3 kΩ - 300 kΩ with a 10-step rotational switch. The earth fault detection can also be turned off with this switch. The earth failure alarms from the PDM require a manual reset on the module. A time delay for the activation of the earth fault is selectable between 0 - 128 seconds with a 9-step rotational switch.

Fuse sizes (BUS 1, BUS 2, AUX -fuses) are installation specific.

The PDM has the following failure outputs:

- 1 x potential free output for general failure
- 1 x potential free output for earth fault

The failure outputs are open when active, meaning that total power failure also will result in an alarm.

23.3.5 Input/Output Module (IOM) v3

Fig 23-16 IOM module

The CPU used in IOM is a high-performance Motorola PowerPC MPC561 controller. The module itself contains diagnostic features on internal system integrity (like memory checksums, CPU watchdog, system temperature) as well as advanced I/O checks based on signal processing, like open/short circuit detection and sensor diagnostics. In addition, depending on application, also other application specific diagnostics is available.

This multipurpose I/O unit is used for data acquisition of analogue/binary/frequency signals, but also for control, such as waste-gate control, by-pass control and LT/HT water thermostat valve control.

23.3.5.1 Wastegate control v9

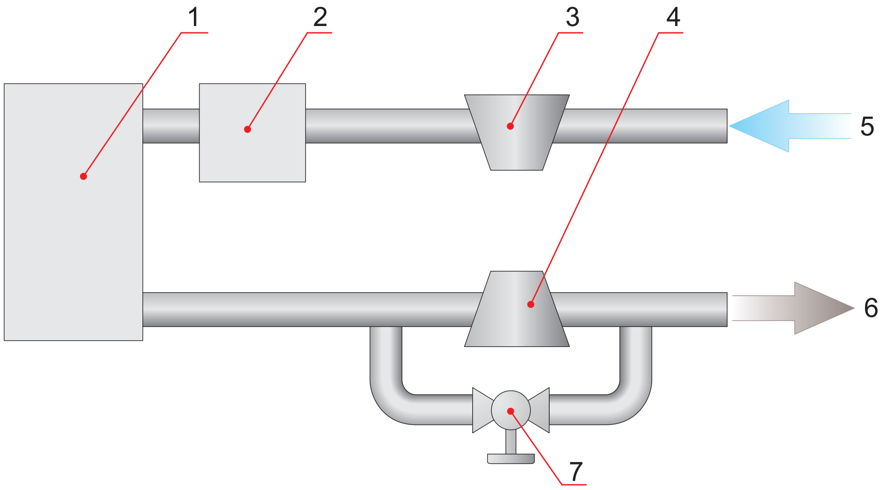
The wastegate is used to limit the charge air pressure on higher engine loads or in cold conditions when intake air density is high. The wastegate control is based on a PID controller that compares the measured charge air pressure with a pressure reference.

The wastegate control is activated after a set delay, typically five seconds, after the engine has reached rated speed.

The charge air pressure reference is taken from a speed and load dependent set of parameters. This derived reference is compensated for receiver temperature and air humidity. If no data of the engine's load is available from the external system, a load equivalent signal is internally calculated, mainly based on the global MFI (Main Fuel Injection) demand signal. The charge air pressure sensor's output is used as feedback for the wastegate control.

The derived reference must be below a safety limit that is set to the maximum charge air pressure allowed for the specific combination of engine and turbocharger. If the derived reference value is higher than this limit, it is adjusted to the value set by the safety limit and a notification is written to the system log.

If any of the input signals fails, the wastegate control closes the wastegate and a notification is written to the system log. No additional alarm information is sent to the external system. The engine's safety system handles all alarms caused by sensor failures, high temperature or speed. When all inputs are restored to the wastegate control, normal operation continues and a notification is written to the system log that the wastegate control is online.



1 Engine
2 Charge air cooler
3 Compressor
4 Turbine
5 Charge air intake
6 Exhaust gas outlet
7 Exhaust wastegate

Fig 23-17 Exhaust wastegate

23.4 Functionality of the UNIC

23.4.1 Speed controller

23.4.1.1 Speed controller

v17

In the speed control algorithm the speed reference is compared with the measured engine speed. The difference between these signals constitutes the input to a PID-controller. The regulation output of the MCM controller will accordingly change, to sustain the reference level.

This output will set the position request of the fuel actuator, i.e. control the diesel fuel rack position. The fuel actuator can either be an electro-hydraulic actuator or a full-electric actuator

23.4.1.2 Dynamics v2

The PID-controller uses different sets of dynamic parameters for operation under acceleration, under no-load conditions and under loading conditions, to obtain optimal stability at all times. The PID settings are speed dependent for start acceleration and for open circuit breaker/clutch conditions, and load/speed dependent when the engine is loaded. A special speed deviation dependent feature is also provided, to minimise large speed fluctuations. The proportional gain is speed deviation mapped, for more aggressive control in case of large deviations from the reference speed.

23.4.1.3 Limiters v3

The three available limiters are the following:

- A start fuel limiter is active during the engine start, up to a rotational speed level of 20 rpm below the rated speed. The start fuel limiter settings in this 8-point table are speed-dependent, and the limiter works in combination with a speed reference ramp used at engine start. The acceleration ramp is set for an optimal acceleration rate.
- A charge air pressure limiter (8-point map) can be used to reduce over-fuelling and black smoke at load steps at low engine load levels. At low load levels, this feature also improves the load acceptance of the engine.
- A load-dependent fuel limiter can be used to set an envelope of maximum fuelling at various engine loads. This feature improves the load acceptance of the engine, but it is also used as a limiter for the maximum load output.

23.4.2 Synchronizing/clutch-in v1

23.4.2.1 Genset v1

When the engine is started, it initially operates in CB open control mode. The speed accelerates up to idle speed, and thereafter (when OS176 Idle select input is low) ramps up to rated speed. When the engine speed reaches rated speed, an external device (synchronizer) activates the synchronization. Commands from this synchroniser unit activate the two binary inputs OS163 Speed increase and OS164 Speed decrease to obtain the requested speed level. The speed reference can be altered between a pre-determined min. and max. speed reference level by using these inputs, thus the internal speed reference is in this way biased so that the generator frequency exactly will match the plant frequency.

When the two frequencies are totally matched (in addition also the phase matching and the generator voltage level must match), the generator breaker can be closed. Alternatively an analogue synchronizer can be used (connected to the dedicated input OS160 Analogue synchronizer). This input is used for synchronization, if binary input OS160 analogue synchronizer enable is set true.

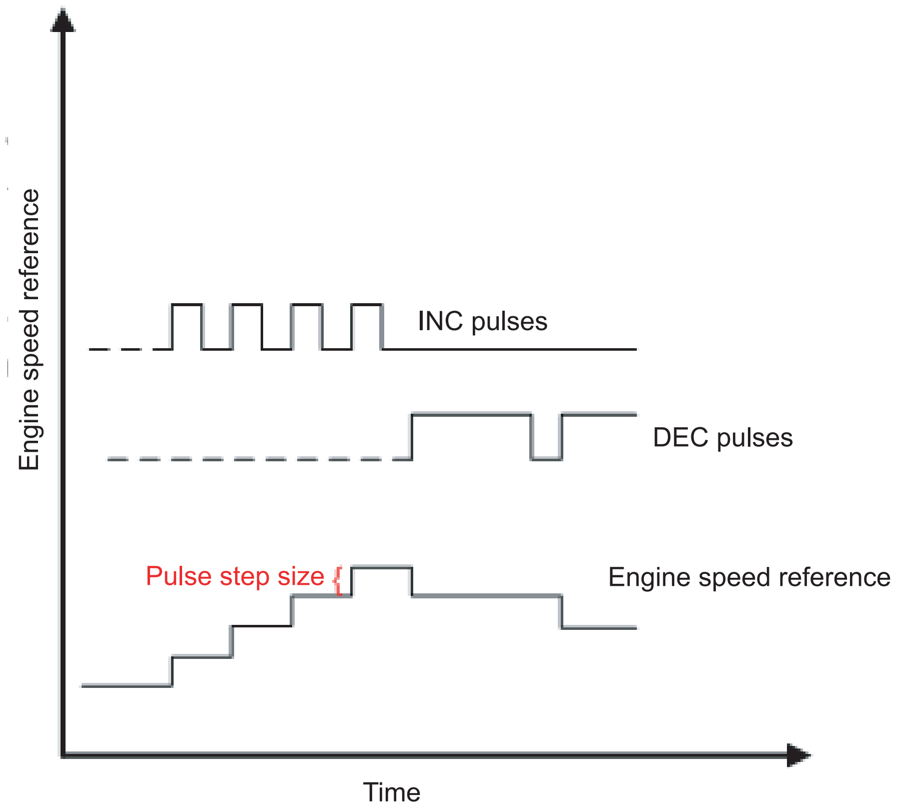


Fig 23-18 Step mode is active when INC/DEC pulse mode selector is set true

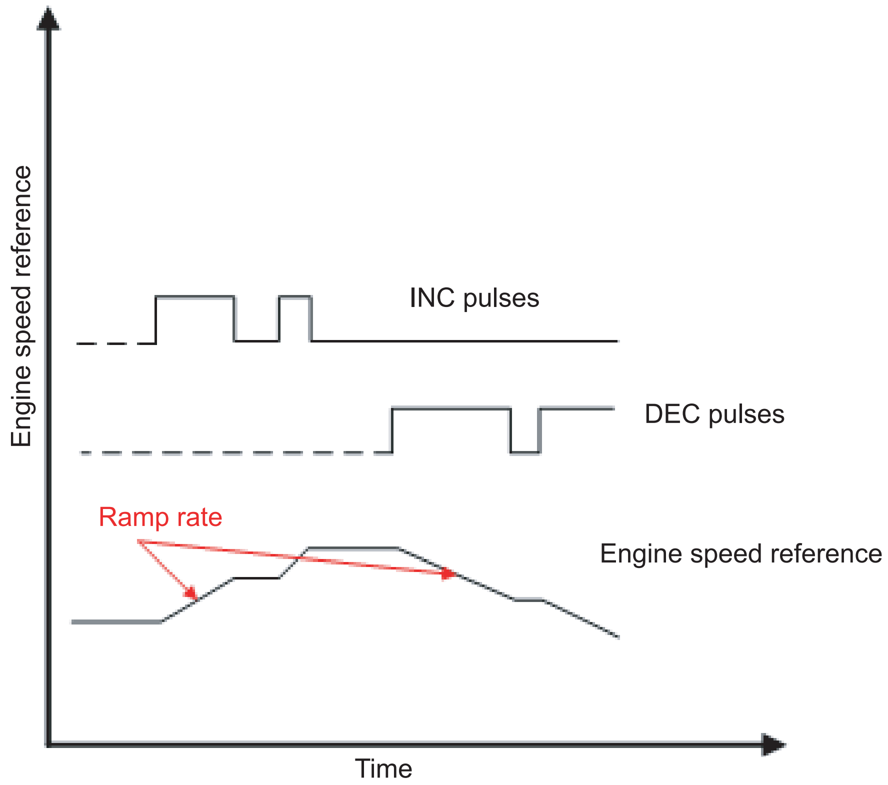


Fig 23-19 Ramping mode is active when INC/DEC pulse mode selector is set false

There are two ways to affect the speed reference with these binary inputs. If ramp mode is configured true (default), the speed reference will be ramped as long as one of these inputs is high. If step mode is configured true, the speed reference is affected a pre-determined step each time one of these input signals is set high (flank trigged).

23.4.2.2 Main Engines

v2

Main engines on ship installations are using an analogue speed reference signal instead of the above described OS163 Speed increase and OS164 Speed decrease inputs. When input OS7325 Analogue speed ref. select is activated, the MCM speed controller will use the reference signal OT190 Analogue speed reference. The internal speed reference will be ramped up and down according to the level of this signal. Max. and min. speed are predefined (configurable).

If input OS7326 Fixed speed select is activated, the speed will (regardless of other input signals) be ramped up or down to a pre-determined fixed speed level. Further synchronisation/clutch-in can then be performed from this level by using inputs OS163 Speed increase and OS164 Speed decrease.

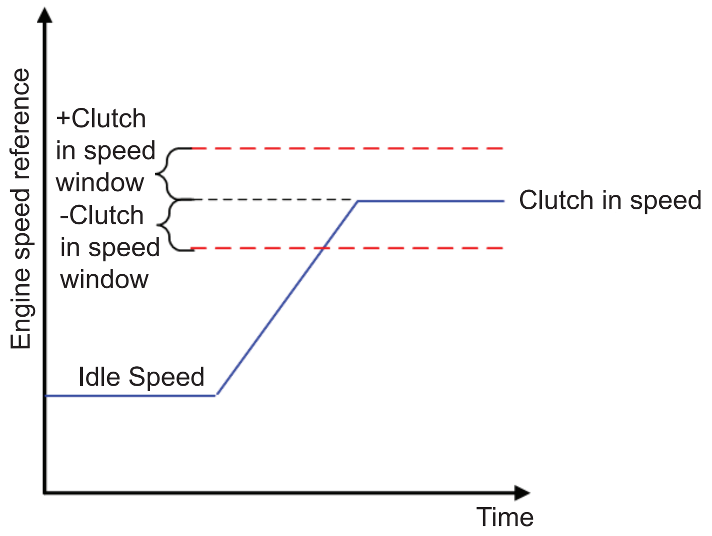


Fig 23-20 **Clutching the first engine**

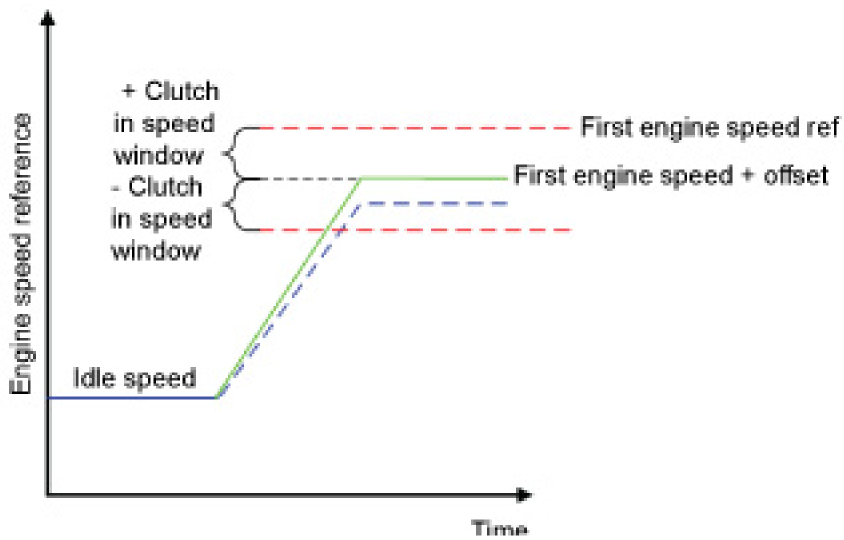


Fig 23-21 **Clutching the second engine**

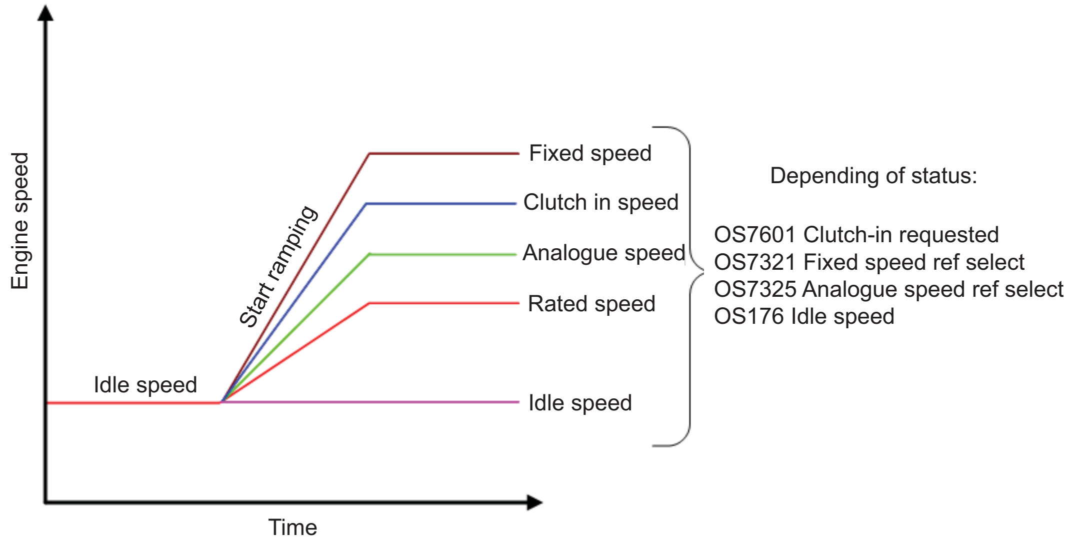


Fig 23-22 Speed goal reference during start sequence, depending on pre-set of binary inputs.

23.4.3 Engine loading, general v2

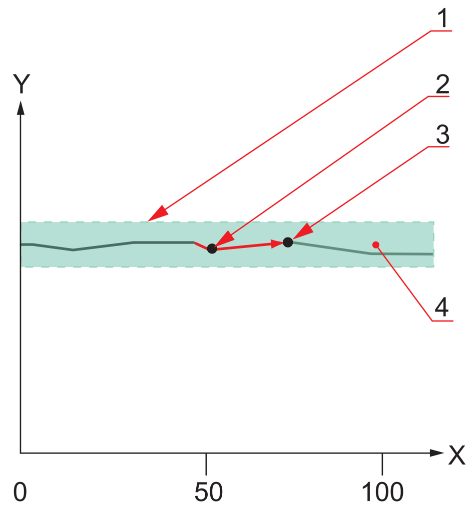
When the generator breaker or clutch is closed, the engine is operated in droop mode, kWmode or isochronous load sharing mode, primarily depending of the pre-selection of the *OS7328 kW control enable* and *OS7329 Isochronous load sharing enable* inputs. The kW and isochronous load sharing modes require that the system to vital parts is functional, if important signals are missing or not communicated, the functionality will automatically switch over to droop mode.

23.4.4 kW control mode v21

In kW control mode, the control loop is a true load control loop where the engine speed is only used for safety purposes. An internal load reference is compared to the measured engine load (*UT793 Generator load* input signal). The error is the input to a PID controller for the load control loop.

The output of the controller determines the position of the fuel rack, and thus the output is set to sustain the load reference level

kW control mode is used particularly on power plant engines. This control mode is activated when the input *OS7328 kW control enable* is activated and the *GS798 Generator breaker status* and *GS799 Grid breaker status* inputs are both closed. The kW control mode has most benefits in base load applications where the grid frequency stability is low. The engine load does not fluctuate according to the frequency in the same way as if it would do in speed control mode with droop.



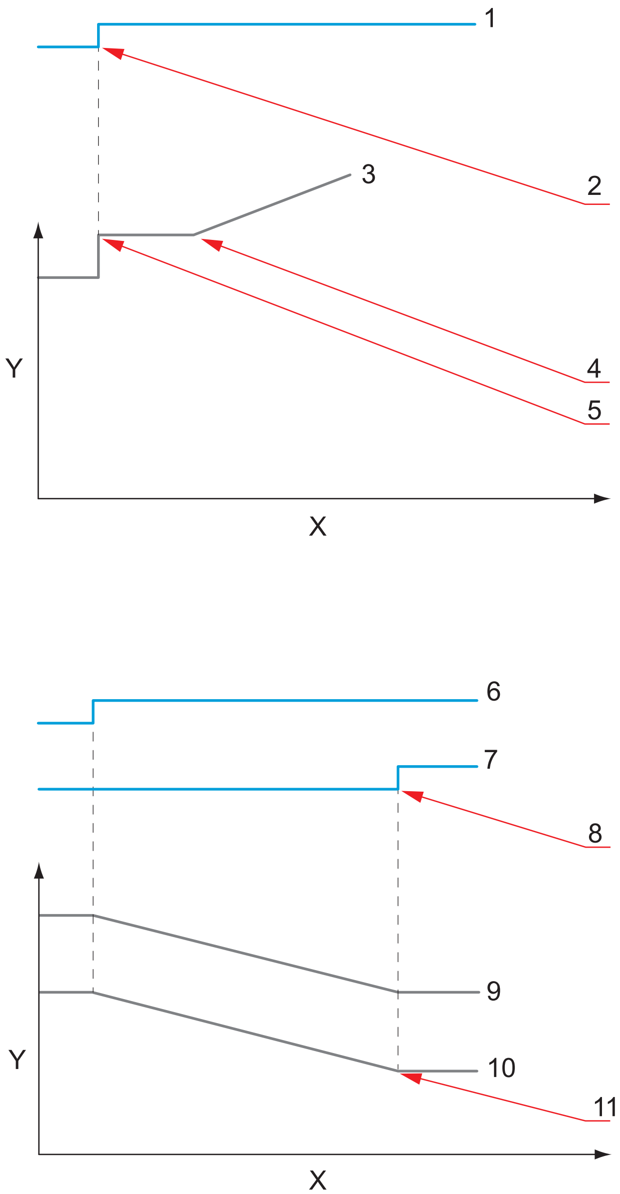
x. Engine speed [rpm]
y. Engine load [%]

1 Operating area for true kW control
2 Operating point with old load reference
3 Operating point after ramping to new load reference
4 Grid frequency

Fig 23-23 kW control mode

If the grid frequency is not within a predefined speed window, or if the *UT793 Generator load* signal fails, the control mode automatically trips to droop mode. The speed reference is updated continuously by the speed control loop in kW control, which means that if a trip occurs, the transfer is almost bumpless. By toggling the *OS7328 kW control enable* input, kW mode is restored, providing that all enabling conditions are met.

When entering this mode from CB open control mode, the load reference is initially set to a predefined base level. This is done to avoid risk of reverse power of the genset when entering this mode from the CB open control mode. The internal load reference is then ramped up to the externally given reference *OT795 kW reference* with a predefined ramp rate.



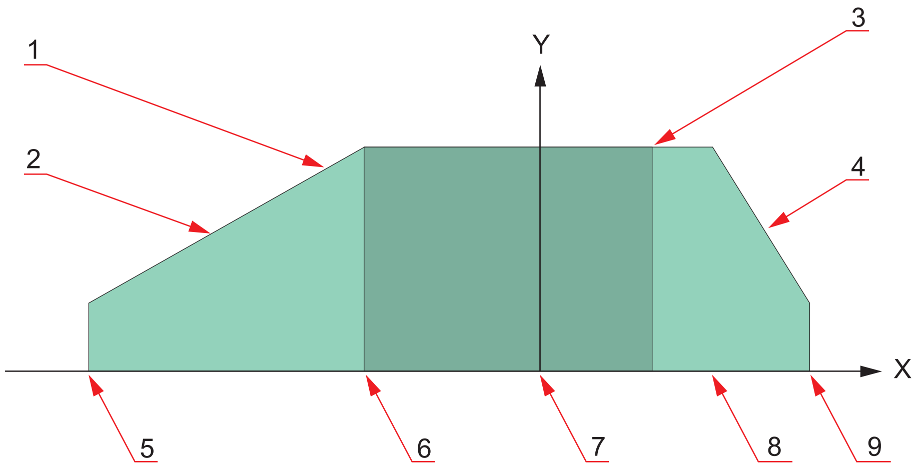
x. Time
y. Engine load reference

1 Gen CB is closed
2 Engine load reference
3 Engine load reference is started to ramp to goal reference
4 Relative base load is set to engine load reference
5 OS7321, Engine unload
6 Gen CB open command is set active
7 Engine load reference
8 Engine load
9 Relative trip load

Fig 23-24 Relative base load reference

If the engine speed increases over a high limit, the internal maximum load reference is set according to the 8-point vector configurable parameter. If the engine speed decreases under a low limit, the internal maximum load reference is reduced according to the setting of a 8- point vector configurable parameter, and the load reference is ramped down according to a configurable parameter (if the load reference was greater than internal maximum load reference).

If the engine speed increases over the high frequency or low frequency limits, the binary output OS799 grid breaker open command is set true after a configurable time, and speed droop control and load sharing mode becomes active as soon as binary input GS799 busbar parallel w. grid status goes false. At this transition the OS799 grid breaker open command output is reset. The binary output IS7331 tripped to droop is then set true.



x. Pel [kW]
y. f [Hz] (speed [rpm])

1 Internal maximum load reference ≠ Maximum available power (kW)
2 Low frequency LR slope (rpm)
3 Internal maximum load reference = Maximum available power (kW)
4 High frequency LR slope (rpm)
5 Low frequency LR trip level
6 Low frequency LR init level
7 Rated speed
8 High frequency LR init level
9 High frequency LR trip level

Fig 23-25 Load envelope diagram

When input OS7321 Engine unload is activated, the load reference target is set to a base load level, and the load reference is ramped down according to a predefined unload ramp rate. When reaching this level, the OS7602 Gen. breaker open command output goes high (engine disconnected) and CB open control sub-mode is entered.

In kW control mode, the controller uses dedicated load-dependent PID settings.

23.4.5 Droop mode

v8

When two or more engines are operating in parallel, some kind of load sharing must be provided. Load sharing means that each engine will contribute equally to the total power demand, and it ensures that load changes are absorbed evenly by the engines in operation.

Droop control is a basic load sharing method, by which parallel running engines share the load by decreasing their internal speed reference proportionally to an increase in load. No communication or signalling is needed between the engines in this mode. The droop value is normally set to 4 %, but the setting can if necessary be changed. Too low droop value means that the load can potentially start oscillating between the engines. Too high droop value means that the plant's frequency decreases more steeply with the load level.

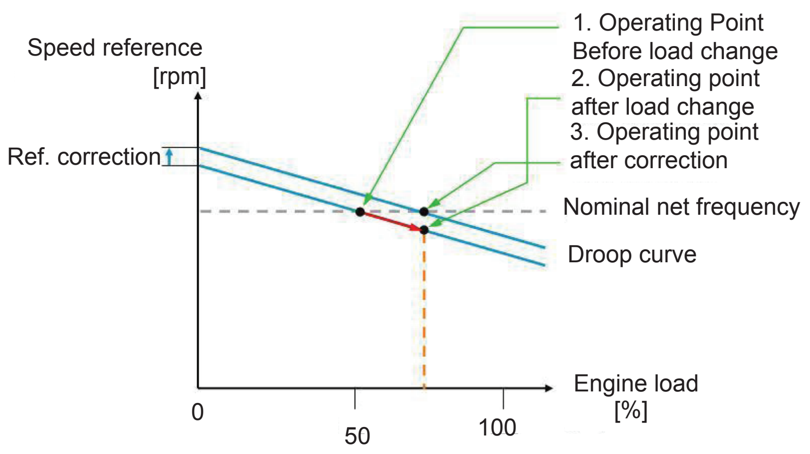


Fig 23-26 Droop mode

Load sharing based on droop, means that the power management system (PMS) may after major load changes have to compensate the effect derived from the droop slope. Therefore, this system should under such conditions activate the *OS163 Speed increase* or the *OS164 Speed decrease* input of UNIC system (in so called cascade control) to compensate for the droop slope i.e. to ensure that the bus frequency is kept within a certain window regardless of net load level. The PMS system must however have a control dead-band implemented, allowing for an uneven load or frequency drift of 1... 2 %.

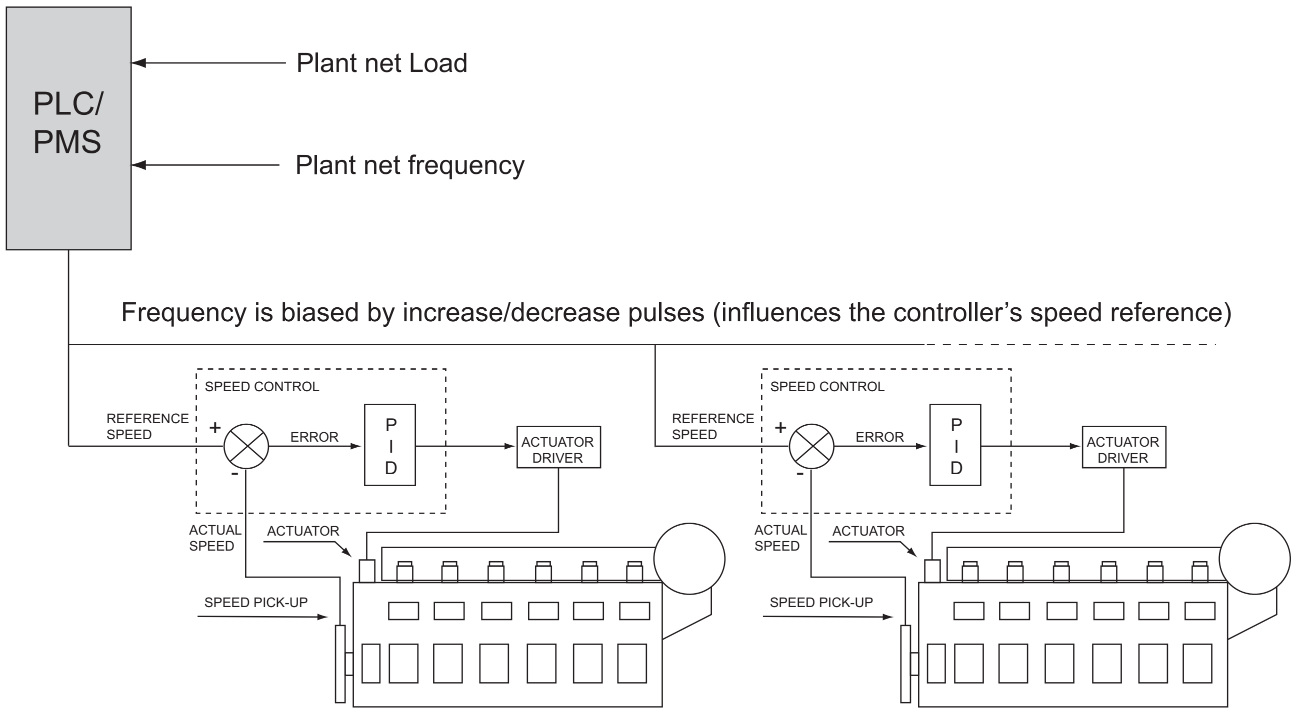


Fig 23-27 External system compensates the negative effect derived from Droop slope

In droop mode the load of the engine is ramped up by setting the *OS163 Speed increase* input high. The internal speed reference in UNIC increases with a pre-defined rate (the rate of change is configurable), and this determines thereby the loading rate. Increase commands are used until the load level of this engine is equal to other sets running in parallel. In other words, the *OS163 Speed increase* and *OS164 Speed decrease* inputs shall not only be used for bus frequency compensation, but also for biasing the load between the engines.

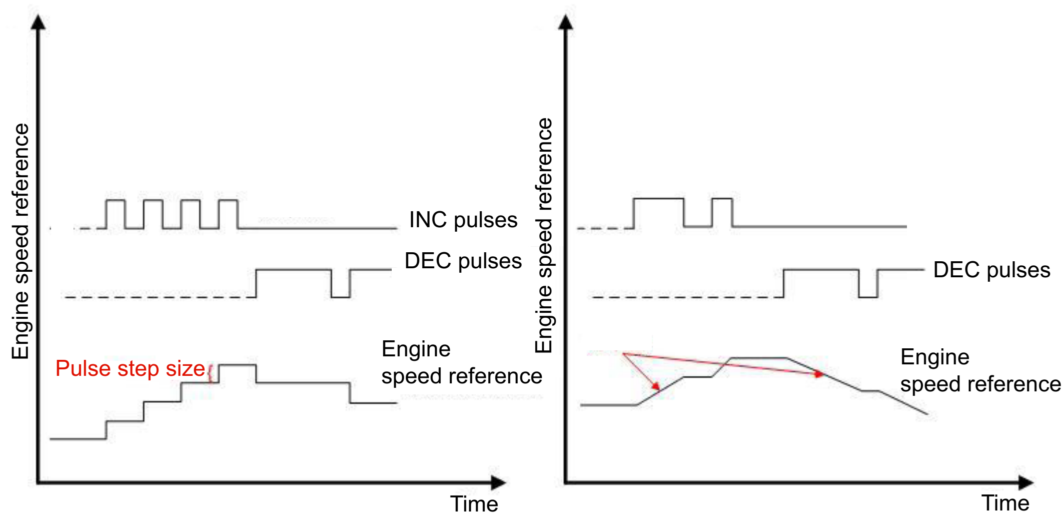


Fig 23-28 Ramp control in droop mode

When it is intended to shut an engine down, the engine load can in the corresponding way be decreased, by activating the *OS164 Speed decrease* input. When the load has reached a low level, the generator breaker can be opened, and the engine be shut down.

Droop mode can also be used on larger grids, but this is not recommended (particularly if the grid frequency has high variations) due to the risk of engine overload. Droop mode is also a backup mode to kW control mode and isochronous load sharing mode, if conditions to keep the engines in these modes of some reason are not fulfilled.

23.4.6 Isochronous load sharing mode (optional) v3

An engine operating in isochronous load sharing mode, will keep the speed at the speed reference, regardless of the load level of the system. Engines operating in isochronous mode need to have the same relative speed reference for load sharing.

In generator engines, the speed reference is initially always rated speed. In propulsion engines the speed reference is set according to the analogue speed reference from the propulsion system controller.

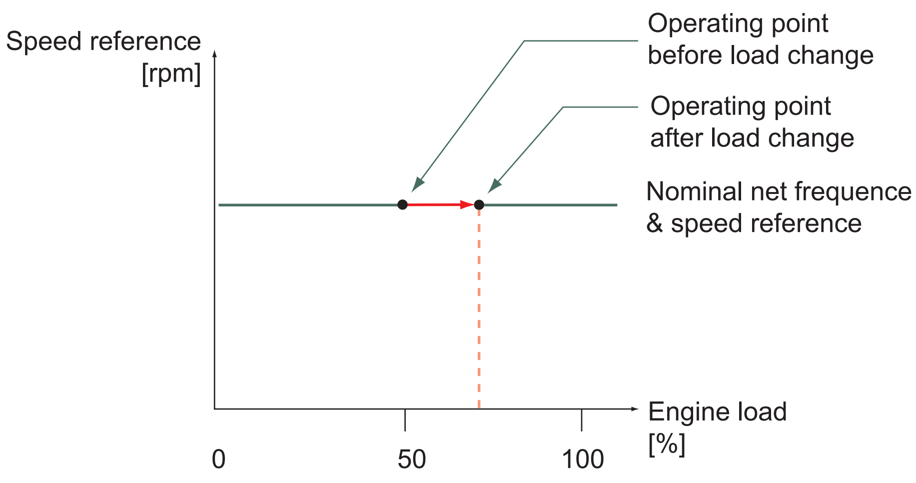


Fig 23-29 Operating point diagram

Two or more main engines running in parallel (analogue speed ref. selected is true on at least one engine) will monitor the speed reference of the engines which have analogue speed reference selected true (over the LS-CAN load sharing bus), and (if several) select the highest one for all engines. The speed reference can only be adjusted between the end levels lowest analogue set speed ref. and highest analogue set speed ref. If fixed speed is selected on one of the engines running in parallel, all the other engines are switched to follow the speed reference of this engine. Now the speed of the system can be increased/ decreased using the *OS163 Speed increase* and *OS164 Speed decrease* inputs or *OT160 Analogue synchronizer* on the engine switched to *fixed speed*. If one engine has the *OS7326 Fixed speed* select input set high, this engine will be master for the other engines running in this mode.

A pre-defined ramp rate is used, to ramp to fixed speed (if the *OS7326 Fixed speed select* input us used) before the *OS163/OS164 inputs* will affect the speed reference. The speed reference can only be adjusted between a pre-defined min. and max. level.

Load sharing in isochronous load sharing mode is provided with communication over LS-CAN. Each engine monitors the relative load itself and of the other engines connected to the same electrical compartment, and calculates a relative system load. The unit compares its own relative load with the relative system load, and biases its internal speed reference, until the two loads are equal.

Always when a new engine is connected to the load sharing compartment it should be softly uploaded. In order to provide soft uploading of an engine in isochronous load sharing mode a pre-defined ramp rate is used. The value of the engine specific load sharing ramp is zero during normal isochronous load sharing operation, i.e. when the relative load of the engines on the load sharing bus is equal. Unloading of an engine running in isochronous load sharing mode is achieved by setting the input *OS7321 Engine unloading* high. When the input is activated the unloading is performed by ramping down the engine load similarly to the uploading case. When the *relative engine load* reaches a pre-defined *trip level*, the binary output *OS7602 Generator breaker open cmd*, and *OS7603 De-clutch* will go high, and the engine will thereby be disconnected.

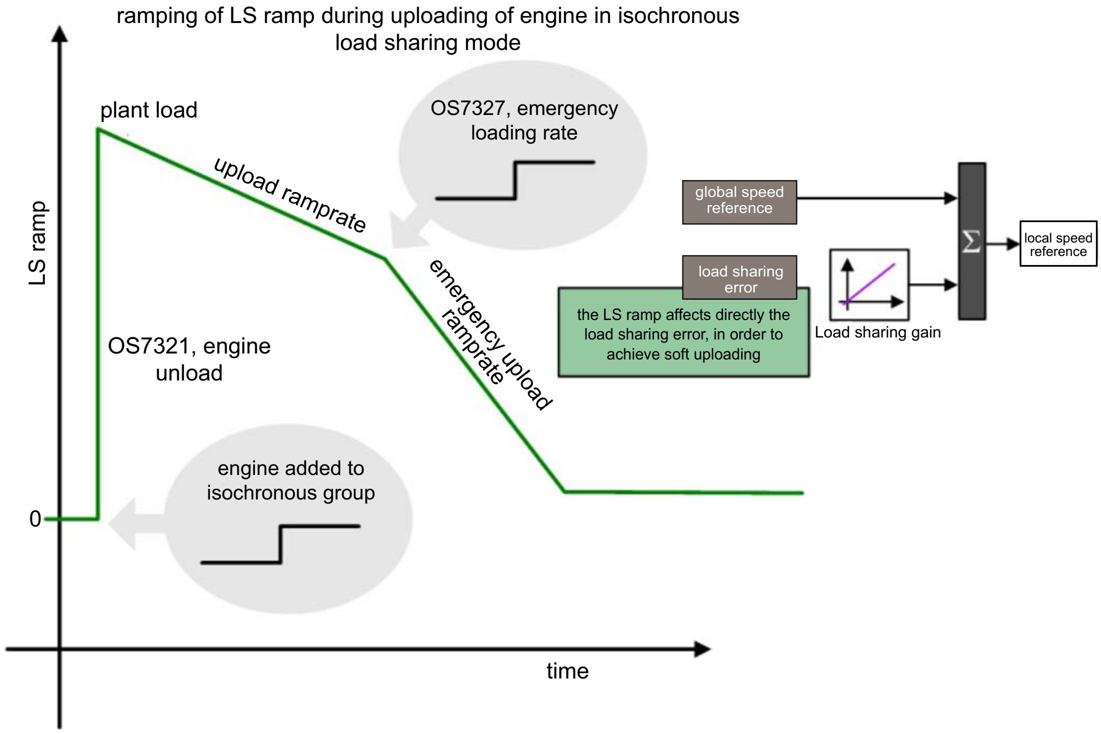


Fig 23-30 Ramping of LS ramp during uploading

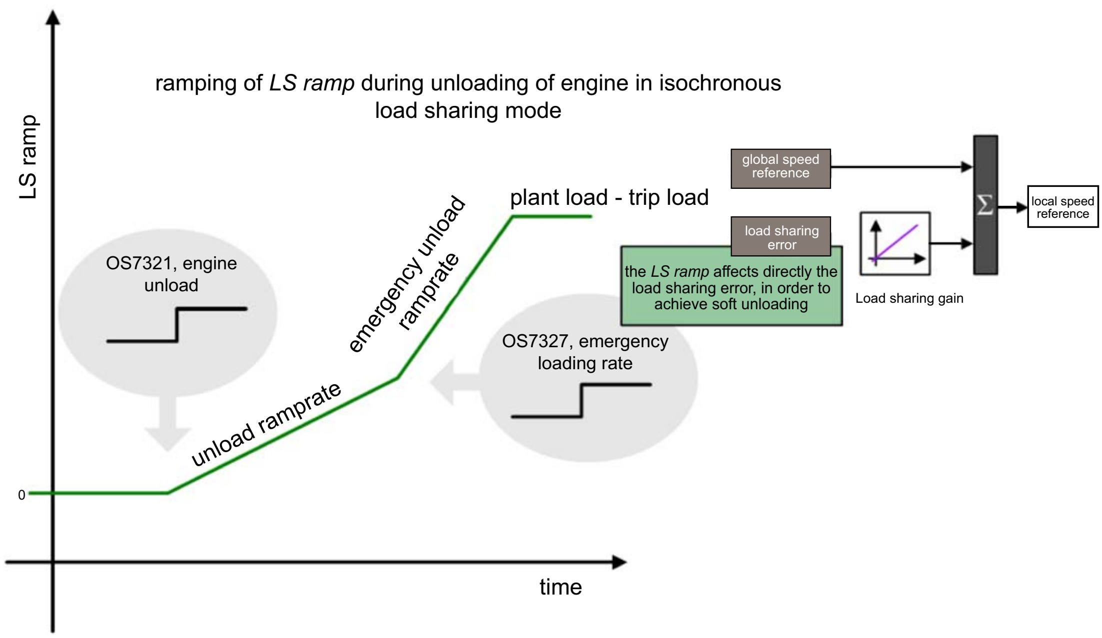


Fig 23-31 Ramping of LS ramp during unloading

Load sharing bias is provided, if it is desired to run some of the engines on the same electrical compartment on a constantly different relative load compared to the other engines. This is achieved by using the *IT796 Asymmetric load sharing bias* input.

In isochronous load sharing mode, the controller will use dedicated load & speed depended PID settings.

23.5 Start/stop management v3

The UNIC engine management system controls and monitors a number of engine parameters, and initiates all required action under various engine conditions. These actions can vary from blocking a start, initiating an alarm, to shutting down the generating set. The UNIC system has because of this reason a number of internal modes. Different modes have different priority, and the mode transitions can occur only according to pre-defined rules. Allowed transitions are visualised in the below flow chart.

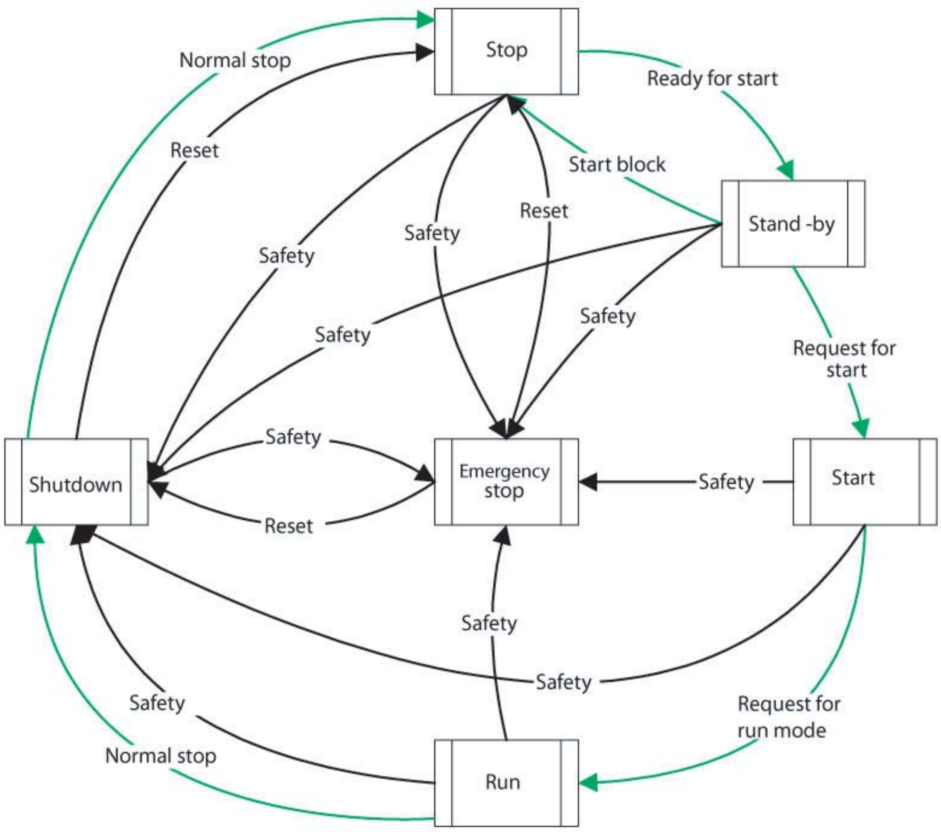


Fig 23-32 Engine modes in UNIC system

23.5.1 Emergency stop mode v10

This mode has the highest priority and can be entered from any other mode. The engine is standstill or under deceleration. Emergency stop mode is entered in case of activation of the local emergency stop button, but also from an emergency stop request from an abnormal engine condition detected by a measurement or an internal UNIC system failure condition (see other document for with list of emergency stops). The remote emergency stop chain is connected to input *OS7305 External shutdown 4*.

In emergency stop mode, the engine will be automatically and instantly stopped (without sequencing), by setting the fuel rack actuator position to zero, and this is additionally secured by deactivation the el. pneumatic stop solenoids.

The engine will always remain in emergency stop mode until the reset input is activated.

23.5.2 Shutdown mode

v9

This mode can be entered from stop mode, stand-by mode, start mode or run mode. The engine is standstill or under deceleration, and brought to this mode by a shutdown request from an abnormal engine condition detected by a measurement (see other document for with list of shutdowns) or by activation of the *OS7309 External shutdown 1* input. This mode is also temporarily entered in the sequence following a normal stop request.

In *shutdown mode* the engine will be automatically and instantly stopped by setting the fuel rack actuator position to zero and this is additionally secured by de-activation the el. pneumatic stop solenoids.

The engine will always remain in shutdown mode until the reset input is activated.

The arrow that goes from run, through shutdown to stop mode indicates a normal stop.

23.5.3 Run mode

v6

Run mode can be entered only from start mode. The engine is running i.e. the rotational speed is above a pre-set speed limit and no stop, shutdown or emergency stop request is active. The start ramp is finished, and the engine is ready for loading, when engine speed has reached reaching rated speed.

In run mode the overruling of pressure alarms and other engine speed related alarms are disabled after a timed delay. The binary output *CV223 Pre-lube control / OS441 Pre-heater control* will be de-activate. This is a command signal connected to the starters of these external devices.

The engine can now be operated and loaded either in droop mode, kW mode or isochronous mode (see *section 23.4.6*) depending on valid pre-selection, according to below scheme.

This mode will remain active until a manual stop is requested, or a shutdown- or emergency stop request has become active (see previous page).

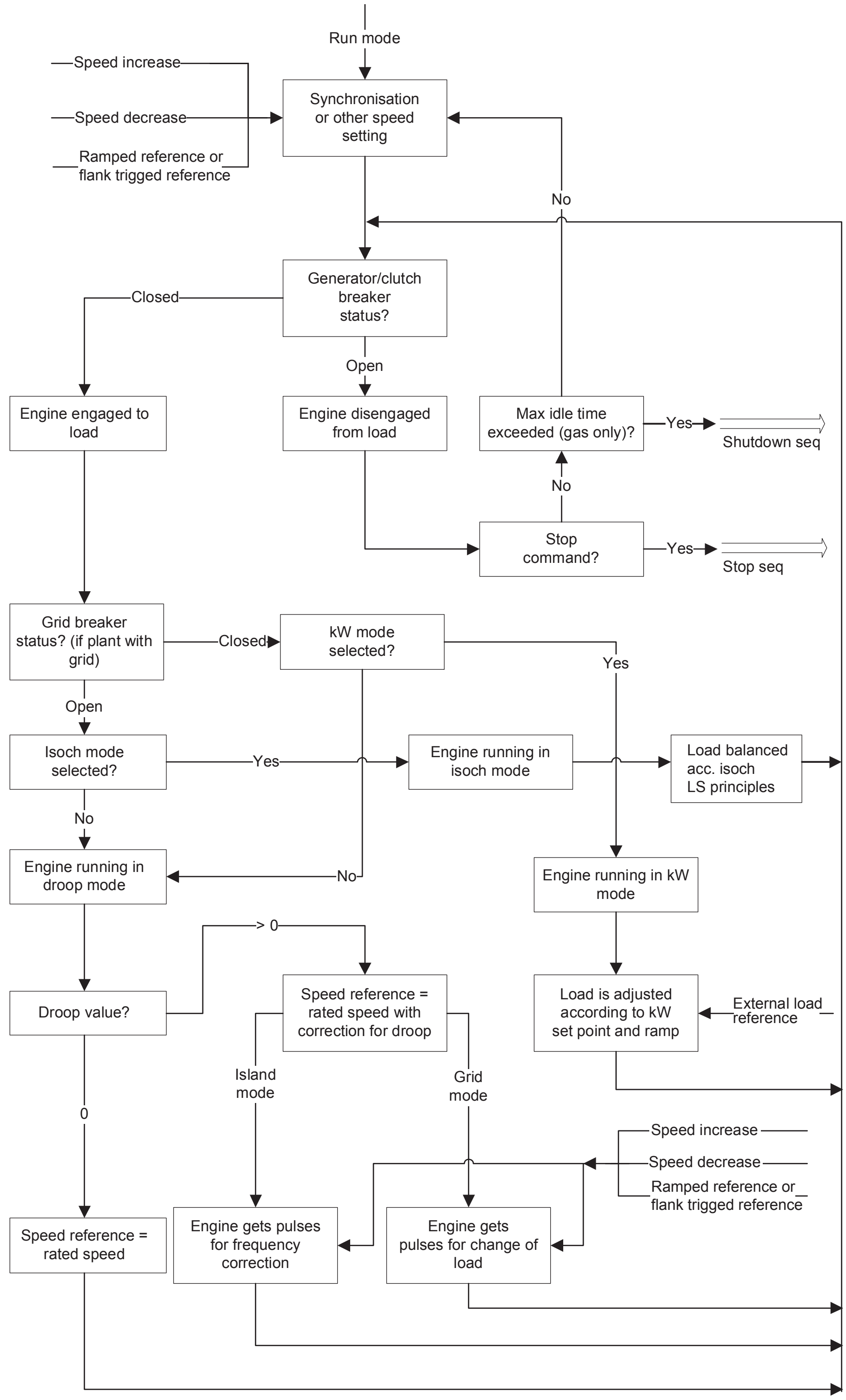


Fig 23-33 Operation sequence in run mode

23.5.4 Start mode

v5

Start mode can only be entered from standby mode. The start is initiated by a remote or local start request. If the local/remote switch on the local control panel (LCP) on the engine is in local mode, a remote start is automatically prohibited and vice versa. Initially, slow turning is performed (standard on some engine types). The engine is rotated two revolutions with reduced air pressure. If the slow turning is not successful, output *IS785 Start failure* is activated and the engine enters shutdown mode. After a successful slow turning, the engine enters the start sequence. The *CV321 start solenoid* control output is active until a pre-set speed is reached or (if not reached) until a delay of 10 seconds has timed out. If the rotational speed has not reached 300 rpm within 20 seconds, the start has failed, and *shutdown mode* is entered. Also in this case, the binary output *IS785 Start failure* is activated.

In case a start blocking is active, it prohibits the initiation of the engine start sequence. During the engine start sequence some internal engine safety is temporarily overruled. Low prelubricating oil pressure start blocking is, however, suppressed within half an hour since last running of the engine, or since last prelubricating oil pump running. A stop, shutdown or emergency stop request interrupts an ongoing start sequence.

If the *OS 7320 blackout start mode* input is activated, the engine start routine overrides the start blockings for low lubricating oil pressure and low HT water temperature (if used).

23.5.5 Stop mode v3

Stop mode can be entered from stand-by mode, shutdown mode or emergency stop mode. When the UNIC system is powered up (initialised), the default mode is always stop mode. The engine is always standstill in stop mode. If no start blocking is active, the mode will automatically transfer to stand-by mode.

If an automatically initiated shutdown or emergency stop has occurred, and the engine has shut down, a reset must be performed before the engine enters stop mode.

If a start blocking is active in this mode, the engine is not ready for start (the binary output *IS872 Ready for start* is low), In this case a transfer to stand-by mode doesn't automatically occur, before the start blocking disappears.

23.5.6 Stand-by mode v3

Stand-by mode can only be entered only from stop mode. The engine is ready to start in this mode (binary output *IS872 Ready for start* is set high), and to initiate a start either the local start button on the LCP must be pressed, or a remote start command must be given. No activation of the reset button/input is necessary.

The engine blow function (described in *section 23.3.1.3* Switches and buttons) can only be performed in this mode.

In stand-by mode, a cyclic slow turning will occur each half hour (on engines using slow turning), if input *OS7317 Remote stand-by request* is set true.

23.6 Sensors and safety handling v10

All sensors on the engine are wired to the modules in the UNIC C2 system. The majority of the sensors are connected to the main control module MCM and to the IOM modules. Exhaust gas temperature sensors are connected to the IOM's. Additionally a number of safety-related sensors are connected to the engine safety module ESM and further to the WIP-1* backup instrument display. The sensors connected to the IOM's are sent over CAN to MCM where they are processed (e.g. safety limits checked). The same information is externally sent out over Modbus TCP/IP through the LDU (Ethernet Gateway) or Modbus Serial from the MCM.

23.6.1 Alarm v3

An alarm condition activates the following action:

- The measured value is shown in inverted colours on the LDU.
- An alarm message is shown on the history page of the LDU.
- On Modbus TCP the alarm bit is set to value 1.
- Common engine alarm is activated (binary output).

When the alarm condition is over, the following actions are taken:

- The measured value is shown in normal colours on the LDU.
- The Modbus TCP alarm bit is set to 0.
- The Common engine alarm is deactivated, if there are no other active alarms.

The UNIC system has sensor failure supervision (alarm) for the following conditions:

- Sensor failures.
- ESM and power supply failures.
- All analogue input signals.
- Emergency stop (binary input).
- External shutdown input.

If the connection to a sensor fails, the sensor failure alarm will be set true. When the sensor failure has been detected, the safety functions for this sensor will be ignored, e.g. a failing sensor can not cause a shutdown. Some measurements (such as engine speed) are redundant and the system will in case of a sensor failure automatically switch over to a backup sensor. In addition some controls have backup strategies based on another measurement, which then will be activated.

The alarm signals and settings for the specific engine are documented in the Modbus TCP list, see installation specific documents for details.

23.6.2 Shutdown

v2

Shutdown sensors are connected to the engine safety module (ESM). Automatic shutdowns are latching and need a reset before it is possible to re-start the engine. Before a re-start, the reason for the automatic shutdown must however carefully be checked.

NOTE

A manually activated stop is only latching until the rotational speed is zero, after this it is possible to restart the generating set without performing a reset.

The engine is as a minimum equipped with the following sensors/signals for automatic shutdown:

- PTZ201 Lube oil press. engine inlet
- PT311 control air press. (on power plant applications)
- TEZ402 HT water temp. jacket outlet
- IS7309 External shutdown 1

Optionally some additional shutdown sensors can come in question, the specific engine's sensors are documented in the Modbus TCP list, see installation specific documents for details.

23.6.3 Emergency stop

v3

Emergency stop sensors/signals are connected to the engine safety module, or are needed for control purpose in the other UNIC system modules.

The engine is as a minimum equipped with the following sensors/signals for **emergency stop**:

- HS723 Emergency stop button
- ST173/ST174 Engine speed (overspeed trip)

Automatic emergency stops are latching and need a reset before it is possible to re-start. Before a re-start, the reason for the automatic emergency stops must however carefully be checked.

The emergency stop signals and settings for the specific engine are documented in the Modbus TCP list, see installation specific documents for details.

23.6.4 Start blocking

v3

Start blocking signals are connected to the main control module MCM or to an IOM module. It is not allowed to by-pass a start blocking, because this may cause a serious hazard either for the engine and its surrounding, or for associated systems.

NOTE

For the pre-lube pressure start blocking, there are some exceptions. A possible prelubrication pressure related start blocking is overridden for 30 minutes after an engine stop, and also for 30 minutes after stopping of the pre-lube pump. The pre-lube start blocking is also overridden, if binary input *OS7320 Blackout start mode* is set high.

The engine is by a minimum equipped with the following sensors/signals for **start blocking**:

- GS171 Stop lever in stop position
- OS223 Pre-lube oil press. (deriving from sensor PTZ201, signal via ESM)
- OS7344 Engine blocked (selector switch on LCP)
- GS792 Turning gear engaged
- OS7312 External start block 1

The start blocking signals and settings for the specific engine are documented in installation specific documents.

23.6.5 Load reduction

v2

Load reduction is an automatic safety measure initiated by UNIC, used to reduce the max load output of the engine under certain abnormal engine conditions. Whenever there is an abnormal situation on the engine or the generator, which endangers a secure or proper operation of the engine, a SP (Set Point) load reduction or SF (Sensor Failure) load reduction can be activated. Load reduction can also be initiated from a VSP (Variable Set Point) or from CS (Conditional Safety) condition. Load reduction is detected and initiated by UNIC, and is used in cases when it still is possible to operate the engine, but only under conditions defined by the engine's safety definitions. The max available load output can be different depending of the type of abnormality. Interaction is needed with the external plant management system, particularly in case of speed droop control mode.

Depending on engine type and application, the number of load reduction functions will vary, see installation specific documents for detailed information.

When no load reduction is active, output *IT797 max. available power* is set as rated load (*OT7354 rated electrical load*). When a load reduction is active, the *IT797 max. available* *power* is reduced according to an internal safety calculation. Process-level initiated load reductions (SP/VSP) are cumulative, and as the load reduction always is reduced from the actual load (*OTY795 actual power*), possible additional consecutive load reductions will further reduce the resulting engine load.

Sensor failure (SF) related load reductions are not cumulative, and the one defining the lowest load level will set the target. If one load reduction is already active, the activation of any sensor failure (SF) load reduction must not lead to any further reduction of the engine load, unless the load reduction percent of the SF load reduction in question defines a lower level than the other load reduction.

23.6.5.1 Load reduction in droop mode v2

In this mode, UNIC cannot itself reduce the load of the engine, thus it can only "request" this reduction from the external plant management system.

The action in case of an active load reduction in this mode is, to set output *OS7315 load reduction request/indication* high as long as the load is higher than the resulting *max. available power* calculation. Also a SP/SF load reduction bit for the specific load reduction cause, will activate in this situation (over external bus and visual on local display). *IT797 max. available power* is sent out as an analogue signal, and *max. available power* is also sent out over the bus to the external system. This load level is used as the target load in the external system, when ramping the load down through activation of binary input *OS164 speed/load decrease*.

When the load reduction process limit is no longer exceeded or when the sensor failure has disappeared, the load reduction status bit for the specific load reduction cause will automatically be set low.

When the engine load is reduced to/under *IT797 max. available power*, output *OS7315 load reduction request/indication* will be set low again. It is configurable to additionally have input *OS7308 Remote shutdown* reset to be resetted, before output *OS7315 load reduction request/indication* will be set low. (As it is not necessarily detectable when/if the cause for the load reduction is eliminated, the restoring of the load is suggested to be manually initiated).

When the load reduction limit(s) are no longer exceeded and *OS7308 Remote shutdown reset* has been activated (if latching configured), *IT797 max. available power* is restored to *OT7354 rated electrical load*. The restoring of the load is externally handled by activation of binary input *OS163 speed/load increase input*.

23.6.5.2 Load reduction in kW/isochronous mode v2

In these modes UNIC can itself reduce the engine load if a load reduction activates, and it is handled in the below described way.

If the engine load is higher than the calculated *max. available power*, i.e. a load reduction is active, the internal load reference will be ramped down to *max. available power*, according to a pre-determined ramp rate. Analogue output *IT797 max. available power* is defined as per this *max. available power* calculation, and the information is also sent out over bus to the external system. The output *OS7315 load reduction request/indication* is kept high as long as the engine load is higher than the resulting *max. available power* calculation. Also a SP/SF load reduction bit (over external bus and visual on local display) for the specific load reduction cause will activate in this situation.

As soon as the engine load has decreased to *IT797 max. available power* the ramping of the load will automatically interrupt.

When the load reduction process limit is no longer exceeded or when the sensor failure has disappeared, the load reduction status bit for the specific load reduction cause will automatically be set low. The output *OS7315 load reduction request/indication* will also then be set low, but only if the load reduction latch is configured false.

As it is not detectable when/if the cause for the load reduction is eliminated, it is preferred that the restoring of the load is manually initiated (activation of input *OS7308 Remote shutdown reset*) after possible corrective action has been performed, to avoid possible load-sawing. If however the latch parameter is set false, no activation of this input is needed, to start the automatic restoring of the load. Restoring of the load will follow an internal pre-defined ramp rate up to the externally requested load level (if kW mode) or to the equal load as other engines (if isochronous mode).

23.7 External interface

v2

Following below, a short description of all the inputs and outputs of the UNIC system.

NOTE

This list covers all signals which can come in question, but these signals are all not used (or needed) for any specific application. Therefore, depending on the application and engine type, the number of I/O will vary. For signal type definition and exact I/O configuration, see wiring diagram and other installation specific documentation.

23.7.1 Binary inputs

v11

- OS7302 Remote start: If no start blocking is active, the activation of this input initiates a start of the engine, in the predetermined fuel mode. If the remote stand-by request input not active, the starting process will include slowturning of the engine (if slowturning is used on the engine type). The input is disabled when the local/remote switch on the engine is in local position.
- OS7317 Remote stand-by request: When the engine is in stand-by mode, the activation of this input will initiate periodical slowturning of the engine. This will ensure a fast and secured start without slowturning, when an engine start is performed. If this input is toggled low/high, a slowturning will immediately be performed, providing that the engine is ready for start.
- OS7312 External start blocking 1: Engine start is prevented, if this input is activated.
- OS7313 External start blocking 2: Engine start is prevented, if this input is activated.
- OS7314 External start blocking 3: Engine start is prevented, if this input is activated.
- OS7304 Remote stop: An activation of this input initiates an immediate stop of the engine. When the engine has reached zero speed + a short delay, the system will automatically enter stop mode and "Engine ready for start" output is set high. The engine can then be re-started without performing a reset. The input is disabled when the local/remote switch on the engine is in local position. As stop mode has higher priority than start mode, simultaneous activation of start and stop (remotely or locally) will result in a stop.
- OS7309 External shutdown 1 : Initiates an immediate shutdown of the engine. This shutdown is a latching function. A signal interruption failure detection (using a 22 kΩ resistor in marine configurations) is provided between this ESM-module input and the external system.
- OS7310 External shutdown 2: Initiates an immediate shutdown of the engine. This shutdown is a latching function. A signal interruption failure detection (using a 22 kΩ resistor in marine configurations) is provided between this ESM-module input and the external system.
- OS7311 External shutdown 3: Initiates an immediate shutdown of the engine. This shutdown is a latching function. A signal interruption failure detection (using a 22 kΩ resistor in marine configurations) is provided between this ESM-module input and the external system.

- OS163 Speed/load increase: An activation of this input will ramp up the speed reference of the internal speed controller. During parallel running in droop mode, the activation of this input will lead to an increase of the engine load. Input also used during synchronisation of the engine. The remote signal is disabled when the local/remote switch on the engine is in local position, and the input will follow the increase command from the local control panel.
- OS164 Speed/load decrease: An activation of this input will ramp down the speed reference of the internal speed controller. During parallel running in droop mode, the activation of this input will lead to a decrease of the engine load. Input also used during synchronisation of the engine. The remote signal is disabled when the local/remote switch on the engine is in local position, and the input will follow the decrease command from the local control panel. If remote increase and decrease commands are activated simultaneously, the decrease command overrules an increase command.
- GS796 Generator breaker status, NC: Same as GS798 but inverted signal.
- OS7321 Engine unload: When this binary input is set high, the engine load will ramp down to a predefined level (if operating in kW mode), whereafter the generator breaker will be controlled open.
- OS7328 kW control enable: When this binary input is set high, the engine control system will go into kW-control mode, if other premises for kW mode are fulfilled.
- OS7329 Isochronous load sharing enable: When this binary input is set high, the UNIC will monitor LS-CAN (loadsharing bus for CAN) and related breakers and clutches (GS798, GS771 and GS772) to judge whether Isochronous loadsharing mode is to be enabled.
- OS7326 Fixed speed select: When this binary input is set high, this will override other speed reference selections and the speed reference will ramp up to a pre-determined fixed speed level. Typically this will be used, when the engine has been running on variable speed (according to input OT190 Analogue speed reference) and the intention is to ramp the speed to the synchronous speed of a shaft generator (for synchronization).
- GS799 Grid breaker status: This binary input informs the speed/load controller about the status of the grid breaker. When the input is high the grid breaker is closed, i.e. this will allow the speed/load controller to enter true kW-control mode (if this mode is requested by setting binary input OS7328 kW control enabled high).
- OS7327 Emergency loading rate: This binary input informs the speed/load controller (operating in kW mode) that the load needs to be ramped up faster compared to the normal ramp rate.
- OS7325 Analogue speed ref. select: When this binary input is set high, the speed reference of the speed controller will be set according to the signal level of the input OT190 Analogue speed reference.
- OS7601 Clutch in request: When a clutch-in is requested, this input is set high. The speed reference will then ramp to a pre-determined speed level ("clutch-in speed") with a pre-determined ramp rate. When the clutch-in speed is reached, the ramping will interrupt, and a clutch-in is possible to perform.
- IS1002 Fuel limit disable: When this binary input is set high, it will override possible active fuel limiters.
- GS771 Busbar breaker status, before: This breaker status input is needed to detect if the busbar breaker near to this engine is closed or open. This will determine with which engine(s) the engine in question will loadshare in isochronous mode. The input is only needed on engines which have isochronous load sharing.
- GS772 Busbar breaker status, after: This breaker status input is needed to detect if the busbar breaker near to this engine is closed or open. This will determine with which engine(s) the engine in question will loadshare in isochronous mode. The input is only needed on engines which have isochronous load sharing.

- **OS176 Idle select**: When this binary input is set high, the engine will ramp the speed to the preset idle speed speed, even if engine is engaged to load.
- **GS798 Generator breaker status**: A signal which indicates that the generator breaker is closed. Will change the dynamics of the internal speed controller. The control mode can (depending on pre-selections) change when the generator breaker closes. See *section 23.4.1.1* describing the speed controller for details.
- **GS7600 Clutch status**: A signal which indicates that the clutch is engaged. Will change the dynamics of the internal speed controller. The control mode can also change, depending on pre-selections (see *section 23.4.1.1* speed controller description for details). Same physical input as above signal.
- **OS7305 External shutdown 4 (emergency stop)**: Initiates an instant shutdown of the engine. Will actuate the engines stop solenoid(s) and in addition set the demand for the fuel rack position to zero. An emergency stop cannot be blocked by the activation of the stop/shutdown override input. As emergency stop mode has the highest priority, activation of any other simultaneous command will be overruled, if emergency stop is activated. A signal interruption failure detection (using a 22 kΩ resistor in marine configurations) is provided between this ESM-module input and the external emergency stop circuit.
- **OS7306 Stop/shutdown override**: Overrides all stops and automatically initiated shutdowns. Emergency stops (local/remote emergency stop buttons), overspeed trip and external shutdowns are however not overridden.
- **OS7308 Remote shutdown reset**: An activation of this input will reset the latch of a shutdown or emergency stop. If the reason for the shutdown or trip isn't first cleared, the function will latch and cannot be reset. The root cause for the engine shutdown must always be investigated, and action taken to correct the problem before a restart is performed.
- **OS7320 Blackout start mode**: When this input is active, and an engine start is initiated, start blockings for low lube oil pressure and low HT water temperature will be overridden. This ensures a secured start in critical situations like a blackout. If the start failure indication alarm is active, the start block (in case of failed slowturning) will be overridden if blackout start mode is selected true.

23.7.2 Binary outputs

v8

- **IB724 Remote control indication**: Indicates that the remote/local switch is in remote position, and engine operation is controlled remotely.
- **IB7324 Shutdown status**: Signal from ESM. Indication that a shutdown or emergency top is active, and that the engine has shut down.
- **IS166 Engine overload alarm**: An alarm indicating that the engine is running with overload. This alarm activates also if a load reduction request is active, and the load is over the preset level.
- **IS181 Speed switch 1**: Output activated at a pre-defined "engine running" speed level. See installation specific documents for details.
- **IS182 Speed switch 2**: Output activated at a pre-defined "engine overspeed" speed level. See installation specific documents for details.
- **IS183 Speed switch 3**: Output activated at a pre-defined third speed level. In some applications duplicated and used in series with pressure switches for start of stand-by pumps. See installation specific documents for details.
- **IS184 Speed switch 4**: Output activated at a pre-defined fourth speed level. See installation specific documents for details.
- **IS190 Ready to clutch**: Indicates that the engine speed has reached the clutch-in speed window, and is ready for clutch-in.

- IS872 Engine ready for start: Output is active when the engine is in stand-by mode (engine standstill and reset) i.e. no start blocking is active.
- IS875 Start failure indication: Indicates that an engine start or engine slowturning has failed.
- IS1001 Fuel limiter active: Indicates that UNIC is limiting the fuel with one or several of the built-in fuel limiters.
- IS7331 Tripped to droop: This output is set high if the engine has been running in either true kW-control mode or isochronous load sharing mode, and certain conditions do not longer allow the engines to operate in these modes. The output is only set high if the trip to droop was automatically initiated, if droop mode was manually selected the output will not be set high.
- IS7323 Shutdown pre-warning: Output activated a pre-defined time before the engine will automatically shut down, to ensure possible manual activation of the system's Stop/ shutdown override input, in critical situations. The shutdowns related to here, are engine-related automatic shutdowns with built-in delays, not emergency stop signals or command signals.
- IS7602 Stop/shutdown status : As above, but also activated at normal stop. Output may be used to control the opening of the generator breaker and other devices needing a status indication from the engine. See also OS7602.
- IS7603 Stop/shutdown status 2: As IS7602. Output may be used to control the opening of the generator breaker and other devices needing a status indication from the engine. See also OS7603.
- IS7601-1 Speed window 1: Output activates when speed is within a pre-defined window. See installation specific documents for details.
- IS7601-2 Speed window 2: Output activates when speed is within a pre-defined window. See installation specific documents for details.
- XS7318 Slowturning pre-warning: Used to start auxiliaries such as generator bearing lubricating oil pump etc. Indicates 20 seconds before a periodic slowturning (engine in stand-by), that this automatically initiated procedure is about to occur. The output stays high also during the slowturning procedure. Not active before normal start since the automation system then has started necessary auxiliaries.
- NS881 Engine control system, minor alarm: Indicates that there is a minor failure in the UNIC system (not activating a shutdown of the engine). This can be due to a missing signal, abnormal supply voltage level or similar. This output signal comprises a signal-loop on the engine, including alarms from all electronic modules, i.e. MCM (one or two), ESM, PDM and WIP-1*.
- NS886 Engine control system, major failure: Indicates that there is a major failure in the UNIC system, which activates a shutdown of the engine. This can be due to a module failure, an internal CAN-communication failure, a power failure or similar. Each time a major failure activates, this output toggles low/high for a pre-set time.
- NS885 Common engine alarm: Indicates that an alarm (any alarm or shutdown initiated by an engine sensor) is active. Each time a new engine alarm activates, this output toggles low/high for a pre-set time.
- OS799 Grid breaker open command: The engine control system has detected a grid related disturbance and requests to disconnect the local network from the utility (i.e. kW control mode is no longer feasible).
- OS7315 Load reduction request/indication: A signal sent to the power management system, which requests reduction of the engine load. The signal stays active as long as there is an abnormal engine condition which sets limits to the max. power output of the engine. The load should be reduced according to levels defined by the analogue output signal IT797 Max available power.

- OS7602 Generator breaker open command: This output is set high when UNIC requests the generator breaker to open.
- OS7603 Clutch open command: This output is set high when UNIC requests the clutch to open. Same physical output as above signal.
- HS723 Emergency stop: The part of the emergency stop loop to be wired outside engine.
- CV223 Pre-lubrication pump control: A signal (based on oil pressure and engine speed) indicating the need for start of the pre-lubrication pump.
- CV432-1 HT valve open control : Signal goes high when UNIC controls the valve to move towards open position.
- CV432-2 HT valve close control: Signal goes high when UNIC controls the valve to move towards closed position.
- CV493-1 LT valve open control: Signal goes high when UNIC controls the valve to move towards open position.
- CV493-2 LT valve close control: Signal goes high when UNIC controls the valve to move towards closed position.
- CV110 FO stand-by pump start: Signal comprising pressure and speed information indicating the need for starting auxiliary equipment. See installation specific documents for details.
- CV210 LO stand-by pump start: Signal comprising pressure and speed information indicating the need for starting auxiliary equipment. See installation specific documents for details.
- CV410 HT jacket water stand-by pump start: Signal comprising pressure and speed information indicating the need for starting auxiliary equipment. See installation specific documents for details.
- CV420 Seat cooling water pump start: Signal comprising pressure and speed information indicating the need for starting auxiliary equipment. See installation specific documents for details.
- CV420-2 Seat cooling water stand-by pump start: Signal comprising pressure and speed information indicating the need for starting auxiliary equipment. See installation specific documents for details.
- CV460 LT water stand-by pump start: Signal comprising pressure and speed information indicating the need for starting auxiliary equipment. See installation specific documents for details.
- CV6500 Wetpac system pump/heater control: For start/stop control of the Wetpac water pump unit, in case of embedded Wetpac functionality in UNIC.

23.7.3 Analogue inputs

v2

- UT793 Generator load : The measured engine load. Feedback signal used by the internal speed/load controller, when in kW-mode. The engine load signal is also used for load-dependent mapping of the speed controller dynamics, and a number of other maps & algorithms.
- OT190 Analogue speed reference: Analogue reference of the engine speed, used by the internal speed controller. This is an optional feature, only used in special applications.
- OT795 kW reference: This analogue signal represents the load reference, i.e. the target load used in true kW-control mode.
- OT160 Analogue synchroniser: Analogue +/- 5 V bias signal of the engine speed reference, used by the internal speed controller at synchronisation. This is an optional feature, only used in special applications.

- **IT796 Asymmetric load sharing bias**: This input will bias the load sharing between two or more engines. This manual load bias might be needed e.g. in case there are reasons to reduce to output of a specific engine due to a restriction or failure which is not or can not be measured be the engine's safety system.
- **UT794 Generator load 2**: This analogue signal represents the load feedback from a generator connected to an engine through the PTO.

23.7.4 Analogue outputs

v7

- **SI196 Engine speed**: Signal proportional to the engine speed.
- **SI518 TC A speed**: Signal proportional to the A-bank turbocharger speed.
- **SI528 TC B speed**: Signal proportional to the B-bank turbocharger speed.
- **IT797 Max available power**: Signal defining the engine's max available power output. The signal is a percentage value of the rated power of the engine, and used during abnormal engine conditions, when the available output power is limited. The binary OS7315 Load reduction request/indication output is active under such conditions, and the power management system must reduce the engine output accordingly.
- **GT165 Fuel rack position**: Signal indicating the fuel rack position, which in some cases is a replacement for the engine load signal. Application specific use.
- **PT601-2 Charge air pressure, engine inlet**: Signal indicating the charge air pressure, which in some cases is a replacement for the engine load signal. Application specific use.
- **CT7001 Engine load for propulsion control**: Signal internally calculated and equivalent to engine load level. Application specific use.
- **CV432 HT water thermostat control**: Direct control signal for the HT water thermostatic valve.
- **CV493 LT water thermostat control**: Direct control signal for the LT water thermostatic valve.

23.7.5 Frequency outputs

v2

- **ST173 Engine speed**: Pulse train signal from ESM proportional to the engine speed.
- **SE167 Engine speed 1 for external governor (optional)**: Sensor signal to be used for external speed controller or similar device.
- **SE168 Engine speed 2 for external governor (optional)**: Sensor signal to be used for external speed controller or similar device.

23D. Introduction to WECSplorerUT (Optional equipment)

This manual is used as a guideline for the WECSplorerUT tool. It describes the functionality of the tool briefly. It is recommended that the user has proper training for the specific system type that is intended to be monitored/tuned with this tool.

23D.1 Overview of WECSplorerUT software tool

v1

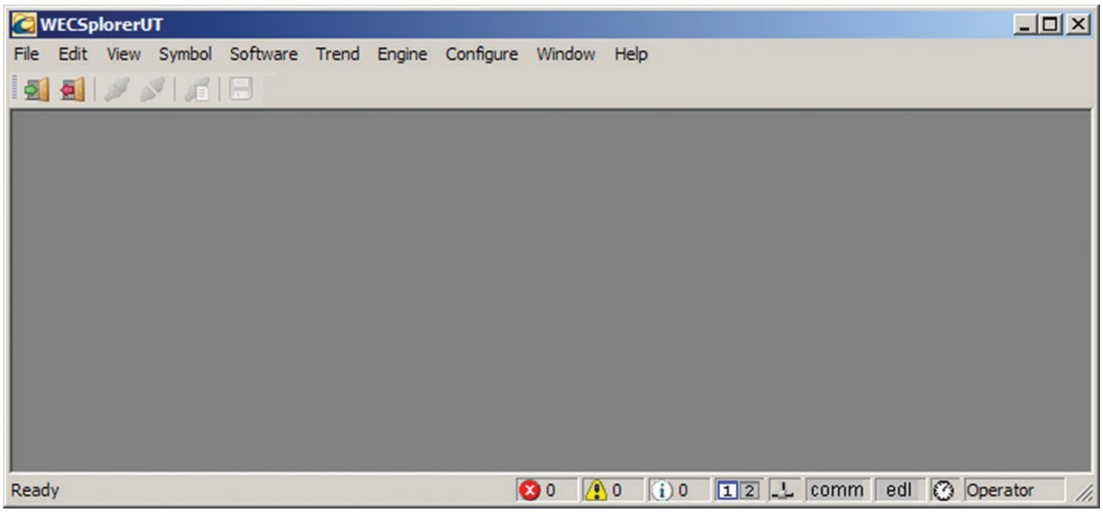


Fig 23D-1 Main page

WECSplorerUT is a Microsoft Windows program used for downloading, updating, monitoring and troubleshooting UNIC automation systems. At present WECSplorerUT supports the following control system modules:

- MCM–10
- MCM–11
- CCM–20
- IOM–10
- LDU–10
- LDU-20
- ESM-20

WECSplorerUT communicates with the control system through WE-CAN+, TCP/IP or CANopen. By issuing commands over these links, WECSplorerUT reads information from and writes information to the control system modules.

23D.1.1 System requirements for the WECSplorerUT software tool

v1

Operating System

- Microsoft Windows XP Pro Eng (service pack 2 or later)

Hardware

- Minimum CPU:1,5 GHz AMD or Intel
- Minimum Memory: 1 GB
- 32 MB video card
- 1024 x 768 resolution with at least 256 colors

CAN Communication

Before running WECSplorerUT, insert the LapCan II card and DNOPto cable into the computer, or the Kvaser USB Leaf Pro cable.

Fig 23D-2 LapCan II

Fig 23D-3 DNOpto cable

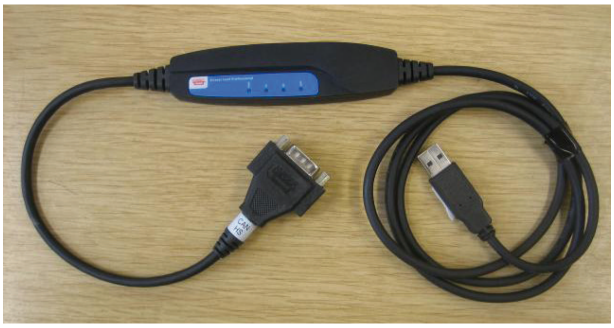


Fig 23D-4 Kvaser USB Pro Leaf cable

23D.1.2 Applying for an user account

v1

- Before you can use the software, you need to apply for an user account.
- Send the following information by E-mail to wecs@wartsila.com

  WECSplorerUT registration:

  - Installation name
  - System number(s)
  - E-mail address
  - Phone and fax number of the installation
  - Order number

  After sending the E-mail you will receive:

  - user name, password and checksum
  - latest project files for the installation

  Before we send the system software package, the installation must be commissioned.

23D.1.3 Adding a new user account

v1

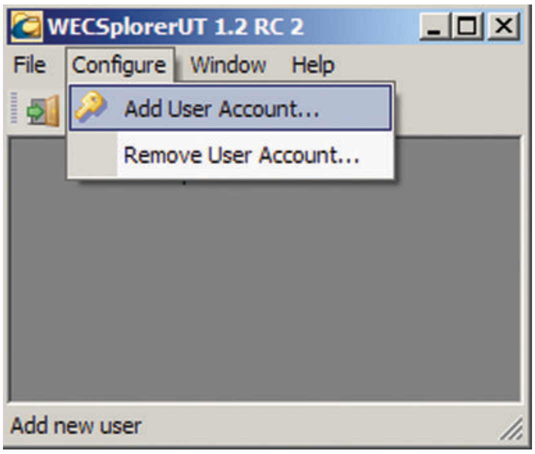


Fig 23D-5 To add an user account

Procedure

1 **Select from Menu bar Configure — Add User Account**

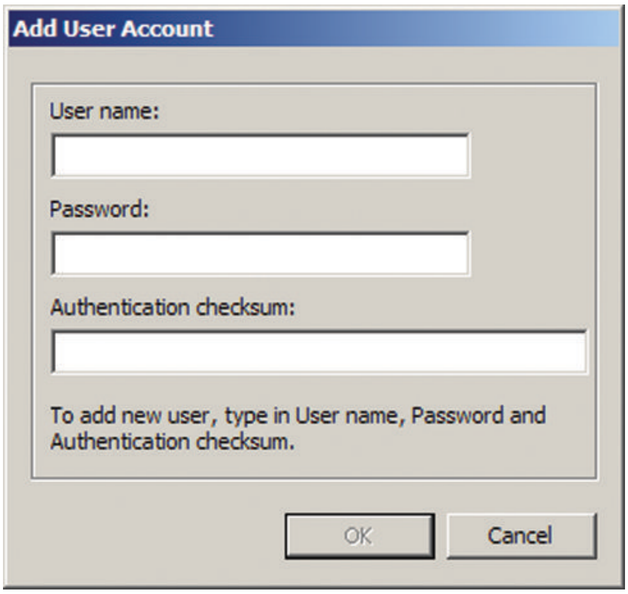


Fig 23D-6

2 **Fill in User name, Password and Authentication checksum.**

3 **Click OK .**

23D.1.4 Log in

v1

Procedure

1 **Select File — Login**

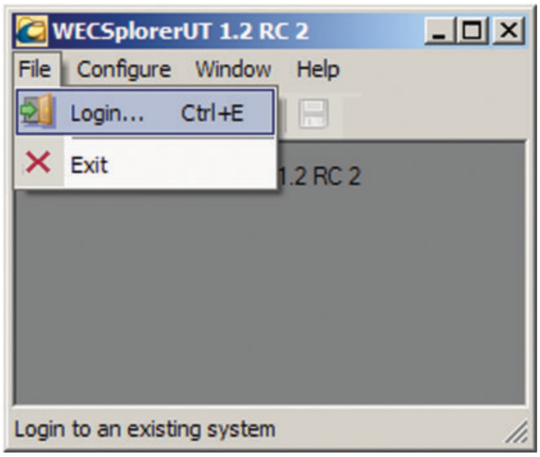


Fig 23D-7 Log in

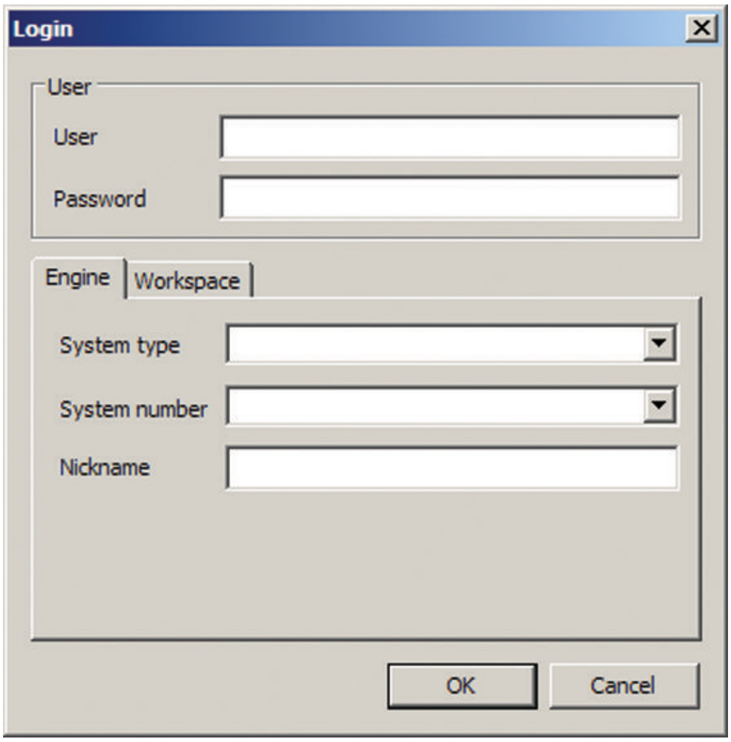


Fig 23D-8

a **Type your Username, in the User box.**

b **Type your Password, in the Password box.**

c **Click OK**

NOTE

The user name and password are case sensitive!

23D.1.5 Importing system specific software

v1

Procedure

1 **To start using WECSplorerUT software, import the specific system software.**

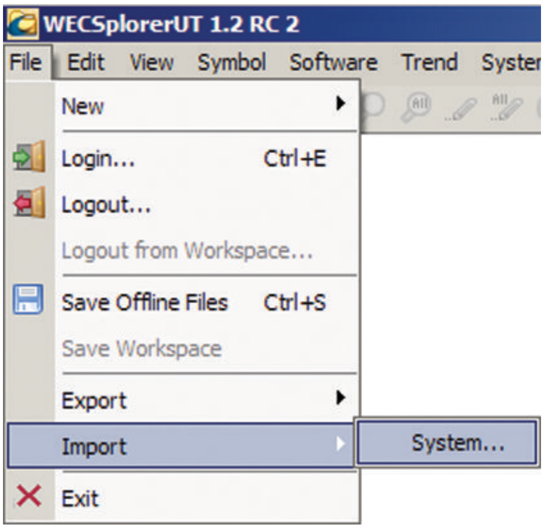


Fig 23D-9

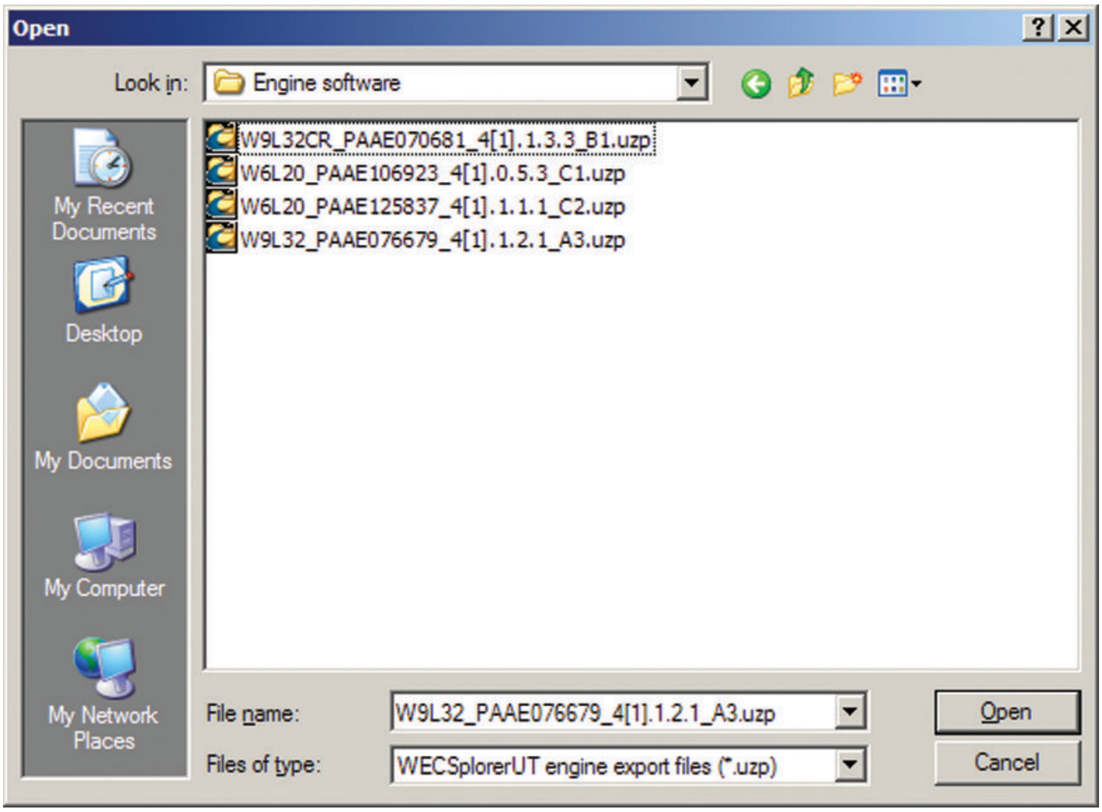


Fig 23D-10

a Select the system specific software to be imported from your hard drive.

One package per system of *.uzp format needs to be imported .

b Click Open.

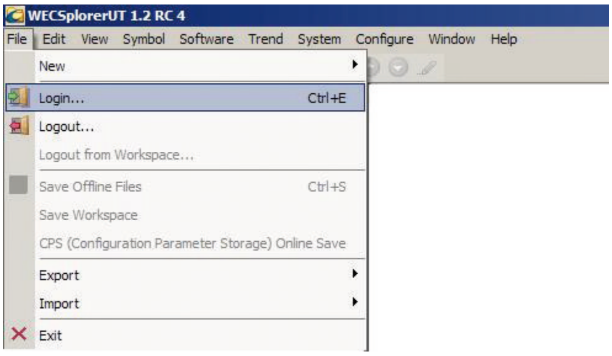


Fig 23D-11 Login

2 **Select File Login ...**

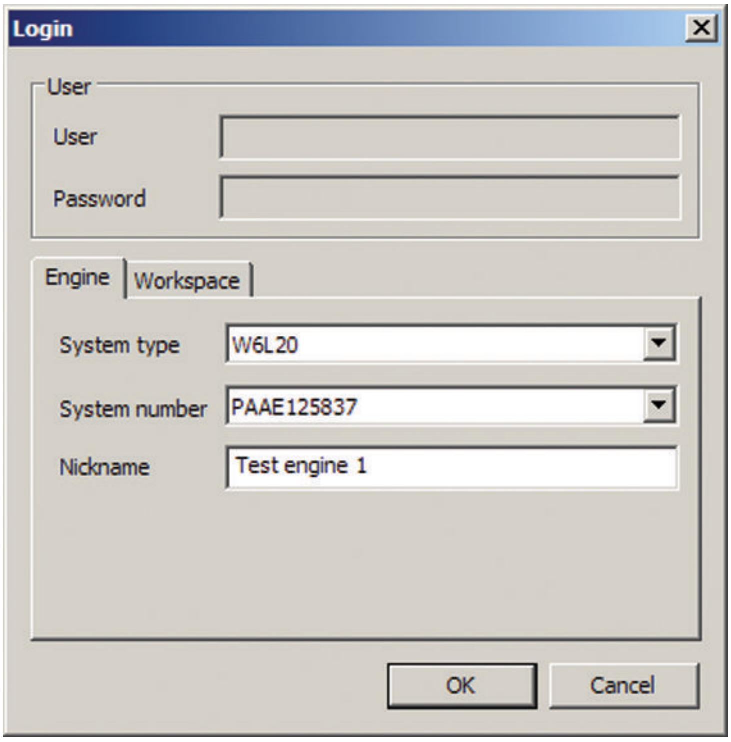


Fig 23D-12

3 **Select System type.**

4 **Select System number.**

5 **ClickOK.**

After successful login, the application opens the symbol tree structure.

A session starts when the user logs in and the session stops when the user logs out. All changes made in offline mode are stored permanently when the user selects logout and save. See Log out for more details about saving and logging out.

	Description
User	User name of the user
Password	Password of the user
System type	Engine or system type
System number	Engine or system number
Nickname	Nickname for the system.

23D.1.6 Log out

v1

NOTE

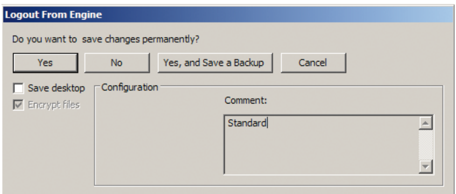
Desktop save is system-specific, not user-specific.

NOTE

Restoring the desktop and STS-tree is user-level dependant.

NOTE

When you want to store the changed or updated system parameters to PC, select **File Save,** or select **File Logout,** and confirm with **Yes.**



Choose **YES** to store your changes to the computer.

Fig 23D-13 Log out from the system

View	Description
Yes (save changes)	Saves the changes to the computer.
No (do not save changes)	All changes are lost.
Yes and Save a Backup	The user is asked to name the backup version. (Default backup folder is date-time). The changes are saved.
Cancel	Logout execution is cancelled.
Save desktop	If selected the current layout of desktop becomes default.

23D.1.7 Exporting the system software

v1

NOTE

You cannot export the system package that you are currently logged into.

Procedure

1 **Select File—Export—System**

Fig 23D-14 Export system

a **Select System type**

b **Select System number**

c **Click Export**

The command exports the selected system software to an UZP file.

The UZP file can be imported back to the WECSplorerUT using File-Import-System function which overwrites later changes.

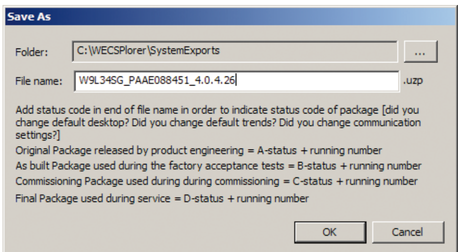


Fig 23D-15 Export

2 **Click OK.**

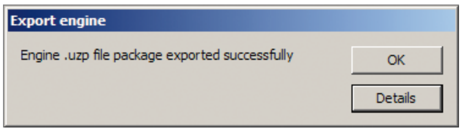


Fig 23D-16 Export system confirmation

3 Click OK.

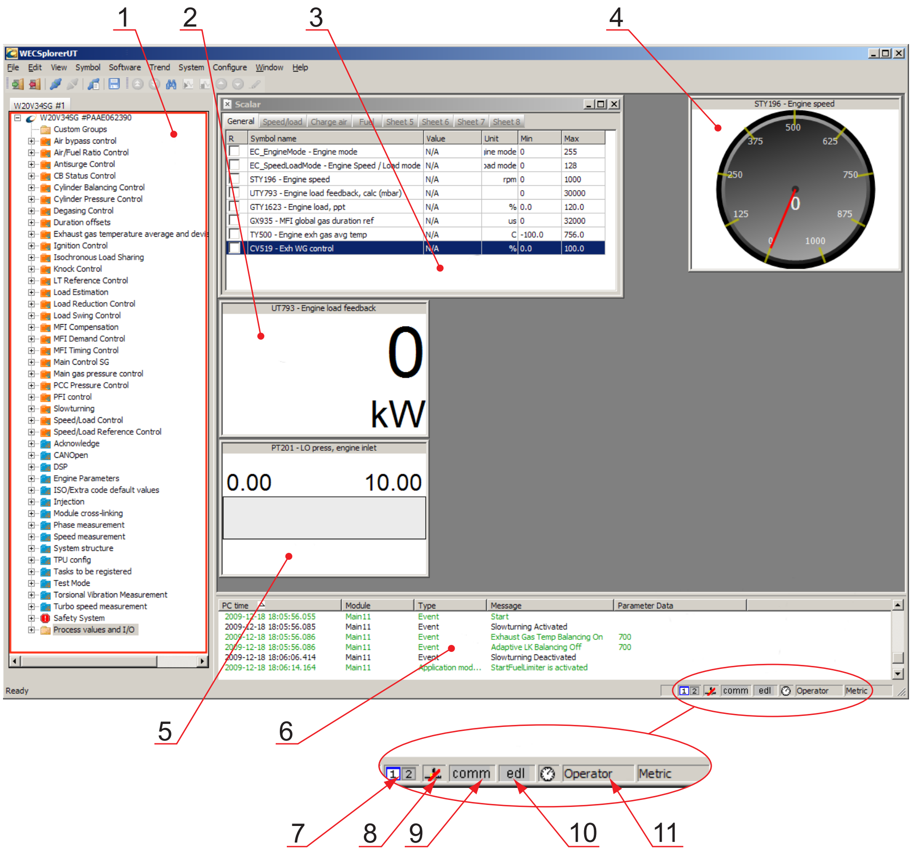
Fig 23D-17 Safety check

4 Select Yes to remove the system from the computer.

5 Select No to keep the system on the computer.

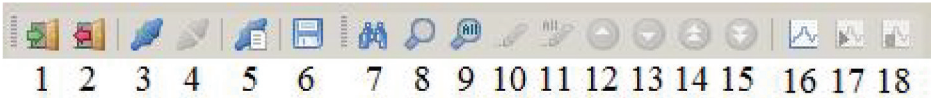
23D.1.8 Main window of WECSplorerUT

v1



1 Symbol tree structure (STS)
2 Value Monitor
3 Scalar window
4 Gauge Monitor
5 Bar Monitor
6 System diagnostic log (EDL)
7 Desktop indicator
8 Indicator for Online/Offline mode
9 Indicator for CAN communication
10 EDL indicator icon
11 Indicator for user level

Fig 23D-18 Main window



1 Login
2 Logout
3 Go online with system
4 Go offline with system
5 System communication settings
6 Save the current session to the working directory
7 Find
8 Read from file or from system in online mode
9 Read all from file or system in online mode
10 Write to file or system in online mode
11 Write all to file or system in online mode
12 Increase value
13 Decrease value
14 Accelerated increase of value
15 Accelerated decrease of value
16 Trend selected symbols
17 Trend option
18 Trend option

Fig 23D-19 Main Toolbar

23D.1.9 Online or Offline mode

v1

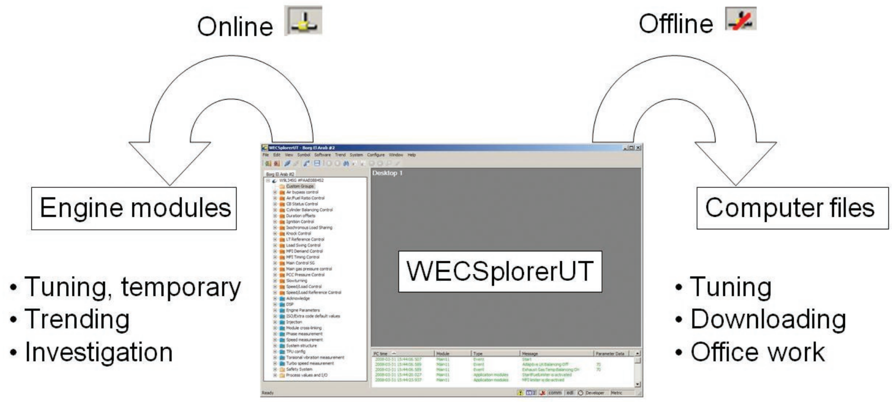


Fig 23D-20 Online or Offline

Once logged into the system, you are in Offline mode, allowing changes to be made to files existing on the Computer.

To monitor, trend or make temporary changes to the system, select the Online mode.

To use the Online mode, the correct system package and communication settings need to be selected. For more information see Setting up communication between computer and the system.

After communication is established, Online mode can be selected from the menu via Engine –> Connect, or by clicking the connect icon on the toolbar.

Term	Description
Offline	All work is done to files in PC, can be used for checking safety settings like set points for alarms, shutdown and trip limits. When downloading software the system needs to be Offline.
Online	Used for testing parameters temporary and for trending of the systems running data. All changes done to parameters in online mode are “temporary”, they will be reset when a power reset of the control system is done.

23D.1.10 Symbol menu

v1

The following commands are available from the symbol menu

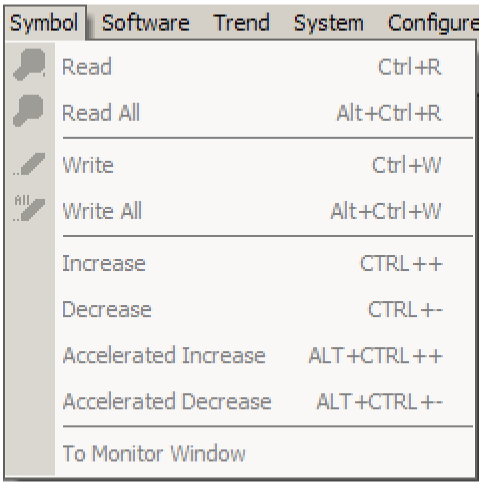


Fig 23D-21 Symbol menu

23D.1.10.1 Reading symbols

v1

Symbol value reading can be done both in offline and online mode. Read can be done for a single value, or for multiple values. Reading is possible always when a readable symbol is active in symbol window.

Reading operation can be executed from

- Symbol menu
- Toolbar button

  for reading single symbol, or toolbar button

  for reading multiple symbols.
- Shortcuts <ctrl> + R for reading or <ctrl> + <alt> + R for read all

23D.1.10.2 Writing software symbol values v1

Symbol value can be written both in offline and online mode. Write can be done for a single value, or for multiple values. Writing is possible when a writable symbol is active in symbol window. Write operation can be executed from:

- Symbol menu
- Toolbar button

  for write, and toolbar button

  for write all
- Shortcuts <ctrl> + W for write or <ctrl> + <alt> + W for write all

Write vs Write all

Write all, writes all changed values to the system (if in **Online mode**) or to file (if in **Offline mode**). Current selection does not matter for Write all command. Changed values are indicated with yellow background in symbol window.

Write command writes selected changed value.

To change a value select symbol and type in a new value. Press enter. The cell turns yellow, this indicates that the value has been changed “on the screen”. Selecting the cell and pressing Write button stores the value on the system or in the computer depending on whether you are in Online or Offline mode.

23D.2 Setting up communication between the computer and the system v1

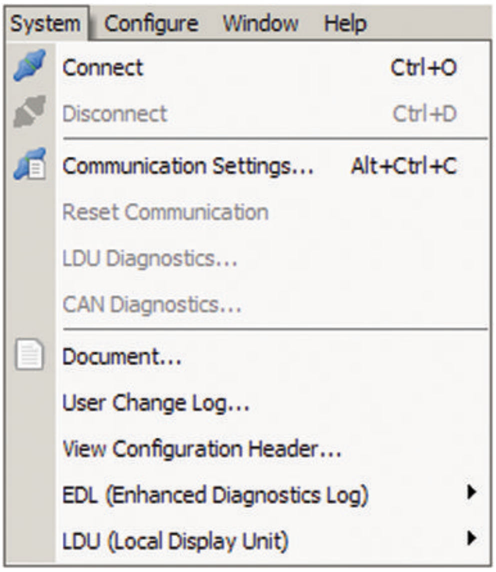


Fig 23D-22 System communication settings

To configure the communication settings, select **System - Communication Settings...**.

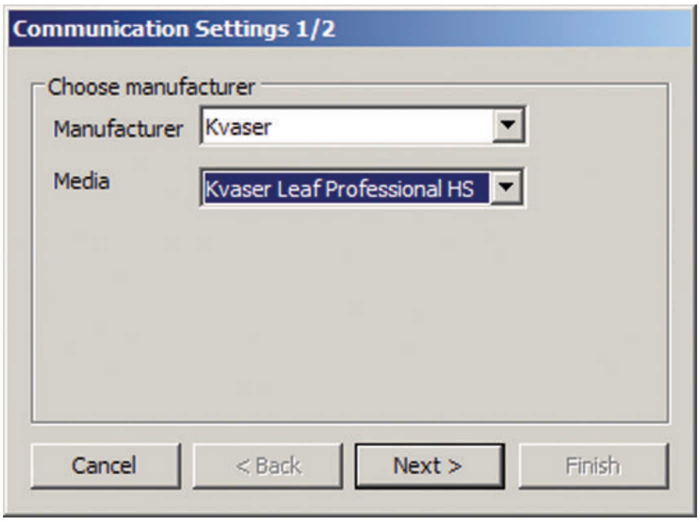


Fig 23D-23 Communication Settings 1/2

Procedure

1 **Set up the connection between the computer and the system.**

a Select the manufacturer of the communication hardware in the drop-down list.

The options are limited by system configuration. The most common options are Kvaser and LDU: TCP/IP.

The Media field displays devices successfully connected to the computer.

b Click Next to open the Communication Settings 2/2 window.

This window displays detailed settings for the selected option. Change the settings, if required.

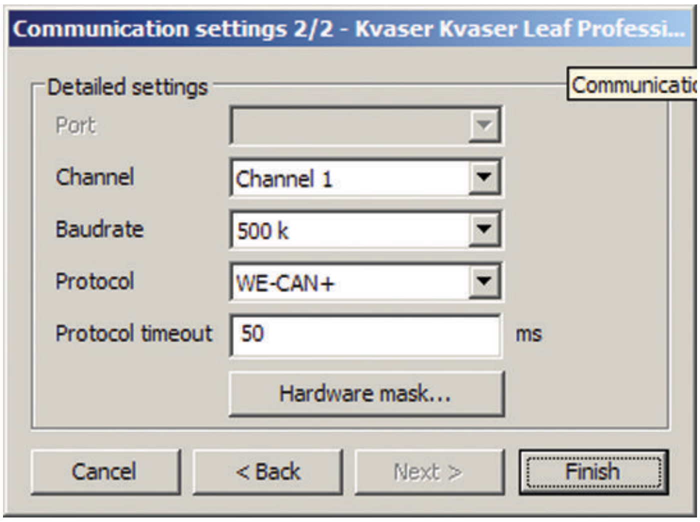


Fig 23D-24Communication Settings 2/2

c Select the channel.

d Select the baudrate.

e Select between CANopen, WE-CAN+, CANopen and WE-CAN+.

f Click Finish.

With **Hardware mask...** you can configure message filtering settings for the CAN device.

NOTE
Communication has now been setup between the system and the computer. But you are still offline to the system.

2 **Check that the CAN communication works.**

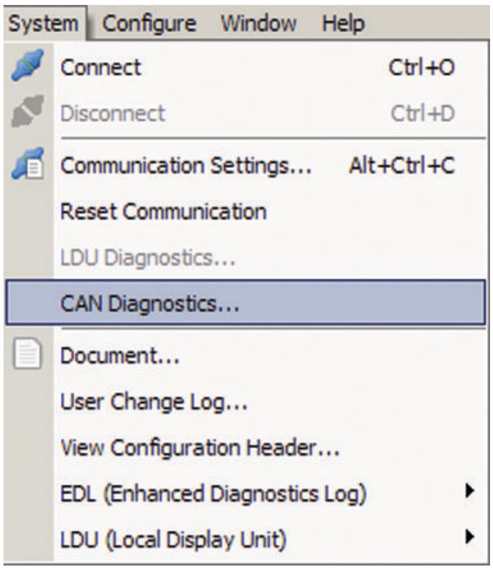
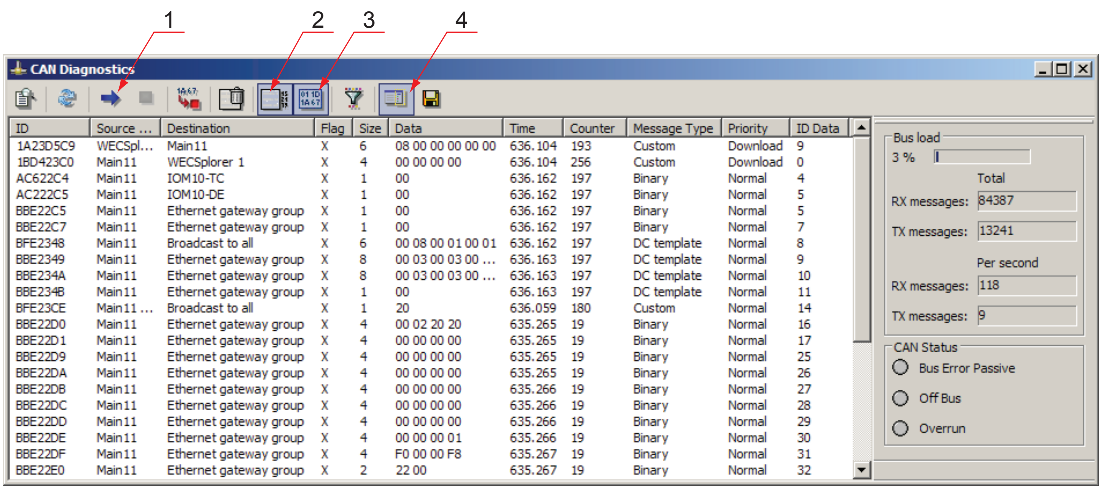


Fig 23D-25 CAN diagnostics

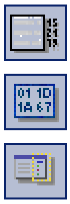
Select **System - CAN Diagnostics** to open the **CAN Diagnostics...** dialog.



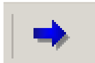
1 Start diagnostics
2 Toggle fixed mode
3 Toggle hexadecimal display
4 Diagnostics information

Fig 23D-26 CAN Diagnostics

a **Activate the following buttons:**



b **Click the blue arrow**



in the toolbar to start diagnostics.

c **If CAN traffic is detected on the BUS, the CAN Diagnostics table displays CAN communication data.**

3 **If LDU module is present, it is possible to configure communication as TCP/IP. See** *Fig 23D-23*.

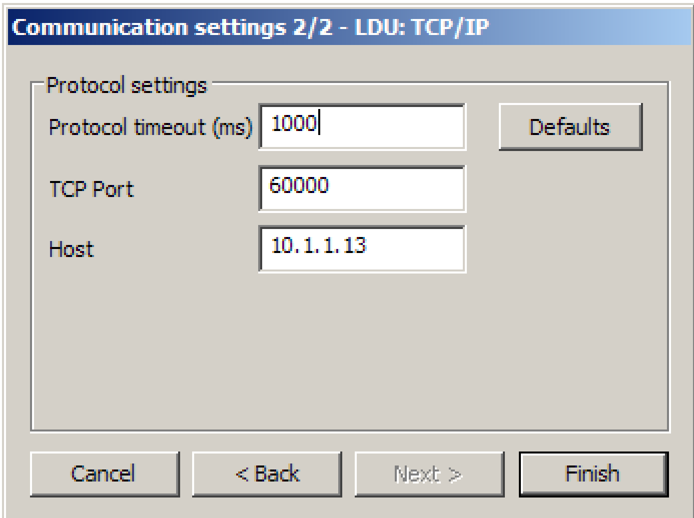


Fig 23D-27 LDU: TCP/IP communication settings

NOTE	
ℹ	Your antivirus or firewall software may prevent outgoing connection using TCP/IP. Ensure that WECSplorerUT has access rights through your antivirus and/or firewall software.

a **Select LDU: TCP/IP in the Manufacturer drop-down list. See** *Fig 23D-23*.

b **Click Next.**

c **Configure Protocol settings.**

Configure protocol time-out, host and TCP/IP port.

d **Click Finish.**

23D.3 Downloading software

v1

Prerequisites

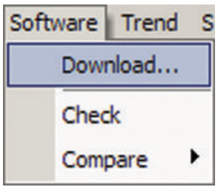


Fig 23D-28 Software download

- Ensure that you are connected to the system.
- Ensure that the communication is working.
- Ensure that you are in offline mode.

CAUTION

Do not download software to a running system.

NOTE

It is only possible to download software and configuration in offline mode.

Procedure

1 **Download software and configuration to the system.**

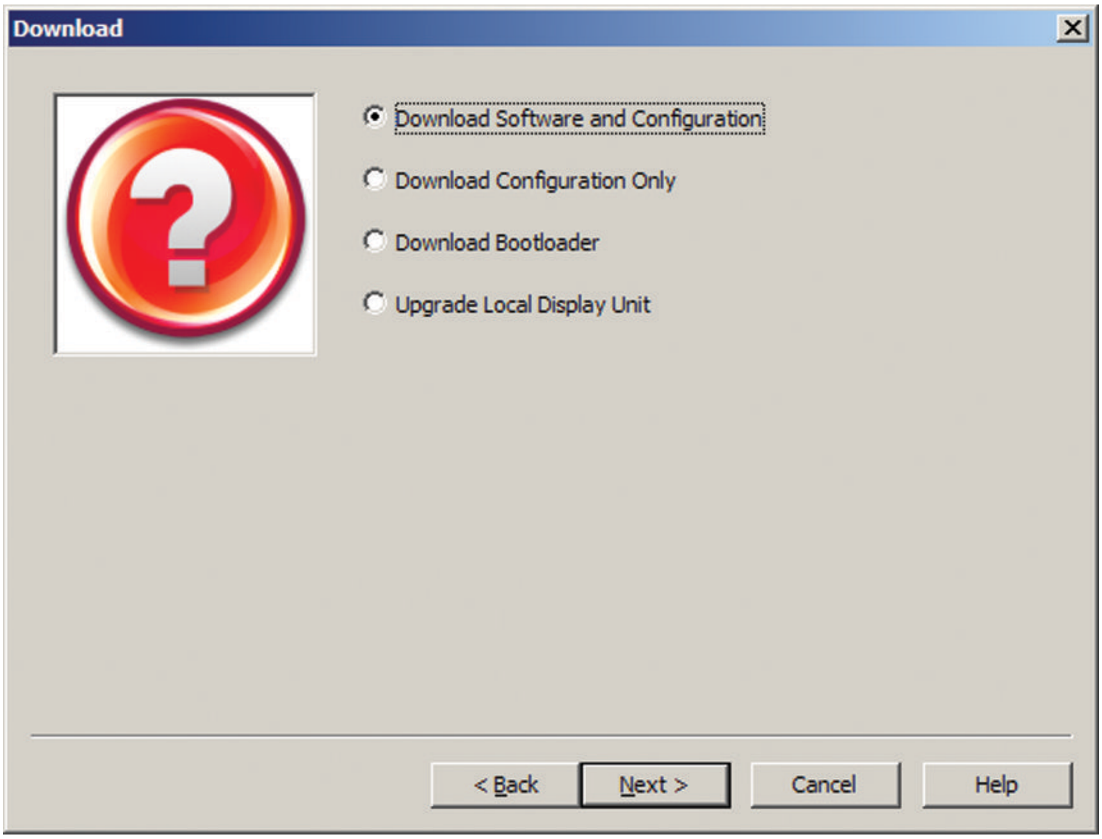


Fig 23D-29 Download Software and Configuration

a Select Software - Download... to open the Download dialog.

Software configuration and download must be used for new and empty modules.

b Select Download Software and Configuration and click Next.

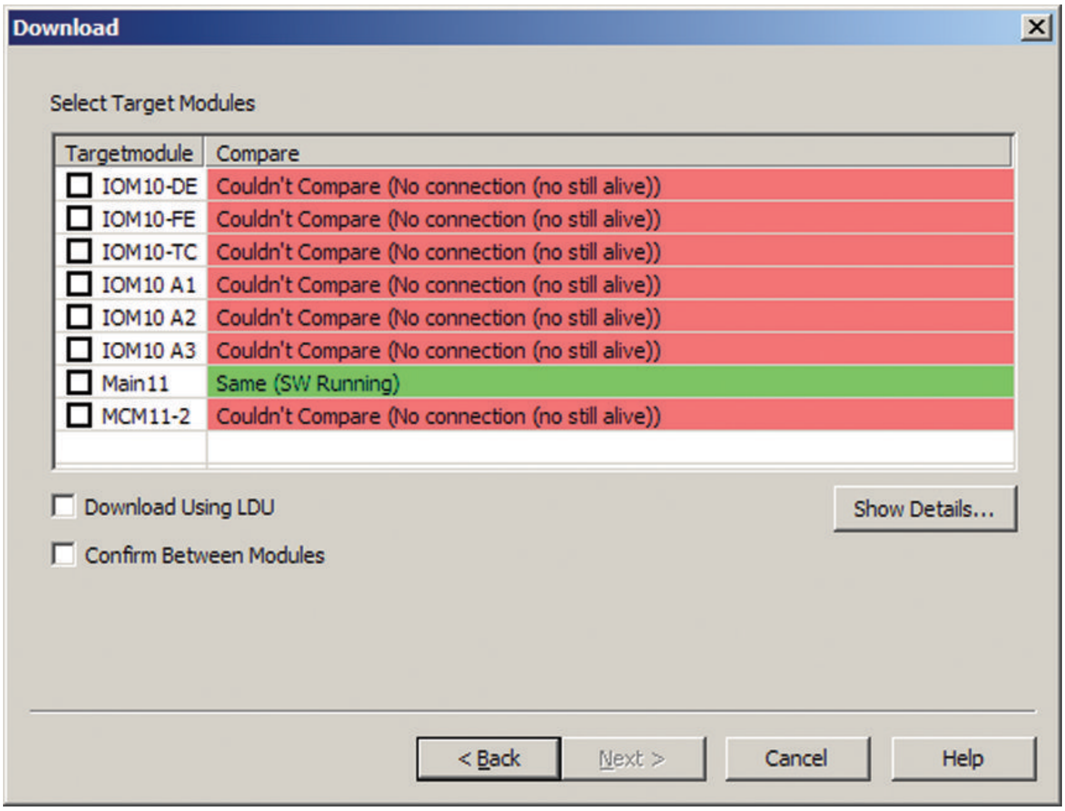


Fig 23D-30Selecting target modules for software download

c **Select one or more target modules for software download.**

The list displays all system modules. In the following example it is possible to download software only to the MCM–11 module.

d **Click Next.**

2 **Download only configuration to the system.**

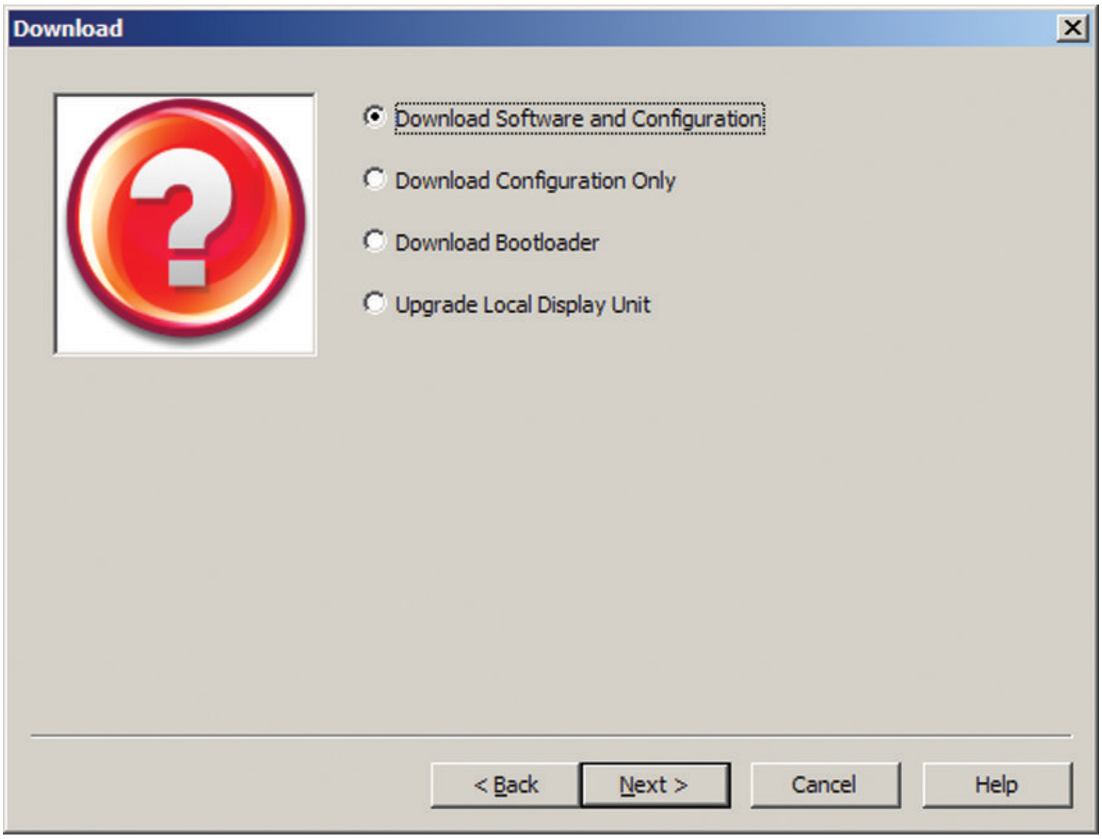


Fig 23D-31 Downloading Configuration

Configuration download can be used when storing symbol changes that have been done.

a Select Download Configuration Only and click Next.

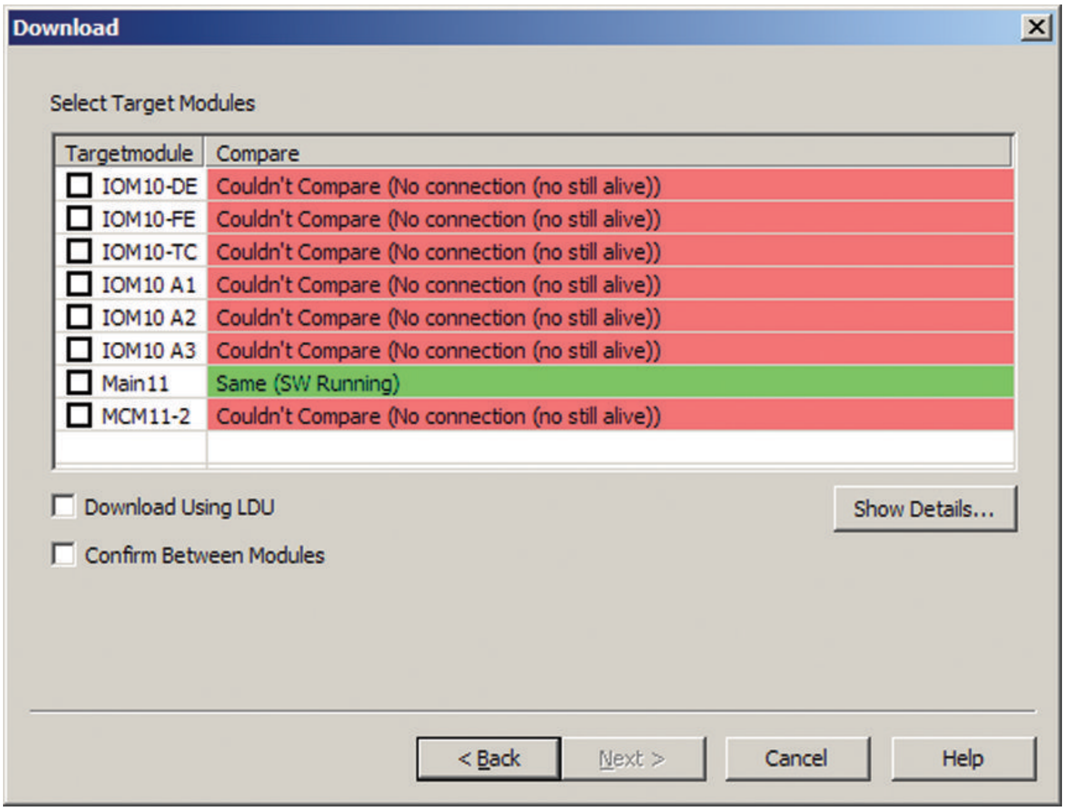


Fig 23D-32Selecting target modules for configuration download

b Select one or more target modules for configuration download.

The list displays all system modules. In the following example it is possible to download configuration only to the MCM–11 module.

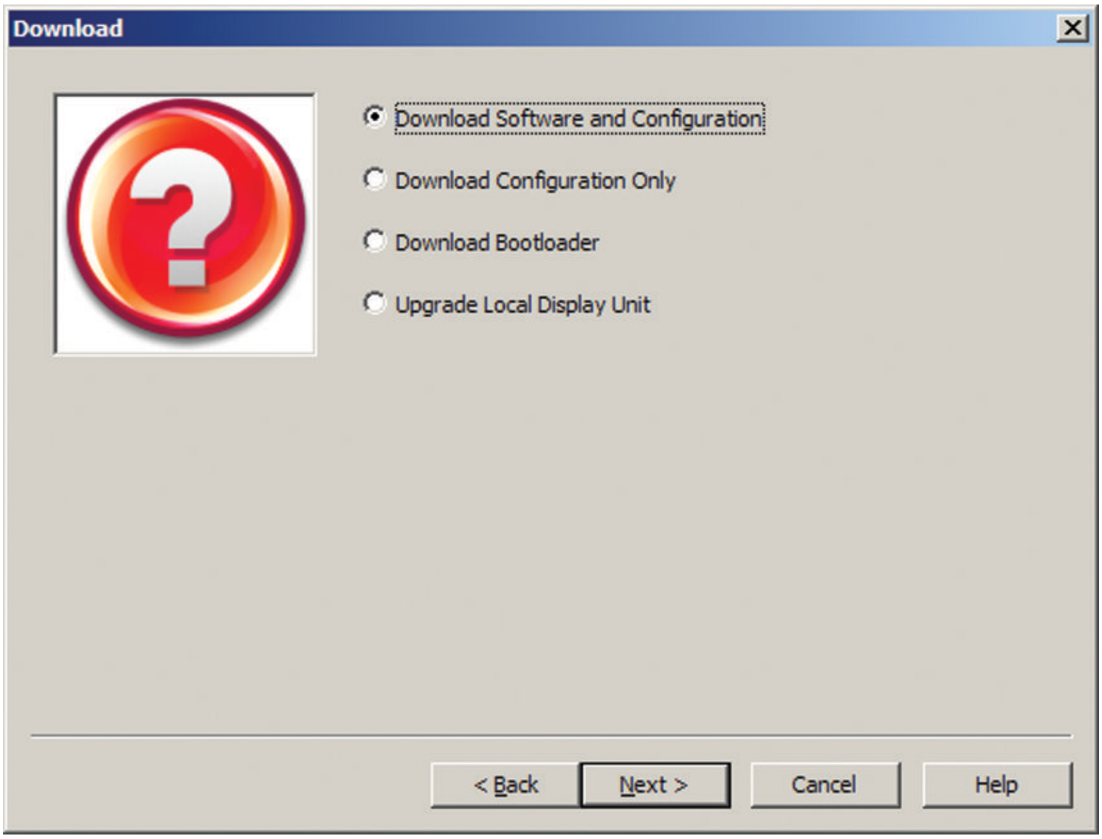


Fig 23D-33 Download Bootloader

3 **Downloading bootloader is only needed, if new empty module is installed on the engine.**

a **Select Download Bootloader in the main Download dialog.**

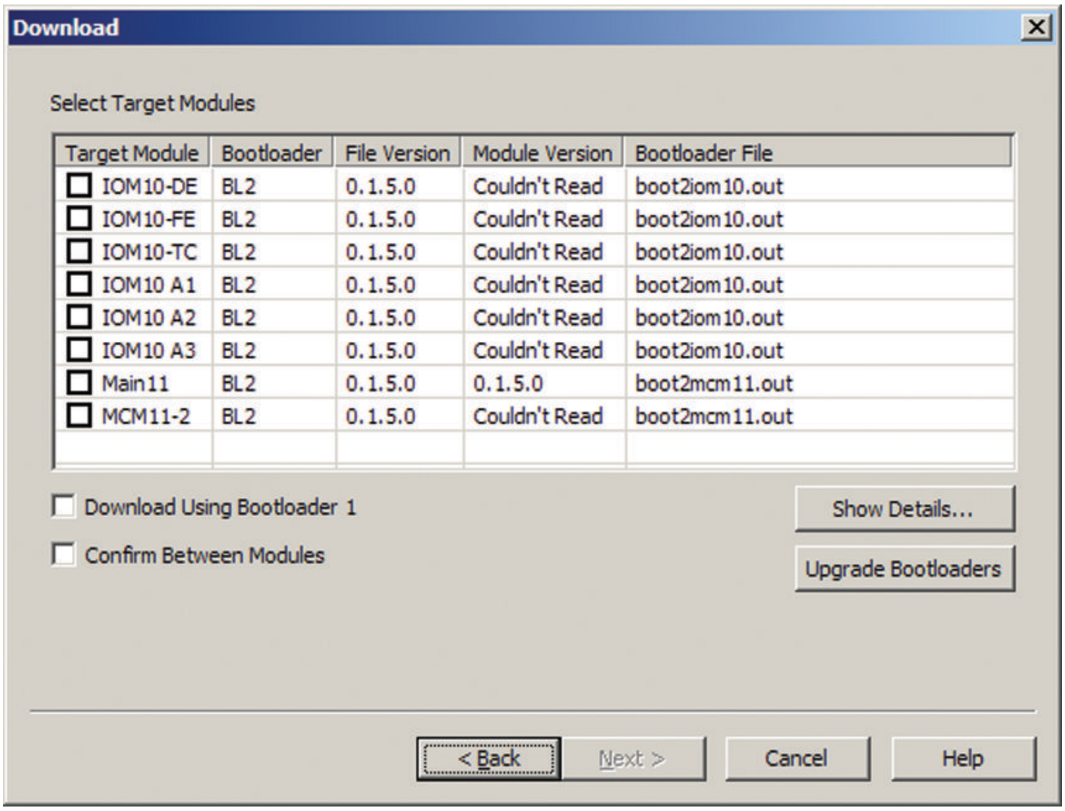


Fig 23D-34Bootloader download

b **Select one or more target modules.**

c **Click Next.**

4 **Upgrade LDU.**

Download software to the LDU located on the engine.

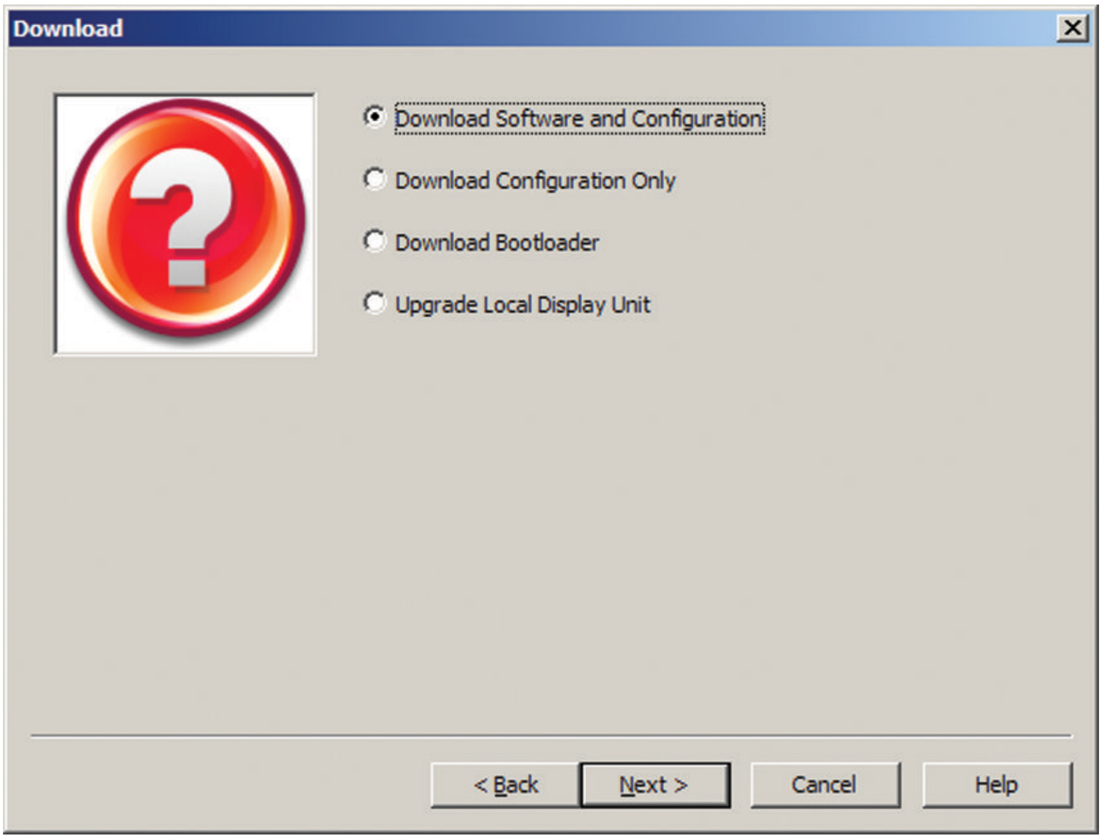


Fig 23D-35 Upgrade Local Display Unit

a **Select Upgrade Local Display Unit in the main Download dialog.**

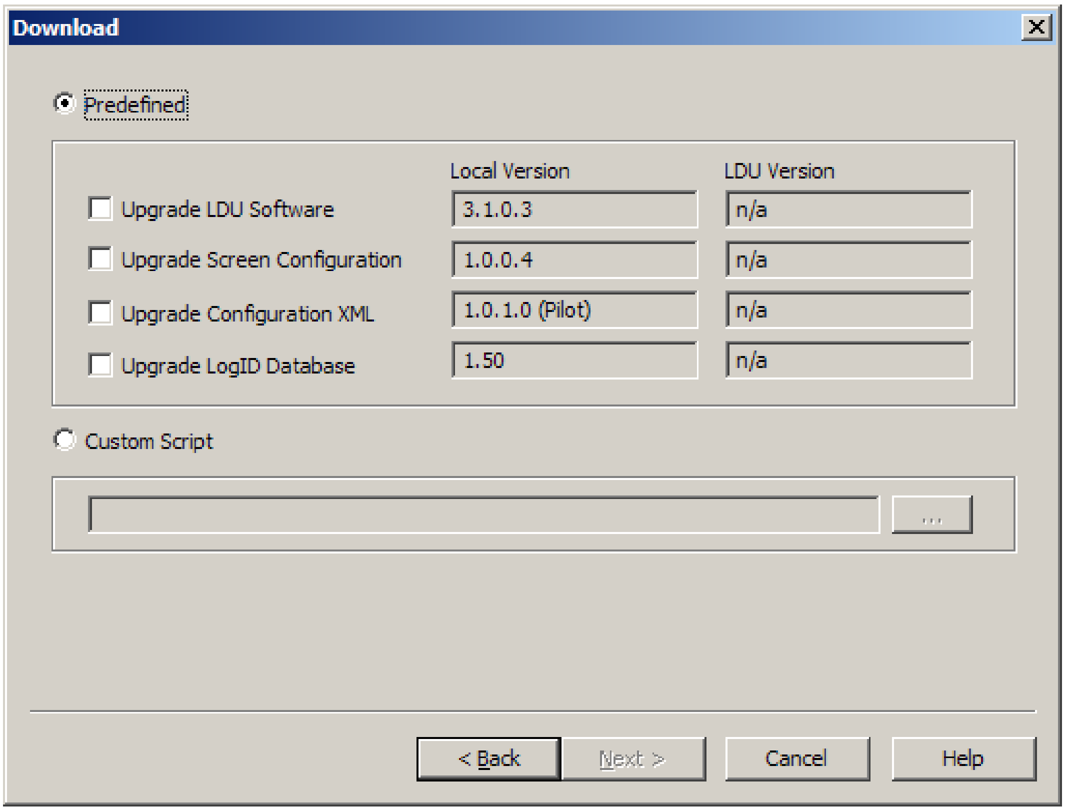


Fig 23D-36Upgrading LDU

b **Check one or more software modules to be downloaded.**

- Update all versions that do not match between local version and LDU version.
- If you use Ethernet connection, you can select all required versions and update them at the same time.
- If you use CAN connection, it is recommended to update each file separately, because of longer download time.

c **Click Next.**

23D.4 Entering the online mode v1

Prerequisites

Before you start:

- Make sure that the computer is connected to the system.
- Make sure that the communications settings have been configured.

For more information see *section 23D.2*.

Procedure

1 **Select System - Connect....**

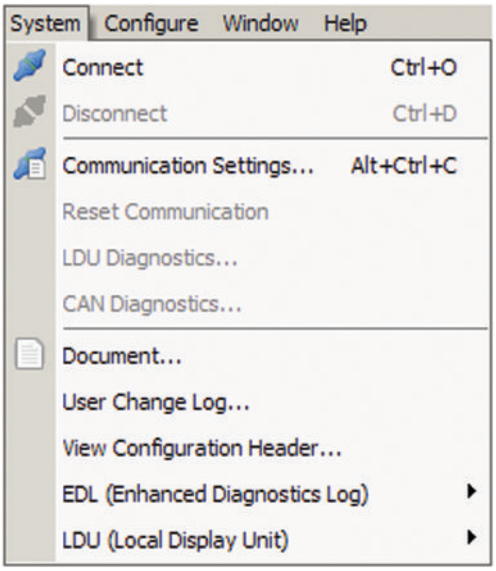


Fig 23D-37 System connect

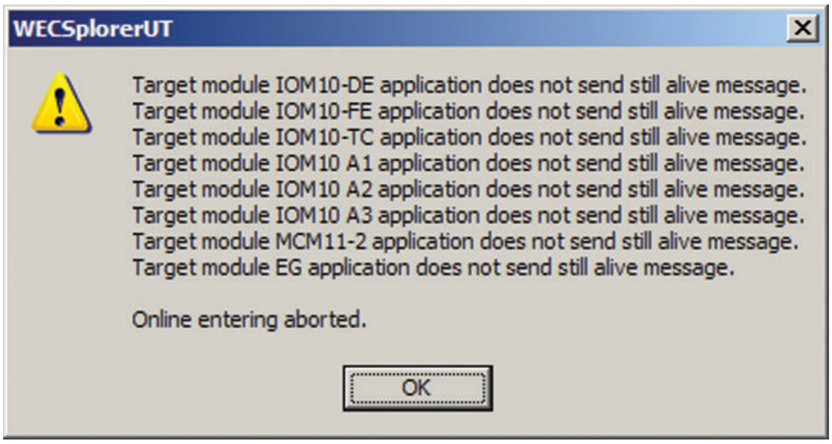


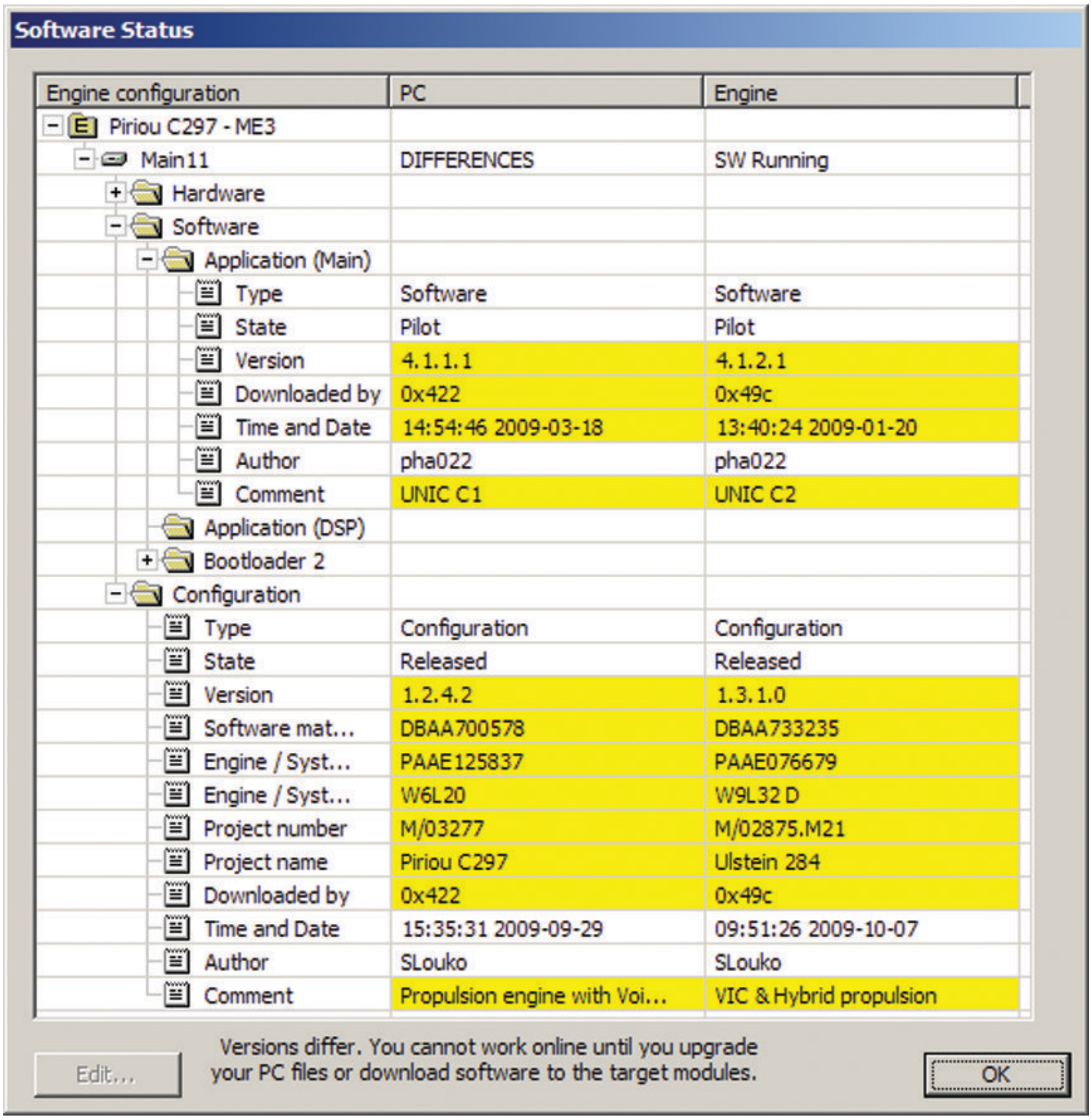
Fig 23D-38 Connecting failure

NOTE

Online entering fails, if any of the system module links are broken or not connected.

2 **Check the software status.**

Before entering online mode, software versions and symbol differences are compared.


Software Status

Engine configuration	PC	Engine
Piriou C297 - ME3		
Main11	DIFFERENCES	SW Running
Hardware		
Software		
Application (Main)		
Type	Software	Software
State	Pilot	Pilot
Version	4.1.1.1	4.1.2.1
Downloaded by	0x422	0x49c
Time and Date	14:54:46 2009-03-18	13:40:24 2009-01-20
Author	pha022	pha022
Comment	UNIC C1	UNIC C2
Application (DSP)		
Bootloader 2		
Configuration		
Type	Configuration	Configuration
State	Released	Released
Version	1.2.4.2	1.3.1.0
Software mat...	DBAA700578	DBAA733235
Engine / Syst...	PAAE125837	PAAE076679
Engine / Syst...	W6L20	W9L32 D
Project number	M/03277	M/02875.M21
Project name	Piriou C297	Ulstein 284
Downloaded by	0x422	0x49c
Time and Date	15:35:31 2009-09-29	09:51:26 2009-10-07
Author	SLouko	SLouko
Comment	Propulsion engine with Voi...	VIC & Hybrid propulsion

Edit...

Versions differ. You cannot work online until you upgrade your PC files or download software to the target modules.

OK

Fig 23D-39 Checking the software version

In the software status window software version differences are highlighted in yellow color. If PC software version is different from system version online entering is aborted.

If there are differences, you must update the software in the computer.

NOTE

If new software is needed, contact wecs@wartsila.com for the latest software.

If the versions match, you can continue by clicking OK.

3 **Check the symbol value differences.**

In the Symbol Value Differences window, you can see the differences that exist between the computer and the system.

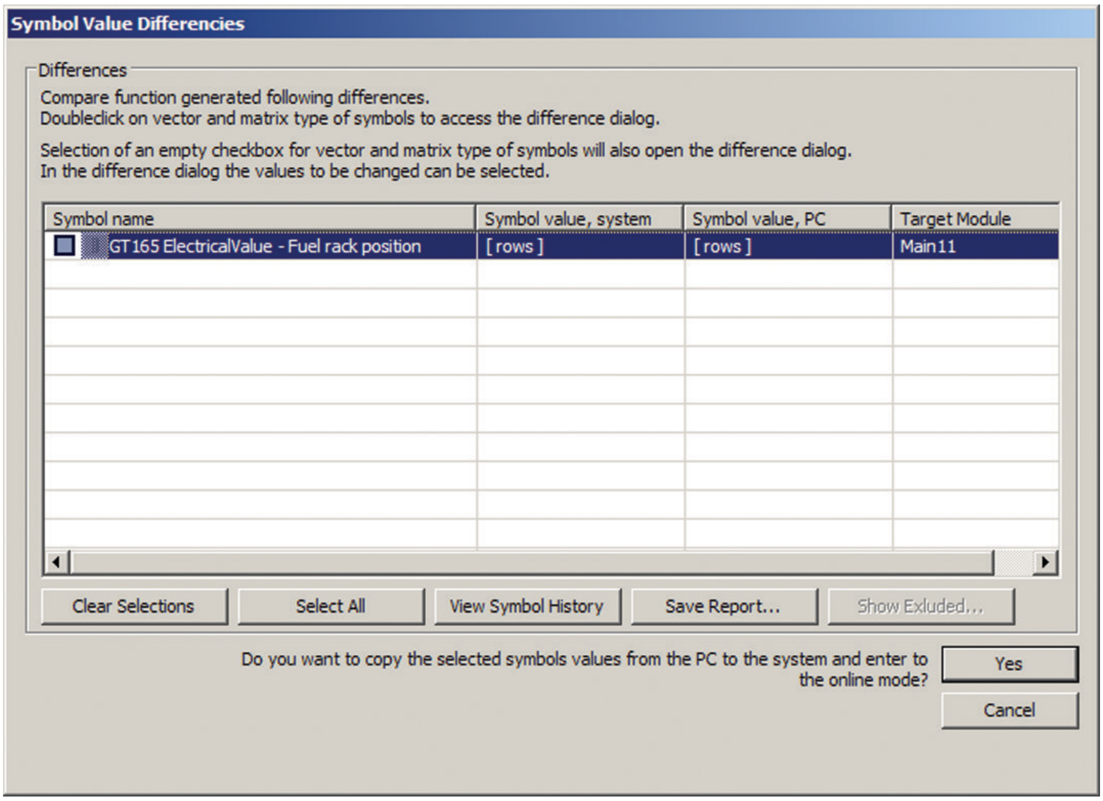


Fig 23D-40 Viewing symbol value differences

Select the symbols you want to copy from the computer to the system.

4 **If the symbol selected was vector or matrix, the following window opens.**
Follow instructions on the screen.

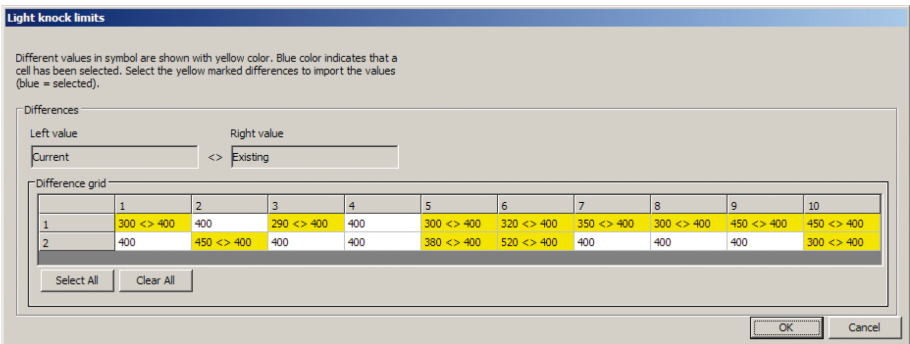


Fig 23D-41 Online entering differences

After selecting correct cells click OK. Confirm selections by clicking Yes. You are now in online mode.

23D.4.1 Configuring update rate

v1

Configuring update rate is available only in online mode.

You can configure the update rate (default 2000 ms) for continuous symbol update, found from Configuring Update Rate.

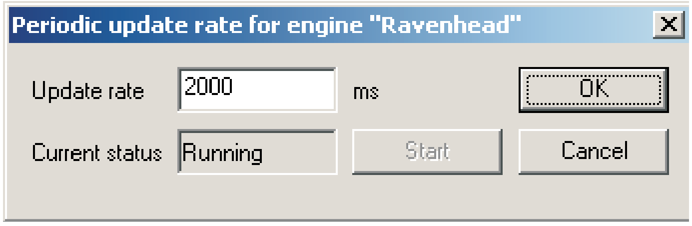
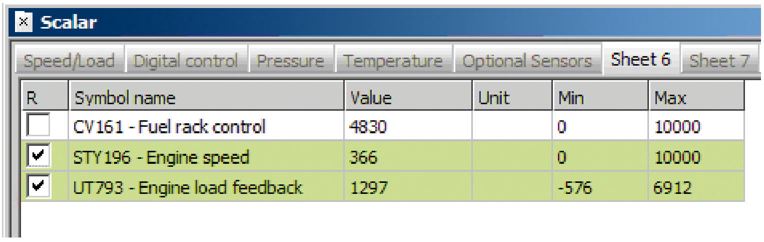


Fig 23D-42 Update rate dialog

If the continuous symbol update fails (for example connection is lost to the system module), restart by clicking the **Start** button.

- **Update rate**
  Update interval in milliseconds
- **Current status**
  Update status. If stopped, no continuous update is active.



- White background = not updating, Green background = updating

Fig 23D-43 Periodic update for symbol

23D.5 Configuring and viewing trends v1

Trending is available only in online mode.

The Trend window displays predefined trend data as a graphical presentation.

Procedure

1 **Configure a trend.**

1 Select **Trend - Create...** to open the Trend Properties dialog.

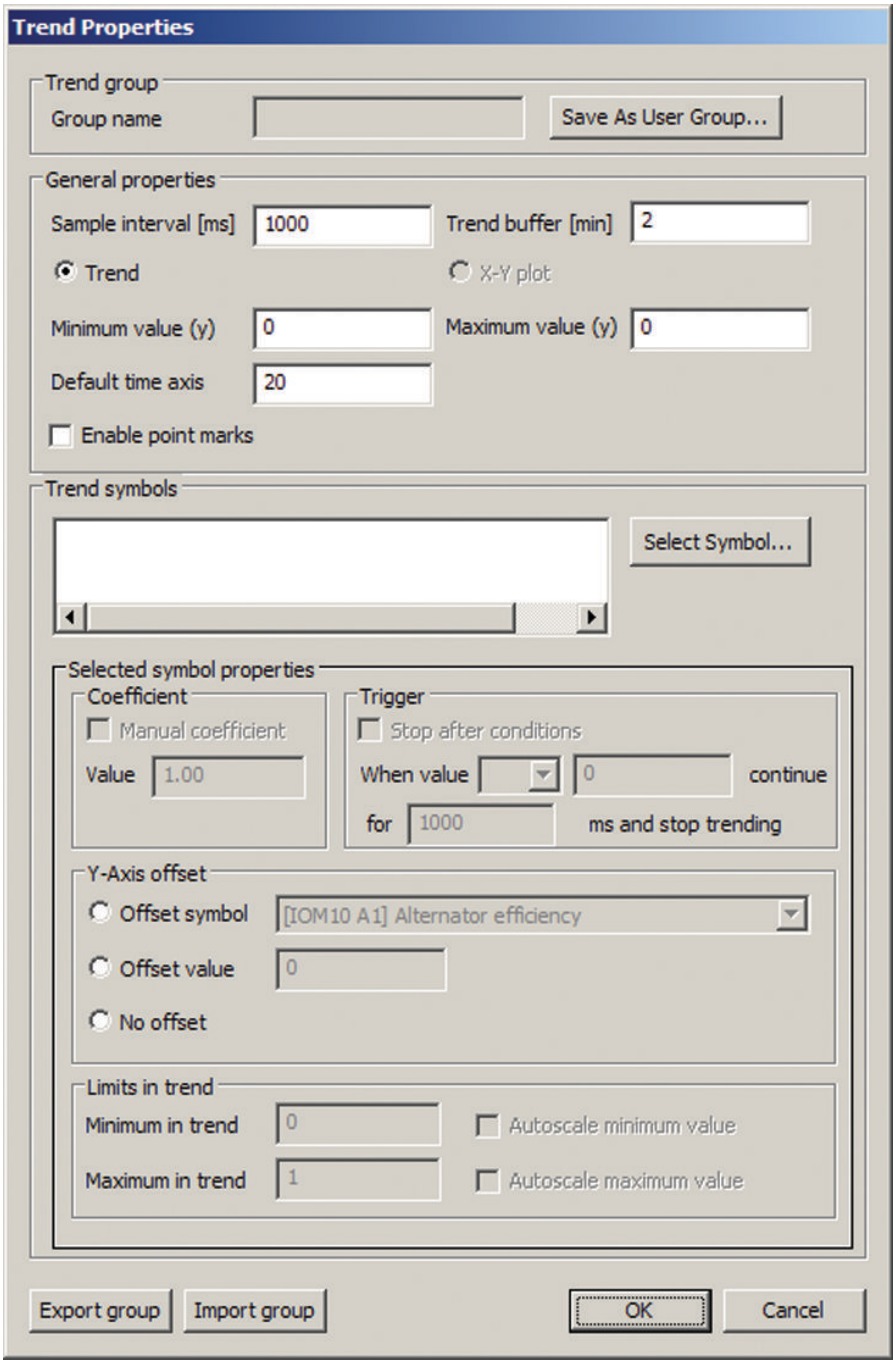


Fig 23D-44Configuring trend properties

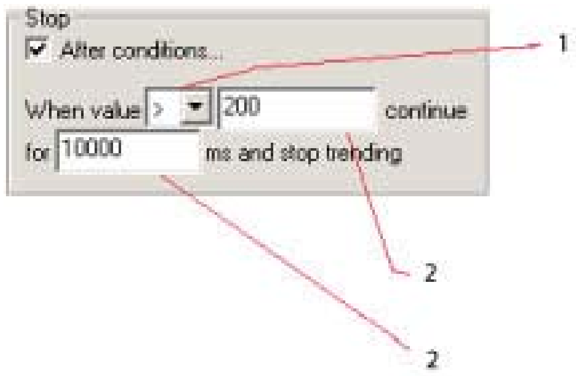
2 Change the general properties if needed.

General properties	Description
Sample interval	Sample interval while trending (in milliseconds)
Trend buffer [min]	Time of data stored in ring buffer
Minimum value	Minimum value displayed in trend window (Y-axis)
Maximum value	Maximum value displayed in trend window (Y-axis)
Default time axis	X-axis length displayed in trend window (in seconds)
Enable point marks	If checked, a small square marks every sample point. Can be used to track actual samples.

Trend symbols	Description
List of selected symbols	Shows selected symbols for the trend.
Select symbol	Adds more symbols to the trend window.

Selected symbol properties	Description
Manual coefficient	If checked, you can give coefficient value for specific symbol. The symbol must be selected in Select symbol box, before checking manual coefficient selection. For example: symbol ex1 has the maximum limit 100 and symbol ex2 has the maximum limit 10, the coefficient for symbol ex1 will be 1 and for symbol ex2 the coefficient will be 10.
Value	Coefficient value. If manual coefficient is selected, you can give a coefficient value for the symbol. The symbol value is multiplied by the value of coefficient. The coefficient only affects the trend display.

Y-axis Offset	Description
Offset symbol	Selected symbol is offset by symbol in drop-down menu.
Offset value	Selected symbol is offset by given value.
No offset	Offset is not used.



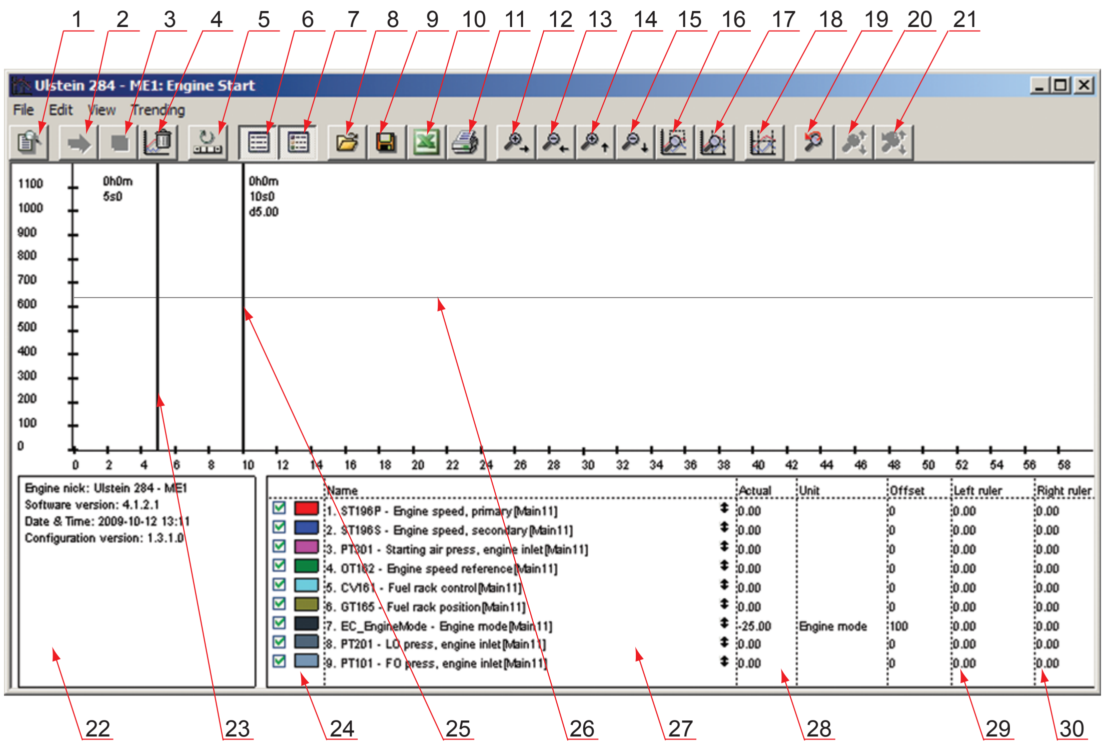
1 Condition to stop trending. Can be less than (<), greater than (>), or equal to (=).
2 Value related to condition to stop trending. When the symbol value is less than, greater than or equal to this value (depending on the condition), the trending stops after the specified time. Example: with the settings above, the trending will stop 10 seconds after the symbol value becomes greater than 200.

Fig 23D-45 Trigger properties

After the trend settings are configured, click OK button, the trend window opens.

23D.5.1 Overview of the trend window

v1



1 Trend group properties
2 Start trending
3 Stop trending
4 Clear trend data
5 Turn autoscroll on/off
6 Turn general legend on/off
7 Turn symbol info on/off
8 Open saved trend file
9 Save trend to file *.wet. (Only possible to open with WECSplorerUT)
10 Save trends to file *.csv. (Opens with excel)
11 Print trend
12 Zoom in x-axis
13 Zoom out x-axis
14 Zoom in y-axis
15 Zoom out y-axis
16 Lasso zoom
17 Ruler zoom
18 Trend ruler visibility
19 Undoes last zoom
20 Autoscale
21 Cancel autoscale
22 General legend
23 Left ruler
24 Remove/insert symbol
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27 Information on symbols
28 Actual data on symbols
29 Values for left ruler
30 Values for right ruler

Fig 23D-46 Trend window

- How to operate the trend window.

  Start the trending by clicking the blue arrow (2) in the toolbar. Zoom the data either with the toolbar buttons (12–15) or with the arrow buttons on the keyboard.

- Trend graph

  The Y axis displays the values predefined in the trend settings, while the X axis displays the time in seconds, from the trending start. You can configure the time base during the trending with the left and right arrows (keyboard). The axis can be zoomed separately. The graph includes two vertical rulers and one horizontal ruler. You can zoom the graph area between the vertical rulers by clicking ruler zoom (17).

  You can also use the rulers to view the values for each symbol at a certain point of the trend. When moving vertical rulers, the average values for each parameter are displayed on the right of the right ruler. When moving the rulers on the trend screen, the actual unscaled value is displayed in the lower right corner of the trend screen. The vertical and horizontal rulers can be moved freely within the trend graph, but the left and right rulers order are fixed.

- Legend windows

  Includes the General Legend and the Symbol Legend windows below the graph.

  The General Legend window displays for example the system nickname and software version. The Symbol Legend window displays the symbol values.

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