INSTRUCTION MANUAL

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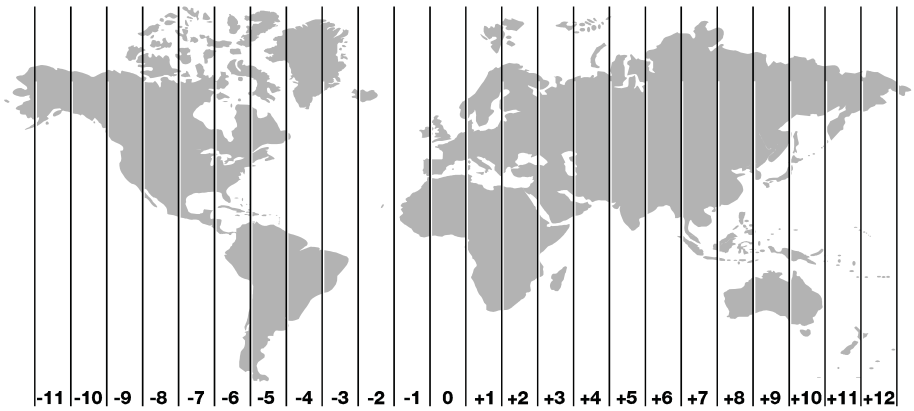

Table of Contents

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 general knowledge of engine operation and maintenance. Such information is therefore not provided in this manual.

The Wärtsilä engines are equipped as agreed upon 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, lube 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.

The exact engine design in every detail is defined by the engine number which is located on the engine name plate.

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.

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

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

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 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.

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

Details located at the operating side may be marked with an "M" (manoeuvring side), and details located at the rear side with a "B" (back side, or B bank on V engines).

Cylinder designation

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

Terminology and cylinder designations

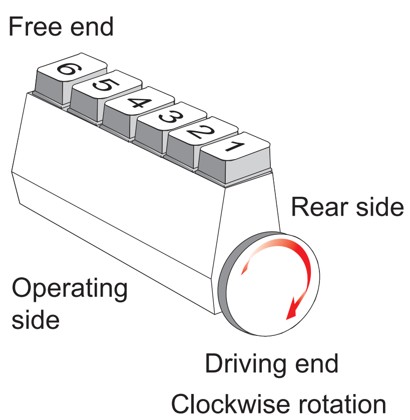

Fig 00-1 V1

Rotational direction

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

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

Top dead centre and bottom dead centre

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

Top dead centre, abbreviated **TDC**, is the top turning point of the piston in the cylinder. TDC for every cylinder is marked on the graduation of the flywheel.

During a complete working cycle, 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.

00.4. Designations and markings

00.4.1. Bearing designation

V4

Main bearings

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

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.

Bearing designation

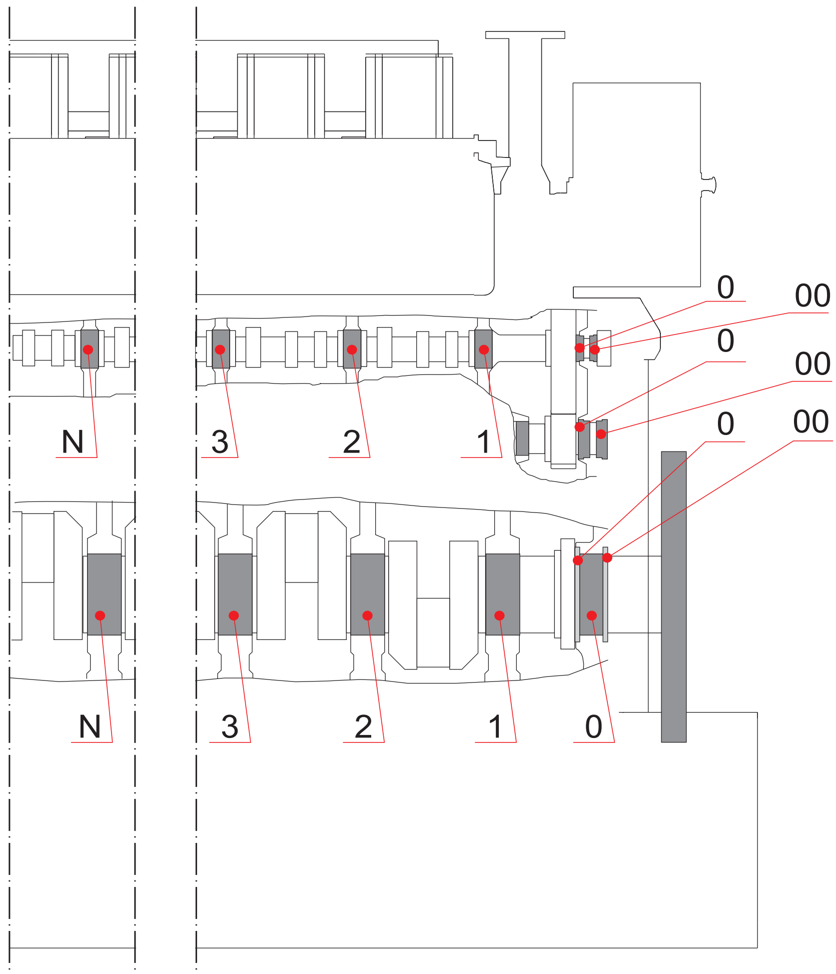

Fig 00-2 V2

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

V2

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

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

00.5.1. Use of symbols

V1

This manual includes different kinds of notes emphasized with a symbol. They are meant to draw the reader's attention to possible danger or aspects to take into consideration when performing an operation.

The following notes and warnings are used:

Warning!
Warning is used in the text whenever there is a risk of personal injury.

Warning!
The electricity warning is used in the text when there is a risk of personal injury due to electrical shocks.

Caution!
Caution is used in the text whenever there is a risk of damaging equipment.

Note!
Note is used in the text for highlighting important information or requirements.

00.5.2. General identified hazards

V1

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	Notes
Dropping parts during maintenance work	4, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	
Turning device engaged during maintenance work and operated unintentionally	3, 4, 10, 11, 12, 13, 14, 16	Warning light is on when the turning device is engaged.
Crankcase safety explosion valves opening due to crankcase explosion	3, 10, 23	
Noise level	3, 4, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 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, 18, 19	
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 while the crankshaft is turned	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.

Identified hazard, hazardous situation or event	Concerned chapters	Notes
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.
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	

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 V1

- 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 shut down
- Crankcase safety explosion valves opening due to a crankcase explosion.

00.5.5. Hazards due to leakage, breakdown or improper component assembly V2

- A fuel pipe bursting and spraying fuel.
- Leakage of:
  - fuel at joints on the low and/or high pressure side
  - lube oil
  - 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/lube oil if sensor is loosened while the circuit is pressurised
- leaks during maintenance work

- Oil spray if running without covers
- Ejection of fuel injector if not fastened and:
  - the turning device is engaged and turned
  - the engine turns due to closed generator breaker or coupling.

00.5.6. Electrical hazards

V1

- 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 start-up 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
  - engine not (fully) safeguarded at high oil mist levels, due to an incorrect electrical connector or leakage in a pipe connection.

00.5.7. Other hazards V1

Injury may be caused by:

- Slipping, tripping or falling
- Improper treatment of water additives and treatment products
- Touching the insulation box, turbo-charger, pipes, exhaust manifold, or other unprotected parts without protection during engine operation
- Dropping parts during maintenance work
- Starting maintenance work too early, 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 V2

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!
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 V2

Electronic control systems are sensitive and can be seriously damaged by external voltage or high-current shocks. To avoid damaging the engine control system certain precautions must be taken when welding.

Follow the instructions that apply to the control system installed on the engine.

00.6.3.1. UNIC precautions checklist V3

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

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 V2

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

The fuel oils may cause long-term harm and damage in water environments and present a risk of contaminating 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/bunkering.

Note!
Study 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 V3

Protection of respiratory organs	Against oil mist: Use respirator with combined particle and gas filter. Against evaporated fumes (hydrogen sulphide, etc.): Use respirator with inorganic gas filter.
Hand protection	Use strong, heat and hydrocarbon resistant gloves (nitrile rubber for example).
Eye protection	Wear goggles if splash risk exists.

Skin and body protection	Wear facial screen and covering clothes as required. Use safety footwear when handling barrels. Wear 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

V1

Fresh lubricating oils normally present no particular toxic hazard, but all lubricants should always be handled with great care.

Used lubricating oils may contain significant amounts of harmful metal and PAH (polyaromatic hydrocarbon) compounds. Avoid prolonged or repetitive contact with the skin. Prevent any risk of splashing. Keep away from heat, ignition sources and oxidizing agents.

There is a risk of long term contamination of the soil and the ground water. Take every appropriate measure to prevent water and soil contamination.

Note!
Study and follow 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

V1

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

Note!
Study 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

V2

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

V1

Note!
Study 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

V1

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

V3

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

V2

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

V3

Hand protection	Use impenetrable acid-proof gloves (neoprene or PVC).
Inhalation protection	Use 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.

01. Main Data, Operating Data and General Design

V2

01.1. Main data for Wärtsilä 20

V6

Cylinder bore...200 mm

Stroke...280 mm

Piston displacement per cylinder..8.80 l

Firing order		
Engine type	Clockwise rotation	Counter-clockwise rotation
4L20	1-3-4-2	1-2-4-3
5L20	1-2-4-5-3	1-3-5-4-2
6L20	1-5-3-6-2-4	1-4-2-6-3-5
8L20	1-3-7-4-8-6-2-5	1-5-2-6-8-4-7-3
9L20	1-7-4-2-8-6-3-9-5	1-5-9-3-6-8-2-4-7

Normally the engine rotates clockwise.

Lubricating oil volume in the engine					
Engine type	4L20	5L20	6L20	8L20	9L20
App. oil volume in litres Normal sump	270	320	380	490	550
Deep sump		330	500	640	710
Special deep sump			540		
Oil volume between max.. and min. marks appr. litres/mm	0.7	1.4	1.5	1.9	2.0

App. cooling water volume (HT) in the engine in litres					
Engine type	4L20	5L20	6L20	8L20	9L20
Engine only	90	105	120	150	160

Lubricating oil volume in the speed governor in litres	
Woodward 3161	2.2
Woodward UG-A	1.4
Regulateurs Europa 2221, 2231	2

01.2. Recommended operating data

V3

Apply to normal operation at nominal speed.

Temperatures, (°C)		
	Normal values (xx)	Alarm (stop) limits (xx)
Load	100 %	0 - 100 %
Lube oil before engine	63 - 67	80
Lube oil after engine	10 - 15 higher	
HT water after engine	86 - 95	105 (110)
HT water before engine	6 - 10 lower	
LT water before charge air cooler	25 - 38	
Charge air in air receiver	50 - 70	75
Exhaust gas after cylinder	See test records	70 higher (xxx)
Preheating of HT water	60	

Gauge pressures (bar)		
	Normal values (xx)	Alarm (stop) limits (xx)
Load	100 %	0 - 100 %
Lube oil before engine at a speed of 720 RPM (12.0 r/s)	4.0 - 5.0	3.0 (2.0)
1000 RPM (16.7 r/s)	4.0 - 5.0	3.0 (2.0)
HT/LT water before HT/LT pump (=static)	0.7 -1.5	
HT water before engine	1.6 + static press. (x)	1.0 or 0.2 + static press. (x)
LT water before charge air cooler	1.6 + static press.(x)	1.0 or 0.2 + static press. (x)
Fuel before engine	(MD) 4 - 7 (x), (HF) 5 - 7	4
Compressed air Air starter	max. 30 9.0	18
Charge air	See test records	

Other pressures (bar)		
	Normal values (xx)	Alarm (stop) limits (xx)
Load	100 %	0 - 100 %
Firing pressure	See test records	
Opening pressure of safety valve on lube oil pump	6 - 8	
Visual indicator and electronic alarm for high pressure drop over lube oil filter	<1.2 - 1.8	1.2 - 1.8

(x) Depending on speed and installation

With engine driven MD-pump pressure might be lower close to min. speed.

(xx) Under 30% load the lubricating oil and water temperatures fall a little.

(xxx) See test records.

01.3. Reference conditions

V2

Reference conditions according to ISO 3046/I (2002):

Air pressure...100 kPa (1.0 bar)

Ambient temperature..298 K (25°C)

Relative air humidity...30%

Cooling water temperature of charge air cooler............298 K (25°C)

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

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

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

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

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

01.4. General engine design

V5

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

The engine block is cast in one piece. The main bearings are hanging. The main bearing cap is supported by two hydraulically tensioned main bearing screws and two horizontal side screws.

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

The lubricating oil sump is welded.

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

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

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

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

The connecting rods are drop forged. The big end is split and the mating faces are serrated. The small end bearing is stepped to achieve large bearing surfaces. The big end bearings are fully interchangeable trimetal or bimetal bearings.

The pistons are of composite type with forged steel or casted skirt and a forged crown screwed together. It is fitted with a Wärtsilä patented skirt lubricating system. The top ring grooves are hardened.

Cooling oil enters the cooling space through the connecting rod. The cooling spaces are designed to give an optimal shaker effect.

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

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

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

The exhaust valves also with stellited seats and chromium-plated stems and seal against the directly cooled valve seat rings.

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

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

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

The turbocharger is normally located at the free end of the engine.

The charge air cooler is made as removable inserts.

The lubricating oil system includes a gear pump, oil filter, cooler with thermostat valve, centrifugal by-pass filter and an electrically driven prelubricating pump.

The oil sump has the capacity to hold the entire volume of oil needed, and all cylinder numbers can be run in wet sump configuration. Dry sump running is also possible.

The starting system. The engine is provided with an air driven starting device of turbine type. The air starter acts directly on the flywheel.

02. Fuel, Lubricating Oil, Cooling Water

V3

Note!
For preventing and minimizing the handling risks, read carefully the chapter about Environmental Hazards.

02.1. Fuel

V10

The Wärtsilä medium-speed diesel engine is designed to operate on heavy fuel (residual fuel) with a maximum viscosity of 700 cSt at 50 °C (approx. 55 cSt at 100 °C, approx. 7200 Redwood No.1 seconds at 100 °F) and will operate satisfactorily on blended (intermediate) fuels of lower viscosity, as well as on distillate fuel. Avoid the use of fuels having lower / higher injection viscosity than the values found in the table below. The use of fuels having too low injection viscosity may lead to the seizure of fuel injection pump plunger or fuel injection nozzle and will also increase fuel leakage in the injection pump leading to increased fuel consumption, deteriorated engine performance and increased risk of cavitation in the fuel system.

The following types of fossil fuels are defined for the Wärtsilä 20:

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

Fuel viscosity limits at engine inlet in running conditions (cSt)		
Engine Type	Fuel	
	LFO, min	HFO
Wärtsilä 20	1,8	16 - 24

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

Blended fuels (residuals and distillate) with a viscosity between approx. 4 and 7 cSt at 100 °C (12 and 30 cSt at 50 °C, 75 and 200 Redwood No.1 seconds at 100 °F) containing between 30 and 60 % distillate should, however, be avoided due to the risk of precipitation of heavy components in the blend, with filter clogging and large amount of centrifuge sludge as a consequence.

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

02.1.1. Fuel treatment

02.1.1.1. Fuel separation

V2

Separation principle

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

Viscosity

The viscosity is very critical in determining the dimensions of the separator. Higher the fuel viscosity, lower the separation capacity. Thus a bigger separator size (or more separators) is required to separate the same amount of fuel/hour. The separator manufactures have tables with flow capacities for standard fuel viscosities. Standard separators can handle fuels up to 700 cSt at 50°C. The viscosity is lowered as much as possible by heating the fuel to maximum temperature, which in standard HFO separators is 98°C. For liquid biofuels the separation temperature is typically 50-55°C. Higher separation temperatures, more than 98°C can also be utilized. But these cannot be handled by standard separators. Separators have to be designed for each case. Higher separation temperatures are used with extremely high viscosity fuels. Separation temperature for distillate fuel is typically 40°C.

Density

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

Flash point

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

Water content

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

Dimensioning of the separator

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

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

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

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

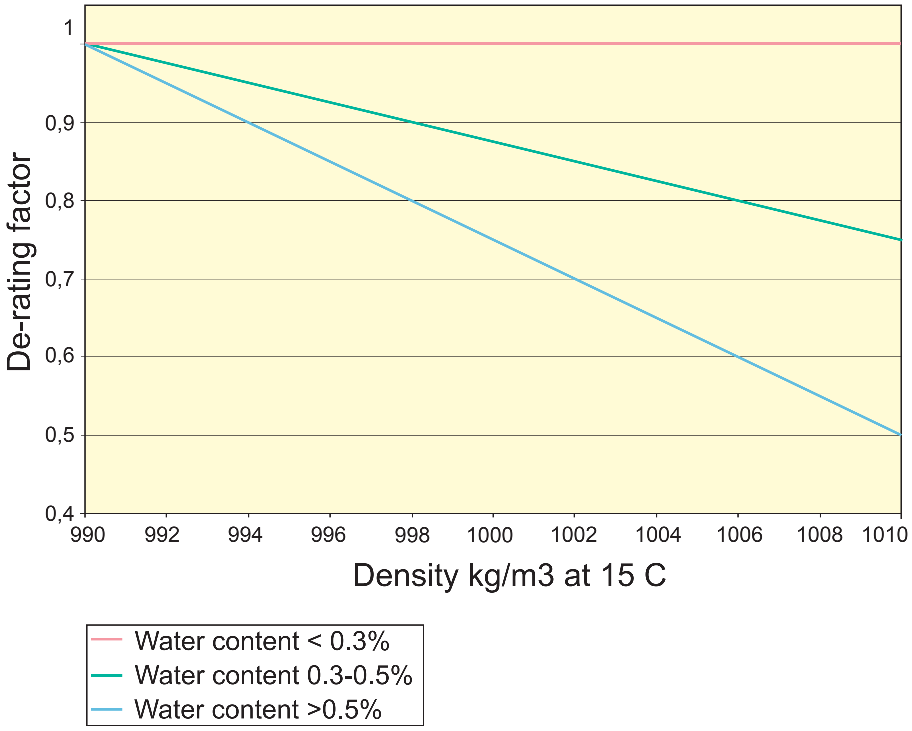

Fig 02-1 V2

Separator modules

The suppliers are making complete modules today, including heaters and feeder pumps, which means that the equipment is automatically calibrated and ready for customer use. The modules include a number of separators needed to meet the capacity of the installation along with an extra standby separator. This also ensures fuel supply when one separator is in service.

02.1.1.2. Heating V2

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

Fuel oil viscosity-temperature diagram

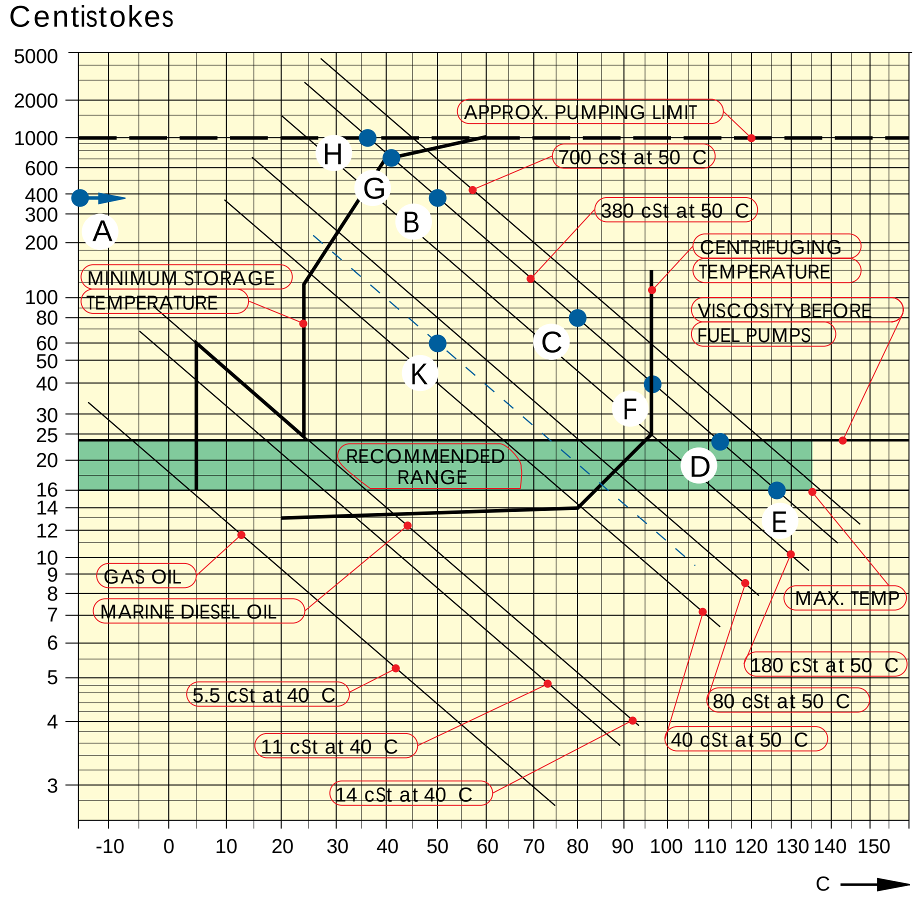

Fig 02-2

320261 V1

Example: *A fuel oil with a viscosity of 380 cSt (A) at 50 °C (B) or 80 cSt at 80 °C (C) must be preheated to 112 - 126 °C (D-E) before the fuel injection pumps, to 97 °C (F) at the centrifuge and to minimum 40 °C (G) in storage tanks. The fuel oil may not be pumpable below 36 °C (H).*

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

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

The diagram in Fig 02-3 can be used for converting various viscosity units to centistokes. The diagram should be used only for conversion of viscosities at the same temperature. The same temperature should then be used when entering the viscosity/temperature point into the diagram in Fig 02-2.

Note!
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. For converting the viscosity at a given temperature to a viscosity at another temperature, a viscosity-temperature diagram or conversion rule must be used.

Viscosity conversion diagram

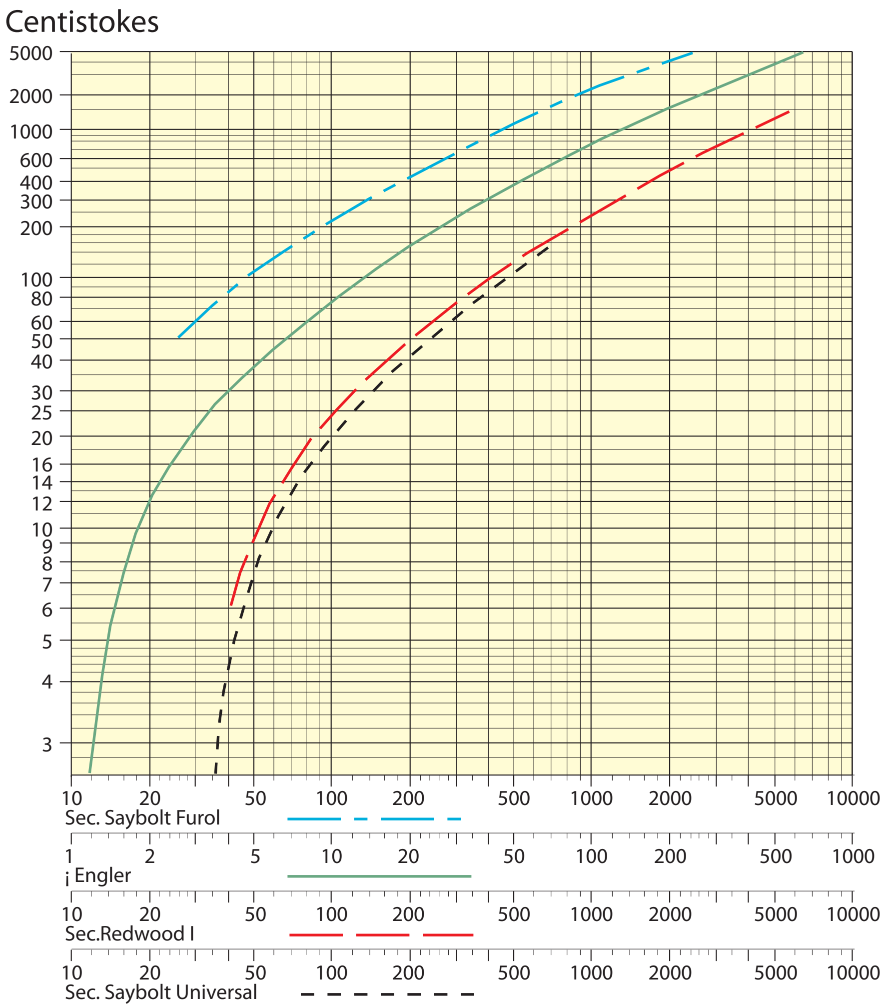

Fig 02-3 320253 V1

02.1.1.3. Viscosity control

V2

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

02.1.2. Maximum limits for fossil fuel characteristics V9

The diesel engine Wärtsilä 20, is designed and developed for continuous operation, without reduction of the rated output, on fossil fuels with the following properties:

Heavy fuel oil:

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

The limits above also correspond to the demands:

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

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

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

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

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

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

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

Light fuel oil:

The fuel specification is based on the ISO 8217:2005(E) standard and covers the fuel categories ISO-F-DMX, DMA, DMB and DMC. 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. In merchant marine applications, its use is restricted to lifeboat engines and certain emergency equipment due to reduced flash point.
- DMA: A high quality distillate, generally designated MGO (Marine Gas Oil) in the marine field.
- 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.
- DMC: A fuel which can contain a significant proportion of residual fuel. Consequently it is unsuitable for installations where engine or fuel treatment plant are not designed for the use of residual fuels.

Fuel characteristics, maximum limits						
		ISO-FDMX	ISO-FDMA	ISO-FDMB	ISO-FDMC 1)	Test method reference
Appearance		Clear and bright		-	-	Visual inspection
Viscosity, max. Injection viscosity, min. 2) Injection viscosity, max. 2)	cSt at 40 °C cSt cSt	5.5 1.8 24	6 1.8 24	11 1.8 24	14 1.8 24	ISO 3104
Density, max.	kg/m³ at 15 °C	-	890	900	920	ISO 3675 or 12185
Cetane index, min.		45	40	35	-	ISO 4264
Water max.	% V/V	-	-	0.3	0.3	ISO 3733
Sulphur, max.	% m/m	1.00	1.50	2.00 3)	2.00 3)	ISO 8754 or 14596 ASTM D 7212 4)
Ash, max.	% m/m	0.01	0.01	0.01	0.05	ISO 6245
Vanadium, max.	mg/kg	-	-	-	100	ISO 14597 or IP 501 or 470
Sodium, max. before engine 2)	mg/kg	-	-	-	30	ISO 10478
Aluminium + Silicon, max.	mg/kg	-	-	-	25	ISO 10478 or IP 501 or 470
Aluminium + Silicon, max. before engine 2)	mg/kg	-	-	-	15	ISO 10478 or IP 501 or 470

Fuel characteristics, maximum limits						
		ISO-FDMX	ISO-FDMA	ISO-FDMB	ISO-FDMC[1)]	Test method reference
Carbon residue, max.	% m/m	-	-	0.30	2.50	ISO 10370
Carbon residue on 10 % V/V distillation bottoms, max.		0.30	0.30	-	-	
Flash point (PMCC), min.	°C	60 [2)]	60	60	60	ISO 2719
Pour point, max.	°C					ISO 3016
- winter quality		-	- 6	0	0	
- summer quality		-	0	6	6	
Cloud point, max.	°C	-16	-	-	-	ISO 3015
Total sediment existent, max.	% m/m	-	-	0.1	0.1	ISO 10307-1
Used lubricating oil [5)]	mg/kg					
- calcium, max.		-	-	-	30	IP 501 or 470
- zinc, max.		-	-	-	15	IP 501 or 470
- phosphorus, max.		-	-	-	15	IP 501 or 500

[1)]Use of ISO-F-DMC category fuel is allowed provided that the fuel treatment system is equipped with a fuel centrifuge.
[2)]Additional properties specified by the engine manufacturer, which are not included in the ISO specification or differ from the ISO specification.
[3)]A sulphur limit of 1,5 % m/m will apply in SOx emission controlled areas designated by International Maritime Organization. There may be also other local variations.
[4)]For fuels having sulphur content below 0,05 % m/m
[5)]A fuel shall be considered to be free of used lubricating oil (ULO), if one or more of the elements calcium, zinc and phosphorus are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO.

The fuel should not include any added substance or chemical waste, which jeopardizes the safety of installations or adversely affects the performance of the engines or is harmful to personnel or contributes overall to additional air pollution.

02.1.3. Maximum limits for liquid biofuel characteristics

V2

The Wärtsilä 20 diesel engines are designed and developed for continuous operation, without reduction in the rated output, on crude liquid biofuels or biodiesels with the properties included in Tables 1 and

2. However, since liquid biofuels typically have lower heating value than fossil fuels, capacity of the fuel injection system must be checked case specifically.

The crude liquid biofuel specification included in Table 1 is valid for crude vegetable based biofuels, like palm oil, coconut oil, copra oil, rape seed oil, jathropha oil, etc. but is not valid for animal based biofuels.

The biodiesel specification in Table 2 is valid for renewable refined liquid biofuels, including both 1st and 2nd generation biodiesels, which are manufactured by using transesterification or hydrogenation processes. Renewable refined liquid biofuels can contain both vegetable and / or animal based raw material and do normally show out very good physical and chemical properties and can be used as well provided that the specification included in the Table 2 is fulfilled. International standards ASTM D 6751-06 or EN 14214:2003 (E) are typically used for specifying biodiesel quality.

Blending of different fuel qualities:

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

Mixing of crude liquid biofuel and distillate fuel will increase the risk of cavitation in the fuel system, since required fuel temperature before engine is normally 65 – 75 °C. At this temperature light fractions of distillate fuel start to already evaporate.

Mixing of crude 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 crude liquid biofuel, i.e. normally above 100 °C in order to achieve a proper injection viscosity.

Biodiesel 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 the engine types from the documents: V92A0459, V92A0572 or V92A0670.

Required fuel temperatures:

Crude 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. For liquid palm oil the fuel temperature before injection pumps shall be kept between 65 and 75 °C. For other types of crude liquid biofuels the temperature requirement can be slightly different and must be confirmed before the use.

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

Table 1: Crude liquid biofuel specification

Crude liquid biofuel specification			
			Test method reference
Viscosity, max. Injection viscosity, min. Injection viscosity, max.	cSt at 40 °C cSt cSt	100 [1)] 1.8 – 2.8 [2)] 24	ISO 3104
Density, max.	kg/m³ at 15	991	ISO 3675 or 12185
Ignition properties [3)]			FIA test
Sulphur, max.	% mass	0.05	ISO 8754
Total sediment existent,	% mass	0.05	ISO 10307-1
Water, max. before engine	% volume	0.20	ISO 3733
Micro carbon residue, max.	% mass	0.50	ISO 10370
Ash, max.	% mass	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 at 50 °C), max.		1b	ASTM D130
Steel corrosion (24 / 72 hours at 20, 60 and 120 °C), max.		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
Iodine number, max.		120	ISO 3961

[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.
[2)] Min. limit at engine inlet in running conditions; 1,8 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.

Table 2: Biodiesel specification based on EN 14214:2003 standard

Biodiesel specification based on EN 14214:2003 standard			
			Test method reference
Viscosity, min. - max. Injection viscosity, min.	cSt at 40 °C cSt	3,50 – 5,00 1,8 – 2,8 [1)]	EN ISO 3104
Density, min. - max.	kg/m³ at 15	860 - 900	EN ISO 3675 / 12185
Cetane number, min.		51,0	EN ISO 5165
Sulphur content, max.	mg/kg	10,0	prEN 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	10,0	EN 14107
Group I metals (Na + K) content, max.	mg/kg	5,0	EN 14108 / 14109
Group II metals (Ca + Mg) content, max.	mg/kg	5,0	prEN 14538
Flash point, min.	°C	120	prEN ISO 3679
Cold filter plugging point, max. (climate dependent requirement)	°C	-44 => +5	EN 116
Oxidation stability at 110 °C, min.	hrs	6,0	EN 14112
Copper strip corrosion (3 hrs at 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	120	EN 14111
Ester content, min.	% m/m	96,5	EN 14103
Linolenic acid methyl ester, max.	% m/m	12,0	EN 14103
Polyunsaturated methyl esters, max.	% m/m	1	
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

Biodiesel specification based on EN 14214:2003 standard			
			Test method reference
Triglyceride content, max.	% m/m	0,20	EN 14105
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; 1,8 cSt.*

02.1.4. Comments on fuel characteristics

V8

Viscosity

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

Density

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

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

Ignition quality

Heavy fuels may have very low ignition quality. This may cause trouble at start and low load operation, particularly if the engine is not sufficiently preheated. Low ignition quality may also result in a long ignition delay and can cause a fast pressure rise and very high maximum pressures. This increases the mechanical load and can even damage engine components such as e.g. piston rings and bearings severely. Deposits on the piston top, on the exhaust valves, in the exhaust system, and on the turbine nozzle ring and turbine blades can also be expected. The turbocharger fouling will lead to decreased turbocharger efficiency, and increased thermal load.

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

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

Ignition quality is not defined, nor limited, in marine residual fuel standards. The same applies to ISO-F-DMC marine distillate fuel.

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

Formula for determining CCAI:

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

Where:

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

Note!
An increased CCAI value indicates decreased ignition quality.

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

Nomogram for determining CCAI

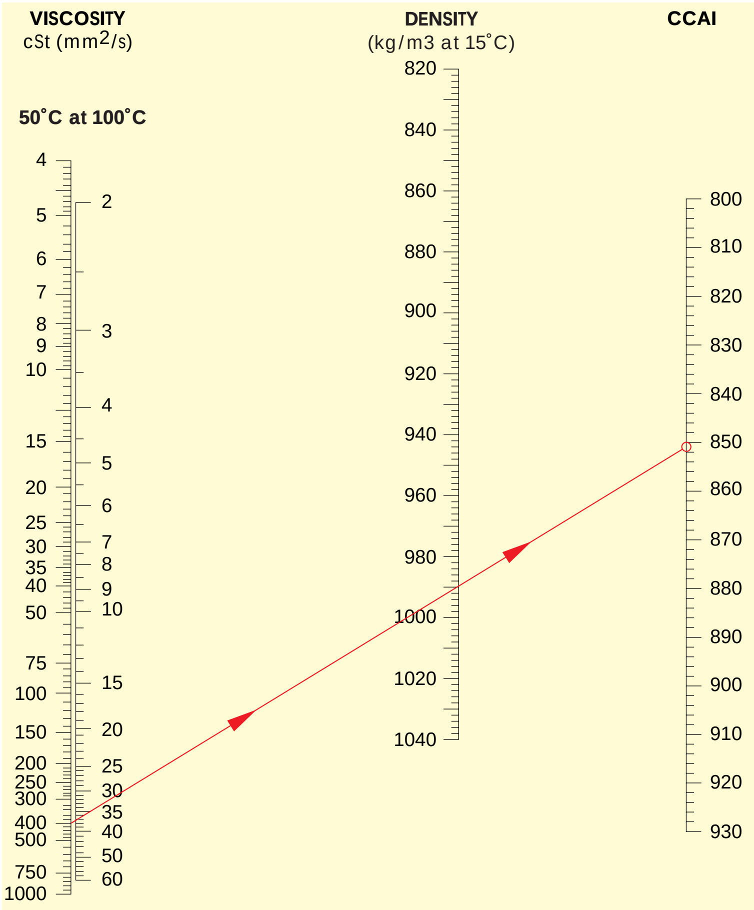

Fig 02-4 320259 V1

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

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

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

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

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

Water content

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

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

To avoid problems and damage in the engine’s fuel injection system, the water content must be reduced to a max. 0.3 % before the engine.

Sulphur

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

Ash content

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

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

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

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

Carbon residue content

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

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

Asphaltene content

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

High asphaltene content may contribute to deposit formation in the combustion chamber and in the exhaust system, especially at low loads.

Flash point

A low flash point (high vapour pressure) is often seen especially for crude oils. The low flash point will not influence the combustion, but the fuel can be dangerous to handle and store. This is especially the case if the pour point is high, and the fuel has to be heated due to this. Special explosion proof equipment and separators can be used in extreme cases.

A high vapour pressure (low flash point) can also cause cavitation and gas pockets in the fuel pipes. These can be avoided by using an elevated pressure in the fuel handling system. It is to be noted that some insurance companies demand the use of fuels having a flash point higher than 60°C.

Pour point

The pour point tells at which temperature the fuel becomes so thick that it does no longer flow. It determines how easy it will be to handle the fuel. The whole fuel handling system, including tanks and pipes, must be heated to a temperature at least 10 - 15°C above the pour point.

Total sediment potential

Total sediment potential (TSP) tells something about the fuel's stability. If the TSP is high, the danger of sediment and sludge formation in tanks and fuel handling systems increases, as well as the probability for filter clogging.

TSP can also be used as a check for the compatibility of two different fuels. For this purpose, samples of the two fuels are mixed. If the TSP for the mix remains low, the fuels are compatible.

02.1.5. Measures to avoid difficulties when running on heavy fuel

V2

Poor fuel quality will adversely influence wear, engine-part lifetime and maintenance intervals.

In order to obtain maximum operating economy it is recommendable:

a) **To limit maximum continuous output,** as much as operating conditions allow, if fuel is known or suspected to have high vanadium content (above 200 ppm) and sodium content.

b) **To limit low load operation,** as much as operating conditions allow, if fuel is known or suspected to have high sulphur content (above 3 mass-%), conradson carbon residue (above 12 mass-%) and/or asphaltene content (above 8 mass-%).

Operation below 20 % of rated output should be limited to max. 100 hours continuously, by loading the engine above 70 % of rated load for one hour before continuing the low load operation or shutting down the engine.

Idling (i.e. generator set disconnected) should be limited as much as possible. Warming-up of the engine at no load for more than 3-5 minutes before loading, as well as idling for more than 3 minutes before stopping, is unnecessary and should be avoided.

02.1.6. Using low sulphur & low viscosity distillate fuel (LFO)

V7

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

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

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

02.1.7. General advice

V4

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

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

The characteristics of heavy fuels blended from residuals from modern refinery processes like catalytic cracking and visbreaking may approach at least some of the 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.

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

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

- Sufficient centrifuging capacity. The best and most disturbance-free results are obtained with the purifier and clarifier in series. Alternatively the main and stand-by separators may be run in parallel, but this makes heavier demands on correct gravity disc choice and constant flow and temperature control to achieve optimum results. Flow rate through the centrifuges should not exceed the maximum fuel consumption by more than 10 %.
- Sufficient heating capacity to keep centrifuging and injection temperatures at recommended levels. It is important that the temperature fluctuations are as low as possible (±2 °C before centrifuge) when centrifuging high viscosity fuels with densities approaching or exceeding 991 kg/m^3 at 15 °C.
- Sufficient preheating of the engine and the fuel systems before starting the engine.
- Keeping fuel injection equipment and the inverse cooling system in good condition.

02.2. Lubricating oil

02.2.1. Lubricating oil qualities

V6

Lubricating oil is an integrated engine component and thus the quality of it is upmost important. All lubricating oils, which have been approved for use in Wärtsilä 20 engine type, have gone through an approval test according to the engine manufacturer's procedure.

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

The list of approved lubricating oils can be found in Chapter 02B: Oil requirements & oil quality.

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

Note!
Before using a lubricating oil not listed in the table, the engine manufacturer must be contacted. The engine manufacturer has available an approval procedure, which at need makes it possible to test new suitable lubricating oil candidate formulations.

02.2.2. Maintenance and control of the lubricating oil V5

a) Use of lubricating oil separator is mandatory for engines running on residual fuel. It is optional for engines running on distillate fuel or natural gas. Continuous centrifuging of engine oil is recommended in order to separate water and insolubles from the oil effectively.

To achieve an effective result, the separation temperature recommended by the separator manufacturers is 95 °C. This temperature is also used to calculate the optimum flow rate. Please check with the lubricating oil supplier the optimal temperature range and use the highest recommended temperature.

With older design of separators, about 20% flow rate calculated from the rated capacity is recommended. But with new Alfa Laval SA/SU series and Westfalia OSD series, the flow rate mentioned in the sizing tables must be used. In order to achieve optimum separation, the separator must be capable of circulating the entire volume of oil, four to five times every 24 hours, at the recommended flow rate.In the separator types being equipped with a gravity disc, the right size of the disc can be chosen according to the lubricating oil density at the separation temperature.

Ensure that the separator’s conditioning water does not leak into the lubricating oil during separation, leading to increased water content in the lubricating oil and possibly to depletion of additives ("washing"). Follow the operation instructions given by the separator manufacturer for optimal performance of the separator.

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

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

b) **During the first year of operation** it is advisable to take samples of the lubricating oil at 500 operating hours intervals. The sample should be sent to the oil supplier for analysis. On the basis of the results it is possible to determine suitable intervals between oil changes. Frequent oil analysis at 500 - 1000 operating hours intervals is also recommended after the first year of operation to ensure safe engine operation. See also section 02.2.5., Handling of oil samples. When estimating the condition of the used oil, the following properties should be observed. Compare with guidance values (type analysis) for new oil of the brand used.

Viscosity. Should not decrease by more than 20% and not rise by more than 25% above the guidance value at 100 °C.Should not decrease by more than 25 % and not rise by more than 45% above the guidance value at 40 °C.

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

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

BN (Base Number).

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

Insolubles. The quantity allowed depends on various factors. However, an n-Pentane insoluble value above 1.5% calls for attention. A value higher than 2% cannot be accepted for longer periods.

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

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

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

d) **Guidance values for oil change intervals** are to be found in chapter 04, Maintenance Schedule. Intervals between changes are influenced by system size (oil volume), operating conditions, fuel quality, centrifuging efficiency and total oil consumption. Efficient centrifuging can result in increased oil change intervals. It is recommended to follow up that the BN value of the lubricating oil keeps within engine manufacturer's limits during the whole oil change interval.

02.2.2.1. Changing the lubricating oil

V7

When changing the lubricating oil, the following procedure is recommended:

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

2 **Clean all the oil spaces with a high quality fibre and lint free cloth.** Clean also the filters and camshaft compartment. Insert new filter cartridges.

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

4 **Fill required quantity of oil in the system.** See chapter 01: Main Data, Operating data and General Design.

Oil samples taken at regular intervals are analysed by the oil supplier. The results of this analysis is plotted as a function of operating hours. This is an efficient way of predicting oil change intervals. Ask the oil supplier for copies of oil analysis report. Send it to the engine manufacturer for evaluation.

When changing the lubricating oil brand from one to another follow the procedure given below. This minimizes the risk of lubricating oil foaming, deposit formation, blocking of lubricating oil filters, damage of engine components, etc.

- If possible, change the lubricating oil brand during an engine (piston) overhaul.
- Drain old lubricating oil from the lubricating oil system.
- Clean the lubricating oil system, if excessive amount of deposit has formed on the surfaces of engine components like crankcase, camshaft compartment.
- Fill the lubricating oil system with fresh lubricating oil.

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

02.2.3. Lubricating oil for the governor V11

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

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

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

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

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

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

02.2.4. Lubricating oils for turbochargers V10

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

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

Oil change interval is 1500 h service for special mineral oils and 2500 h service for synthetic lubricating oils.

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

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

02.2.5. Handling of oil samples V2

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, see Instruction Manual attachments .

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

02.2.5.1. Lubricating oil sampling V1

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

02.2.5.2. Fuel oil sampling V1

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

02.2.6. Dispatch and transportation

V2

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

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

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

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

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

02.3. Cooling water

V1

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

Before treatment, the water must be limpid and meet the specification found in the end of this chapter. Further, the use of an approved cooling water additive or treatment system is mandatory.

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

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

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

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

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

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

02.3.1. Additives

V8

As additives, use approved products from well-known and reliable suppliers. In marine applications suppliers' wide distribution networks makes it easier to get the same product in different geographical locations.

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

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

Warning!
Sodium nitrite is toxic. Handle with care and dispose all possible residuals in accordance with valid environmental regulations.

Corrosion rate as a function of nitrite concentration

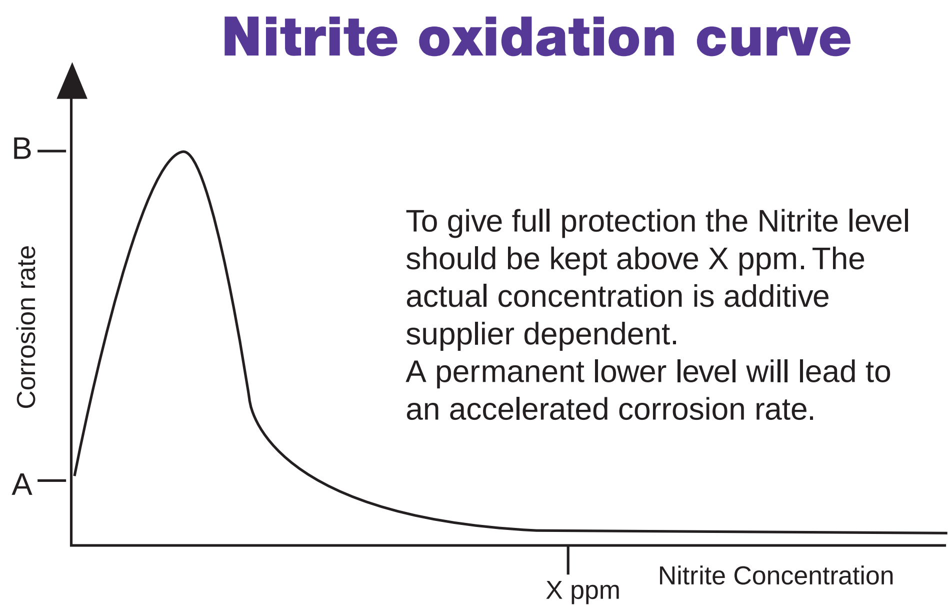

Fig 02-5

320260 V1

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

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

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

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

02.3.2. Treatment

V3

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

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

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

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

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

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

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

02.3.3. Derating engine output

V1

Use of glycol in LT water circuit

The maximum allowed amount of glycol in the LT water circuit is 50%. There will not be derating if the glycol content is less than 20%.

For LT circuit with glycol content above 20%, an offset is applied to the K2 derating factor (derating from charge air coolant temperature) according to the table below. This offset is applied to compensate for the increased charge air cooler pinch point when using glycol. The degree of offset is greater for engines with 1-stage CAC, due to a higher sensitivity to glycol.

LT-circuit glycol content	K2 -offset in T_{ref}[1]	
	2-stage CAC	1-stage CAC
0-20%	0°C	0°C
30%	-3.3°C	-6.6°C
40%	-6.7°C	-13.3°C
50%	-10°C	-20°C

[1] K2 derating break point for CA cooling water temp (engine and PP/SP specific)

Offset in derating constant K2 (example: 2-stage CAC)

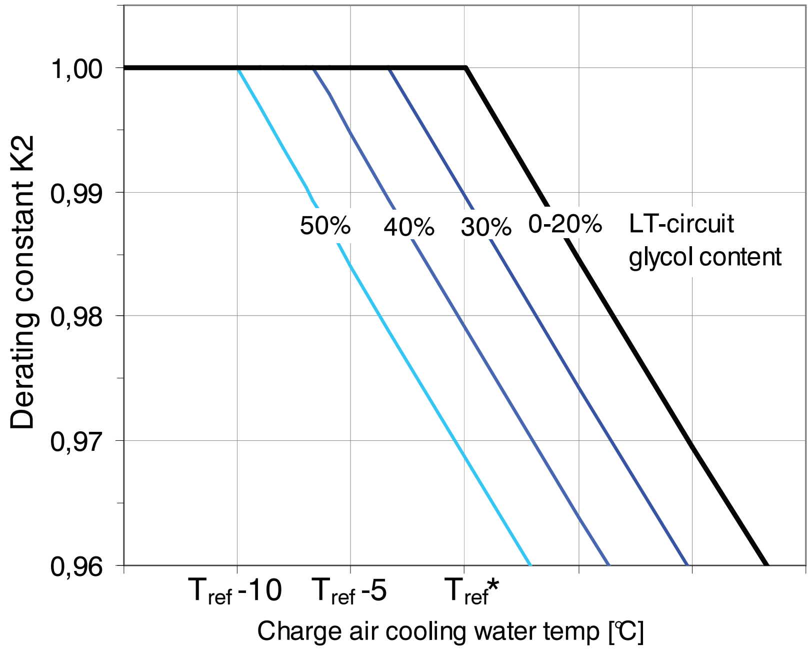

Fig 02-6 V1

Use of glycol in HT water circuit

The maximum allowed amount of glycol in the HT water circuit is 20%. If the HT-circuit glycol content is required to be above 20% arrange the cooling circuits so that the whole HT-circuit can be kept inside the heated engine room, cooled with an intermediate cooler by a secondary circuit (e.g. LT-circuit). With this arrangement the use of glycol in the HT-circuit can be avoided altogether.

Note!
In exceptional cases where the engine room is subject to sub-zero temperature, a maximum HT-circuit glycol content of 50% is permitted.

In case of HT-circuit glycol content above 20% and 2-stage charge air cooler, both stages of the charge air cooler must be included as part of the LT-circuit. Also check the lubricating oil cooler capacity when using glycol in the cooling water.

02B. Oil requirements & oil quality

02B.1. Requirements and oil quality

V6

Document No:
4V92A0665
Revision: j

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

If a low sulphur (S max. 0.2 % m/m) distillate fuel is used, a lubricating oil with a BN of 10-15 is recommended.

When operating with heavy fuels, BN 50-55 lubricants are recommended as a first choice. 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 also be used when operating on heavy fuel as well if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.

On heavy fuel operation BN 30 lubricants are recommended only in special cases, such as installations equipped with an SCR catalyst. Lower BN products can improve the cleanliness of the SCR catalyst. With BN 30 oils, lubricating oil change intervals may be rather short, but total operating costs may be reduced if the maintenance intervals of the SCR catalyst can be increased.

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

If both distillate fuel and residual fuel are used periodically as fuel, lubricating oil quality has to be chosen according to recommendations for residual fuel operation, i.e. BN 30 is the minimum. The optimum BN in this kind of operation depends on the relative operating periods and the sulphur contents of the fuels. Thus in particular cases BN 40 or even higher BN lubricating oils should be used.

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

An example of a BN depletion curve with different BN lubricating oils

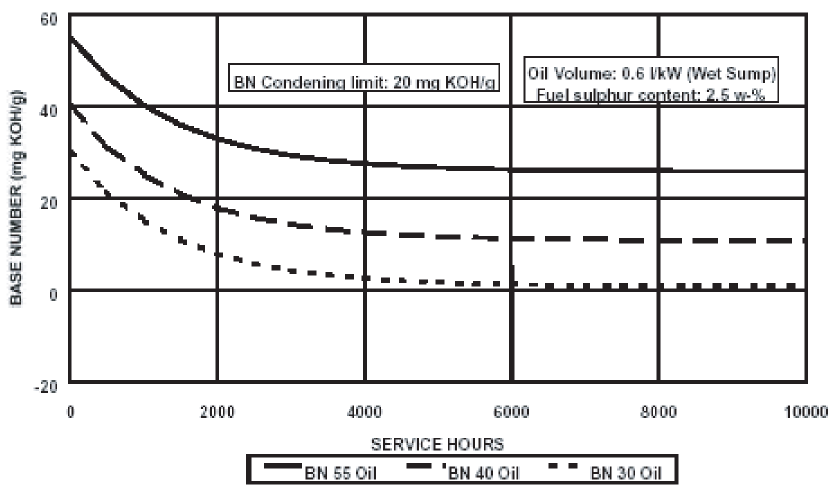

Fig 02B-1 92A0645J V2

Additives

The oils should contain additives that:

- Stabilize oxidation.
- Prevent corrosion.
- Improve load carrying capacity.
- Neutralize residues of combustion and oxidation.
- Prevent deposit formation on internal engine parts (piston cooling gallery, piston ring zone and bearing surfaces in particular).

Foaming characteristics

Fresh lubricating oil should meet the following limits for foaming tendency and stability, according to the ASTM D 892-92 test method:

Sequence I: 100/0 ml

Sequence II: 100/0 ml

Sequence III: 100/0 ml

Base oils

Use only Virgin base stocks.

02B.2. Condemning limits for used lubricating oil V3

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

Property	Unit	Limit	Test method
Viscosity	cSt at 40 °C	max. 25% decrease max. 45% increase	ASTM D 445
Viscosity	cSt at 100 °C	max. 20% decrease max. 25% increase	ASTM D 445
Water	% V/V	max. 0.30	ASTM D 95 or D 6304
Base Number	mg KOH/g	min. 20 in HFO operation, max. 50% depletion in LFO operation	ASTM D 2896
Insolubles	% m/m in n-Pentane	max. 2.0	ASTM D 893b
Flash Point, PMCC	°C	min. 170	ASTM D 93
Flash Point, COC	°C	min. 190	ASTM D 92

02B.3. Change of lubricating oil brand

V3

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

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

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

02B.4. Approved lubricating oil qualities for Wärtsilä 20 engines

V6

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

GAS OIL, MARINE DIESEL OIL AND LIQUID BIO FUEL OPERATION

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

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

TABLE 1				
SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
BP	Energol HPDX 40	SAE 40	12	A,F
	Energol IC-HFX 204	SAE 40	20	A,B,F
Castrol	HLX 40	SAE 40	12	A,F
	MHP 154	SAE 40	15	A,B,F
	Seamax Extra 40	SAE 40	15	A,B,F
	TLX Plus 204	SAE 40	20	A,B,F
Chevron (Texaco + Caltex + FAMM)	Delo 1000 Marine 40	SAE 40	12	A,F
	Delo 2000 Marine 40	SAE 40	20	A,B,F
	Taro 12 XD 40	SAE 40	12	A,F
	Taro 20 DP 40	SAE 40	20	A,B,F
ExxonMobil	Delvac 1640	SAE 40	12	A,F
	Mobilgard ADL 40	SAE 40	15	A,B,F
	Mobilgard 412	SAE 40	15	A,B,F
	Mobilgard 1 SHC	SAE 40	15	A,B,F
Indian Oil Corporation	Servo Marine 1040	SAE 40	10	A,F
	Servo Marine 2040	SAE 40	20	A,B,F
Petrobras	Marbrax CCD-410-AP	SAE 40	12	A,F
	Marbrax CCD-415	SAE 40	15	A,B,F
	Marbrax CCD-420	SAE 40	20	A,B,F
Shell	Gadinia Oil 40	SAE 40	12	A,F
Statoil	MarWay 1040	SAE 40	10.6	A,F
Total / Lubmarine	Disola M 4015	SAE 40	14	A,F
	Disola M 4020	SAE 40	20	A,B,F

HEAVY FUEL AND CRUDE OIL OPERATION

Modern trunk piston diesel engines consume less amount of lubricating oils. This, among other things, stresses the trunk piston severely. Also, residual combustion products that contaminate the lubrication oil can form deposits on certain engine components and cause severe problems. Due to this many lubricating oil suppliers have developed new lubricating oil formulations with better fuel and lubricating oil compatibility.

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

TABLE 2				
SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
BP	Energol IC-HFX 404	SAE 40	40	C,D
	Energol IC-HFX 504	SAE 40	50	C,D
Castrol	TLX Plus 404	SAE 40	40	C,D
	TLX Plus 504	SAE 40	50	C,D
	TLX Plus 554	SAE 40	55	C,D
Cepsa	Troncoil 4040 PLUS	SAE 40	40	C,D
	Troncoil 5040 PLUS	SAE 40	50	C,D
	Ertoil Koral 4040 SHF	SAE 40	40	C,D
	Ertoil Koral 5040 SHF	SAE 40	50	C,D
Chevron (Texaco + Caltex + FAMM)	Taro 40 XL 40	SAE 40	40	C,D
	Taro 50 XL 40	SAE 40	50	C,D
	Taro 40 XL 40 X	SAE 40	40	C,D
	Taro 50 XL 40 X	SAE 40	50	C,D
	Delo 3400 Marine 40	SAE 40	40	C,D
	Delo 3550 Marine 40	SAE 40	55	C,D
Chinese Petroleum Corporation	Marilube Oil W 404	SAE 40	40	C,D
	Marilube Oil W 504	SAE 40	50	C,D
ENI S.p.A.	Cladium 400 S SAE 40	SAE 40	40	C,D
	Cladium 500 S SAE 40	SAE 40	50	C,D
	Cladium 550 S SAE 40	SAE 40	55	C,D
ExxonMobil	Exxmar 40 TP 40	SAE 40	40	C,D
	Exxmar 50 TP 40	SAE 40	50	C,D
	Mobilgard M 440	SAE 40	40	C,D
	Mobilgard M50	SAE 40	50	C,D
Fuchs	Titan PSW 40 SAE 40	SAE 40	40	C,D
	Titan PSW 55 SAE 40	SAE 40	55	C,D
Indian Oil Corporation	Servo Marine K-4040	SAE 40	40	C,D
	Servo Marine K-5040	SAE 40	50	C,D
	Servo Marine K-5540	SAE 40	55	C,D
Lukoil	Navigo TPEO 40/40	SAE 40	40	C,D
	Navigo TPEO 50/40	SAE 40	50	C,D
	Navigo TPEO 55/40	SAE 40	55	C,D

TABLE 2				
SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
Morris Lubricants	Aquamor 140MD	SAE 40	40	C,D
	Aquamor 150MD	SAE 40	50	C,D
Nippon Oil Corporation	Marine T404	SAE 40	40	C,D
	Marine T504	SAE 40	50	C,D
Pertamina	Martron 440	SAE 40	40	C,D
	Martron 450	SAE 40	50	C,D
	Salyx 440	SAE 40	40	C,D
	Salyx 450	SAE 40	50	C,D
	Medripal 440	SAE 40	40	C,D
	Medripal 450	SAE 40	50	C,D
Petrobras	Marbrax CCD-440	SAE 40	40	C,D
	Marbrax CCD-450	SAE 40	50	C,D
Petron	Petromar XC 4040	SAE 40	40	C,D
	Petromar XC 5540	SAE 40	55	C,D
Petronas Lubricants International	Disrol 400 SAE 40	SAE 40	40	C,D
	Disrol 500 SAE 40	SAE 40	50	C,D
	MAEO 4040	SAE 40	40	C,D
	MAEO 4050	SAE 40	50	C,D
Repsol YPF	Neptuno W NT 4000 SAE 40	SAE 40	40	C,D
	Neptuno W NT 5500 SAE 40	SAE 40	55	C,D
Shell	Argina X 40	SAE 40	40	C,D
	Argina XL 40	SAE 40	50	C,D
Total / Lubmarine	Aurelia XL 4040	SAE 40	40	C,D
	Aurelia XL 4055	SAE 40	55	C,D
	Aurelia TI 4040	SAE 40	40	C,D
	Aurelia TI 4055	SAE 40	55	C,D

Approved system oils - fuel categories A, B, C and D. Lubricating oils with BN 30 included in Table 3 are designed to be used when operating on crude oil with low sulphur content (< 1 % m/m). Further, on heavy fuelled installations BN 30 lubricants enhance the cleanliness of the SCR catalyst. However, due to low lubricating oil consumption with BN 30, oils change intervals are shorter than with higher BN lubricating oils.

TABLE 3				
SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
BP	Energol IC-HFX 304	SAE 40	30	A,B,C,D
Castrol	TLX Plus 304	SAE 40	30	A,B,C,D
Cepsa	Troncoil 3040 PLUS	SAE 40	30	A,B,C,D
	Ertoil Koral 3040 SHF	SAE 40	30	A,B,C,D
Chevron (Texaco + Caltex + FAMM)	Taro 30 DP 40	SAE 40	30	A,B,C,D
	Taro 30 DP 40X	SAE 40	30	A,B,C,D
	Delo 3000 Marine 40	SAE 40	30	A,B,C,D
Chinese Petroleum Corporation	Marilube Oil W 304	SAE 40	30	A,B,C,D
ENI S.p.A.	Cladium 300 S SAE 40	SAE 40	30	A,B,C,D
ExxonMobil	Exxmar 30 TP 40	SAE 40	30	A,B,C,D
	Mobilgard M 430	SAE 40	30	A,B,C,D
Fuchs	Titan PSW 30 SAE 40	SAE 40	30	A,B,C,D
Indian Oil Corporation	Servo Marine K-3040	SAE 40	30	A,B,C,D
Morris Lubricants	Aquamor 130MD	SAE 40	30	A,B,C,D
Nippon Oil Corporation	Marine T304	SAE 40	30	A,B,C,D
Pertamina	Martron 430	SAE 40	30	A,B,C,D
	Salyx 430	SAE 40	30	A,B,C,D
	Medripal 430	SAE 40	30	A,B,C,D
Petrobras	Marbrax CCD-430	SAE 40	30	A,B,C,D
Petron	Petromar XC 3040	SAE 40	30	A,B,C,D
Petronas Lubricants International	Disrol 300 SAE 40	SAE 40	30	A,B,C,D
Shell	Argina T 40	SAE 40	30	A,B,C,D
Total / Lubmarine	Aurelia XL 4030	SAE 40	30	A,B,C,D
	Aurelia TI 4030	SAE 40	30	A,B,C,D

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

APPROVED LUBRICATING OILS FOR ABB VTR-TURBOCHARGERS

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

SPECIAL LOW FRICTION SYNTHETIC OILS: CHANGE INTERVAL: 2500 hours ABB´s List 3b				
MANUFACTURER	BRAND NAME	VISCOSITY cSt at 40°C	VISCOSITY cSt at 100°C	VI
BP	Enersyn TC-S 68	68	8.5	98
Chevron (Texaco + Caltex + FAMM)	Cetus PAO 68	68	10.3	138
Castrol	Aircol SR 68	68	10.5	142
ENI S.p.A.	Dicrea SX 68	71.6	10.5	134
ExxonMobil	Compressor Oil RS 68 Rarus SHC 1026 SHC 626	67 66.8 69.9	10 10.4 10.9	135 144 147
Shell	Corena AS 68	67.8	10.1	145
Total / Lubmarine	Barelf SM 68	73.8	11.4	147

LUBRICATING OILS FOR GOVERNOR / ACTUATOR

An oil of viscosity class SAE 30 or SAE 40 is suitable and the same oil as in the engine can be used . 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 good control during start-up. Oil change interval: 2000 service hours.

LUBRICATING OILS FOR STARTING MOTOR

According to starting motor manufacturer Tech Development Inc., the following lubricating greases are approved.

LUBRICATING GREASES FOR STARTING MOTOR, TDI 45M and T50-P	
MANUFACTURER	BRAND NAME
NYE Lubricants	Rheolube 377AL

02C. Raw water quality

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

V10

Revision: e
Document No:
4V92A0765

FOR WÄRTSILÄ 20, ENGINE TYPES

02C.2. Raw water quality requirements

V5

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

Property	Limit
pH	min. 6,5
Hardness	max. 10 °dH
Chlorides	max. 80 mg/l
Sulphates	max. 150 mg/l

For raw water, evaporated water and a good quality tap water are normally suitable. Distilled (evaporated) water without additives absorbs carbon dioxide from air creating a high risk of corrosion. Fresh water generated by a reverse osmosis plant often has a higher chloride content than specified above. However, if the quality requirement is fulfilled, it can be used as well. Sea water causes severe corrosion and deposit formation, even if supplied to the system in small amounts and cannot be used. Rain water is neither suitable as cooling water, because of high carbon dioxide and oxygen contents resulting in a high risk of corrosion.

02C.3. Approved cooling water additives

V5

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

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

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

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

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

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

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

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

02C.4. Use of glycol

V3

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

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

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

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

03. Start, Stop and Operation

V1

03.1. Start

V1

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 high pressure pump),
- both cooling water systems, LT- and HT-water circuit, are in running order (correct pressures, circulating water preheated and precirculated sufficiently to heat the engine),
- the oil level in the governor and turbocharger is correct,
- the starting air pressure exceeds 7.5 bar,
- the starting air system is drained of condensate,
- the fuel and cooling water systems are properly vented from air,
- power supply to all control systems is OK.
- if the engine is not preheated it must be run 15 minutes before the full load.

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

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

03.1.1. Local start

V5

1. **Start the prelubricating oil pump to obtain a oil pressure of about 0.5 bar.** Normally, the prelubricating oil pump is running when the engine is stopped (switch in auto-mode). The prelubricating oil pump is automatically switched off when the engine reaches 300 RPM in running mode.
2. **Turn the crankshaft by two revolutions or run the engine on starting air for some revolutions keeping the stop lever in stop position and the indicator valves open.** This eliminates the risk of water locks and close the indicator valves later.
3. **Disengage the turning gear from the flywheel.**

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

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

6 **A second start attempt is automatically blocked by a time relay until the engine is absolutely standing still.**

7 **After start, check that the pressure and temperature values are normal.**

03.1.2. Remote and automatic start

V2

If the engine has been out of operation for more than a week, it must first be started manually, as mentioned in point 1

Note!
Engines with automatic start must be tested once a week.

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

In automatically starting engines, the priming pump operates continuously thus keeping the engine ready for start. Every second day, ensure that the pump is running.

2 **Press the remote start button of the remotely controlled engine.** The solenoid valve located on the engine is energized and allows starting air into the engine. Press the start button long enough (2-3 seconds) to make the engine start. The remote tachometer or a signal lamp indicates that the engine is running. In some cases the remote control starts the priming pump. After the oil pressure increases to about 0.5 bar, the engine starts automatically. Between each attempt to start the engine via the external control system (if the first start attempt fails), ensure that the engine has stopped completely. This time gap is normally about 30 seconds but has to be checked/adjusted case by case. The number of automatic starting attempts must be limited in order to reserve some capacity of the starting air bottles.

3 **When the engine reaches a predeterminated speed, an auxiliary relay energized by the remoted tacho transmitter cuts off the starting circuit and the starting air solenoid valve closes.** At the same time the current to the priming pump is disconnected thus preventing the pump from operating when the engine is running. On certain installations the priming pump continues to operate at low engine speed to assist the

engine driven lubricating oil pump to maintain the oil pressure. After a fixed time (10-30 seconds) the system for alarm, stop and speed remote control is automatically connected.

03.2. Stopping the engine

V5

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

Note!
When overhauling the engine, make absolutely sure that the ready/blocked switch is in "blocked" position and the priming pump is disconnected.

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

2 **Close the starting air shut-off valve located before the pressure regulating valve.**

3 **Push the STOP button or move the stop lever into STOP position.** The time of slowing down offers a good opportunity to detect possible disturbing sounds.

03.2.1. Stopping the engine for a lengthy time

V1

1 **Check that the indicator valves are closed.** See chapter 12: Operation and maintenance of the indicator valve. It is also advisable to cover the exhaust pipe opening to prevent water from entering the cylinders via the exhaust manifold.

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

3 **Run the engine by the air starter.** Ensure that the indicator valves are open. start the engine once a week to check that everything is in order.

03.2.2. Remote stop

V6

1 **Engines with built-in circulating water pump:** Idling more than 3-5 minutes before stopping is unnecessary and should be avoided.

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

3 **When the engine stops and the speed decreases below a certain limit, the system for alarm, stop and speed remote control will be disconnected and the signal lamp will indicate that the engine is shutting down.** In engines equipped with automatic lubricating oil priming pumps, the pump will be started at the same time.

03.2.3. Automatic stop V5

When the shut-down solenoid is energized from the automatic shut-down system due to some disturbance, the engine will stop as in remote stop. Before this, an alarm device will normally initiate an alarm signal indicating the reason for the shut-down.

When the engine stops because of overspeed, the electro-pneumatic overspeed trip device may have tripped.

03.3. Normal operation supervision V2

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

03.3.1. Every second day or after every 50 running hours V5

1 **Read the values of thermometers, pressure gauges and the load of the generating set.** Compare the values, with those at the corresponding load in the Acceptance test records and curves.

Guidance values are stated in Chapter 01: Main Data, Operating Data and General Design.

- If the difference between exhaust gas temperatures of various cylinders is larger than 70°C at loads higher than 25% the cause should be established.
- At loads higher than 80%, the charge air temperature should be as low as possible, but not so low that condensation occurs, see Fig 03-1. At loads lower than 25% it is favourable to have the charge air temperature as high as possible.

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

3 **Check the indicator for pressure drop over the lubricating oil automatic filter.** A too large pressure drop indicates clogged filter candles, which results in reduced oil filtration when the overflow valves are open (from a differential pressure of 2 bar upwards). Reduced oil filtration results in increased wear. Clean or change clogged filter candles.

4 **Check the oil level in the oil sump/oil tank.** Estimate the appearance and consistence of the oil. The presence of water may be simply controlled by dropping oil onto a hot surface (about 150°C). If the drops "frizzle", the oil contains water. Compensate for oil consumption by adding maximum 10% fresh oil at a time.

5 **Check that the ventilation (de-aerating) of the engine circulating water system (the expansion tank) is working.** Check that the leakage from the "tell-tale" drainage holes of the circulating water pumps is not excessive.

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

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

8 **Check that the "tell-tale" drainage holes of the oil coolers and the circulating water coolers are open.**

9 **Clean the compressor side of the turbocharger by injecting water.** See Chapter 15: Turbocharging and Air cooling.

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

11 **On a stopped generating set, prime the engine and turn the crankshaft into a new position.** This reduces the risk of crankshaft and bearing damage due to vibrations.

Condensation in charge air coolers

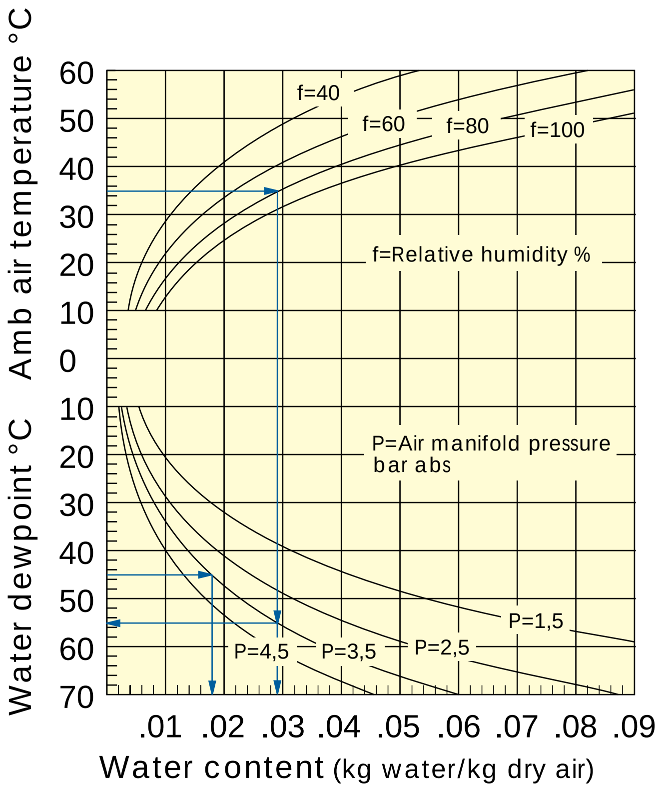


Fig 03-1 V1

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

03.3.2. Every second week or after every 250 running hours V5

1 **Clean the centrifugal lubricating oil filters.** If the deposits are thicker than 8 mm, reduce the cleaning interval to retain filtering efficiency. Maximum deposit capacity is 16 mm.

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

Note!
There are hot surfaces inside the hot box, when the engine is warm.

3 **Clean the turbine side of the turbocharger by injecting water.** See Chapter 15: Turbocharging and Air cooling.

03.3.3. Once a month or after every 500 running hours V7

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

2 **Check the cylinder pressures.**

At the same time, note the load of the engine. The position of the load indicator or the injection pump racks offers an accurate measure of the engine load.

Note!
Measuring the cylinder pressures without simultaneously noting the engine load is practically useless.

3 **Check the function of the cooling system.**

03.3.4. In connection with maintenance work V3

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 a statement of operating times are of limited value ("go/no-go" only).
- lubricating oil changes.
- cleaning of centrifugal lubricating oil filters.
- change of lubricating and fuel oil filter cartridges.
- change of parts in connection with maintenance according to Chapter 04: Maintenance Schedule.

03.3.5. General maintenance V1

1 **There is no automatic supervision** or control arrangement that can replace an experienced engineer's observations.

LOOK at and LISTEN to the engine!

2 **Strong gas blow-by** past the pistons is one of the most dangerous things that can occur in a diesel engine. If gas blow-by is suspected (e.g. because of a sudden increase of the lubricating oil consumption) check the crankcase pressure. If the pressure exceeds 20 mm H2O (100% load), check the crankcase venting system and cylinder tightness, if in order, check the function of the radial turbocharger.

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

Idling (i.e. main engine declutched, generator set disconnected) should be limited as much as possible.

03.4. Start after a prolonged stop (more than 8 h)V4

1 Check:

- lubricating oil level
- circulating water level in the expansion tank
- raw water supply to heat exchangers
- fuel oil level in the day tank (it is a troublesome and time consuming job to vent the fuel system if the feed pump has sucked in air!)
- starting air pressure
- that the control shaft system and the injection pump racks move freely, otherwise there is a risk of overspeed.

2 **Observe all points in Chapter 03: Local start.** Point 2 becomes more important the longer the engine has been stopped.

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

4 **After starting, check that pressure and temperature reach the normal levels.**

03.5. Start after overhaul

V5

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

2 **Activate manually the solenoid** for the overspeed trip device. Check that all injection pump racks move to a value less than 5 mm.

3 **If the injection pumps,** camshaft or its driving mechanism have been touched, check the injection timing. If the camshaft or its driving mechanism have been touched, check the valve timing of one cylinder, at least.

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

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

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

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

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

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

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

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

9 **See the instructions** in chapter 03., sections 03.1 and 03.4 when starting.

03.6. Supervising operation after overhaul

V2

1 **At the first start, listen carefully for possible jarring sounds.**

Caution!
If anything unusual is noticed, stop the engine immediately.

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

3 Check the condition of the stopped engine.

a) Stop the engine.

b) Check the temperature of the main and big end bearings.

c) Check the temperature of all other bearings which have been opened.

d) If everything is in order, restart the engine.

4 Check the engine for leakage of gas, water, fuel or lubricating oil.

a) Check the fuel lines, injection pumps and injection valves.

Note!
Observe if the oil leakage from the pipes increases.

5 Check the condition of the running engine.

a) Check:

- Pressure and temperature
- Automatic alarm and stop devices
- Pressure drop over the fuel filter and lubricating oil filter
- Oil level in the oil sump/oil tank
- Condition of the oil
- Ventilation of the engine cooling water system
- Quantity of leak fuel
- Inspection ports in the coolers
- Content of additives in the cooling water
- Cylinder pressures
- Crankcase pressure.

b) Listen for jarring sounds.

c) Vent the filters.

03.7. Running-in

V4

1 **After piston overhaul, follow programme A as closely as possible.** The piston rings have slid into new positions and need time to bed in. If the programme cannot be followed, do not load the engine fully until it has run for at least 4 hours.

2 **After changing the below, follow programme B as closely as possible.:**

- piston rings
- pistons or cylinder liners
- honing of cylinder liners

Running-in programme

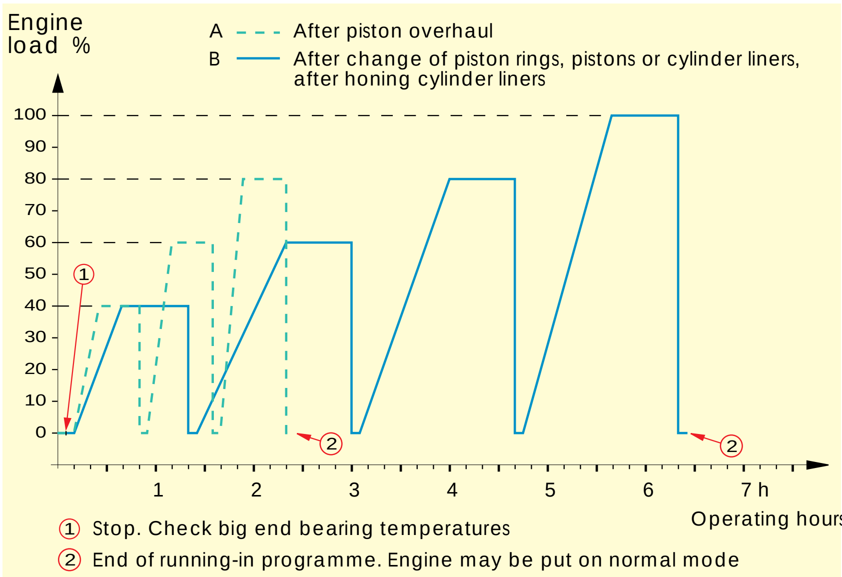


Fig 03-2

V1

Caution!
If the programme cannot be followed, do not load the engine fully until it has run for at least 10 hours.

Caution!
Avoid running-in at a continuous low load.

The important thing is to vary the load several times. The ring groove will tilt differently at each load stage, and consequently the line of contact between the ring and cylinder will change.

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

04. Maintenance Schedule

V3

The maintenance in general is necessary for the engine according to the operating conditions especially when attached with generating set or similar attachments. Because of the difficulty of anticipating the various operating conditions that may be encountered in the field, the periods stated in the schedule should be used for guidance purposes only. They must not however be exceeded during the warranty period.

If, at a shorter interval than recommended, observations or inspections indicate that it is necessary to perform a maintenance procedure or to replace a component, such work should not be delayed. While using diesel or intermediate fuels of comparatively good quality as fuel, it may be possible to extend the stated maintenance intervals considerably depending on the load of the engine. See also the chapter for the turbocharger and the governor and the instructions in chapter Start, Stop and Operation.

- **For Risk Reduction** see chapter 00: Risk Reduction.
- **For Environmental Hazards** see chapter 00: Hazardous substances
- **Before any steps are taken,** read the corresponding item in this Manual carefully.
- **At all maintenance work,** observe the utmost cleanliness and order.
- **Before dismantling,** check that all systems concerned are **drained or the pressure is released.** After dismantling, immediately cover holes for lubricating oil, fuel oil and air with plugs.
- **When exchanging a worn-out or damaged part** provided with an identification mark stating cylinder or bearing number, mark the new part with the same number on the same spot. Every exchange should be entered in the engine log and the reason should be clearly stated.
- **Always renew all gaskets , sealing rings and O-rings** at maintenance work.
- **After reassembling,** check that all screws and nuts are tightened and locked, if necessary.

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

Warning!
During any form of maintenance, make absolutely sure that the gear box is not engaged and the generator breaker is secured to avoid any engine rotation.

Warning!
Accidental turning of engine may cause personal injury and/or engine damage.

04.1. How to select application and fuel quality V2

There are two different types of applications defined:

- Average load is above 75 % of nominal engine output.
- Average load is below 75 % of nominal engine output.

Three types of fuel are defined:

- HFO 1 Heavy fuel oil of normal quality.
- HFO 2 Heavy fuel oil of below normal standard quality.
- DO Diesel oil or light fuel oil (LFO).

Fuel characteristics, maximum limits			
		HFO 1	HFO 2
Sulphur	% mass	1.5	1.5 - 4.5
Ash	% mass	0.05	0.05 - 0.15
Vanadium	mg/kg	100	100 - 600
Sodium	mg/kg	50	50
Sodium, before engine	mg/kg	30	30
Aluminium + silicon	mg/kg	30	30 - 80
Aluminium + silicon, bef. eng.	mg/kg	15	15
Conradson Carbon residue	% mass	15	15 - 22
Asphaltenes	% mass	8	8 - 14
CCAI		850	850 - 870

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

04.2. Every second day

V5

Every second day, irrespective of the engine being in operation or not		
Automatic prelubrication	**Check operation.**	03.1.2 18.7
Crankshaft	**Marine engine:** In a stopped engine, turn the crankshaft into a new position.	

04.3. Once a week

V1

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

04.4. Interval: 50 operating hours

V12

Interval: 50 operating hours		
Air cooler	**Check draining of air cooler.** Check that the draining pipe is open, check for leakage.	15.2.1 03.3.1
Cooling system	**Check water level in cooling system.** Check the water level in the expansion tank(s) and/or the static pressure in the engine cooling circuits.	19.2, 19.7
Connecting rod	**Check tightening of the connecting rod screws.** Check the tightening of the connecting rod screws after the first 50 operating hours on a new engine and after overhaul (those screws that have been opened).	11.4.4 07
Fuel and lubricating oil filters	**Check pressure drop indicators.** Change filter cartridges if high pressure drop is indicated.	17.2 03.3.1 23.1
Gauges and indicators	**Take readings.** Read and record (use form No. WV98V089) all temperature and pressure gauges, and also the load of the engine.	03.3.1
Governor, actuator	**Check oil level in governor.** Check oil level, and look for leaks.	See manufacturers instructions.
Injection and fuel system	**Check leak fuel quantity.** Check the amount of leak fuel from the injection pumps and injection nozzles.	03.3.1 17

Interval: 50 operating hours		
Injection pipes	**Check tightening of 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 opened).	16.2 07.1
Lubricating oil sump	**Check oil level in sump.** Check oil level with a dip stick, compensate for consumption.	18.1 02.2.1
Main bearings	**Check tightening of main bearing screws.** Check the tightening of main bearing screws after the first 50 operating hours on a new engine and after overhaul (those screws that have been opened).	10.4 07.1
Turbocharger	**Water cleaning of compressor.** Clean the compressor by injecting water.	15.1.4
	Check the turbine side V-clamp ring tightening on TPS chargers. If specified, after the first 50 operating hours on a new engine and, after overhaul.	See manufacturer's instructions
	Check fastening bolts at feet, tighten housing bolts and piping joints. Once after commissioning or overhaul; then every 4000 hrs. See the turbocharger makers manual.	
Valve mechanism	**Check valve clearances.** Check the valve clearances after 50 hours running in new and overhauled engines. Check tightening of rocker arm screws and valve/yoke adjusting screw nuts.	12.2.5 06.1 07.1.3
Multiduct	**Check 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 should be at normal operating temperature.	07.1

04.5. Interval: 100 operating hours

V7

Interval: 100 operating hours		
Turbocharger	**Water cleaning of turbine.** Clean the turbine by injecting water; adjusted acc. to operation.	15.1.2

04.6. Interval: 250 operating hours

V5

Interval: 250 operating hours		
Centrifugal filter	**Clean centrifugal filter.** Clean more often if necessary. Remember to open the valve before the filter after cleaning. Check the condition of bearings and shaft journals.	18.6
Control mechanism	**Maintenance of control mechanism.** Check for free movement, clean and lubricate.	22.1
Lubricating oil	**Take oil sample.** In a new installation or after change to use of a new lubricating oil brand, take samples for analysing.	02.2.2

04.7. Interval: 500 operating hours

V7

Interval: 500 operating hours		
Circulating water	**Check water quality.** Check content of additives.	02.3.2 02.3.1
Cylinder pressure	**Check cylinder pressure.** Record firing pressures of all cylinders.	03.3.3
Lubricating oil	**Take oil sample.** Take oil sample for analysis. Use of lubricating oil can be prolonged as long as the analysis results are within the specified limits set by the engine manufacturer. For a new installation, see the interval: 1000 hours. Clean all oil spaces with a high quality fibre-free / lint free cloth when changing lubricating oil.	18.1
Turbochargers	**Wash filter mat on silencer.** After completing 3000 operating hours or being washed five times replace with a new one.	15.1.1 See manufacturers instructions.

04.8. Interval: 1000 operating hours

V9

Interval: 1000 operating hours		
Automation	**Functional check of automation.** Check function of the alarm and automatic stop devices.	23.3.2 01.2
Fuel filter	**Replace fuel oil filter cartridges.** Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced when the pressure difference indicator shows too high pressure drop).	17 17.2
Lubricating oil	**Change lubricating oil.** Change oil in a new installation (wet sump installations). Take samples for analysing. Use of lubricating oil can be prolonged, in steps of 500 operating hours, as long as the analysis results are within the specified limits set by the oil supplier or the engine manufacturer. Change oil in an installation (wet sump installations) that is not purifying regularly the lubricating oil, independently of oil analysis result. Clean all oil spaces with a high quality fibre-free / lint free cloth when changing lubricating oil.	18.1 02.2.2
Valves	**Check of valve condition.** Check valve clearances. Check cylinder tightness (valves, piston rings) with a pneumatic test. Check that the inlet and exhaust valves move freely in their guides. This should preferably be done when the engine has been out of operation for a couple of hours.	12.2.5 06.1 12A

04.9. Interval: 2000 operating hours

V8

Interval: 2000 operating hours		
Charge air cooler	**Check water side of charge air cooler.** The first time check and possible cleaning of the **waterside** . If in good condition and deposits unsignificant: future intervals 4000 running hours.	15.2.1
Measuring instruments	**Checking of gauges.** Check pressure and temperature gauges. Replace faulty ones.	23.1
Governor	**Change oil in governor.** Change lubricating oil.	02.2.3
Injection valves	**Inspect injection valves.** Test the opening pressure. Dismantle and clean nozzles. Check the effective needle lift. Check the springs. Replace the O-rings. .	16.4.2
Overspeed trip device	**Check function of overspeed trip.** Check function and tripping speed	22.4

04.10. Interval: 4000 operating hours

V8

Interval: 4000 operating hours		
Air cooler	**Clean the charge air cooler.** Clean the air and water side of the charge air cooler and pressure test it. Look carefully for corrosion.	15.2.1
Automation	**Check connectors and cables.** Check mounting and connection. Make a visual check of all cables and replace these cables that are damaged.	23.1
Camshaft and valve mechanism	**Visually inspect contact faces of camshaft.** Check the contact faces of the cams and tappet rollers. Check valve yoke and adjusting screw nut and that the rollers rotate. Rotate the engine with the turning gear.	14
Control mechanism	**Check control mechanism.** Check for wear in all connecting links between the governor and all injection pumps.	22.1
Flexible coupling	**If specified** check alignment, use form WV98V041. Check condition of coupling.	See manufacturers instructions.
Crankshaft	**Check crankshaft alignment.** Check alignment, use form No. WV98V036. Alignment check has to be performed on a warm engine.	11.1.2
Resilient mounts	**Inspect buffer clearance,** reset if necessary. Inspection to be made at least once a year.	

Interval: 4000 operating hours		
Cylinder liners	**Inspect jacket water spaces.** Pull one cylinder liner. If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment. Replace the distance shim under liner if installed.	02.3 10.6
Exhaust manifold	**Check the expansion bellows, nuts and pipe support of the flange connections.** Tighten loose nuts. Replace supports and bellows if necessary.	20.1
Lubricating oil cooler	**Clean the lubricating oil cooler.** If the lubricating oil temperature before the engine is within normal operating values, the interval can be prolonged. Unnecessary opening of the cooler should be avoided. Clean the lubricating oil cooler before the alarm limit for the lubricating oil temperature is reached. Examine carefully for corrosion.	18.4
Lubricating oil automatic filter	**Inspect lubricating oil filter candles.** Replace worn parts and clean the candles and safety filter mesh, if necessary. Mechanical cleaning not allowed.	18N.1.1
Nozzles	**Check the nozzle condition in a test pump.** **Recommendation:** Replace the nozzles by new ones	16.4.2
Turbocharger	**Inspect and clean.** Clean the compressor and turbine mechanically if necessary.	15.1.1 19.7
	Inspect nozzle ring.	15.1.2

04.11. Interval: 8000 operating hours

V8

Interval: 8000 operating hours		
Camshaft driving gear	**Inspect camshaft driving gear.** Check clearances and backlash. Replace parts, if necessary.	13
Flexible hoses	**Visually inspect the flexible hoses.** Replace, if necessary.	
Governor driving gear	**Inspect governor driving gear.** Replace parts, if necessary.	22.3
HT-water pump	**Inspect HT-water pump.** Dismantle and check. Replace shaft seals and worn parts. Check backlash.	19.8
HT-water pump driving gear	**Inspect HT-water pump driving gear.** Replace parts, if necessary. Check backlash.	19.8

Interval: 8000 operating hours		
HT-water thermostatic valve	**Clean and inspect HT-water thermostatic valve.** Clean and check the thermostatic element, valve cone-casing and sealings.	19.9
LT-water thermostatic valve	**Clean and inspect LT-water thermostatic valve.** Clean and check the thermostatic element cone-casing and replace sealings. Check the function of the valve.	19.9
LT-water pump	**Inspect LT-water pump.** Dismantle and check. Replace shaft seals and worn parts. Check backlash.	19.8
LT-water pump driving gear	**Inspect LT-water pump driving gear.** Replace parts, if necessary. Check backlash.	19.8
Lubricating oil pump	**Inspect the lubricating oil pump.** Dismantle and check. Replace worn parts. Check backlash.	18.2
Oil pump driving gear	**Inspect oil pump driving gear.** Replace parts, if necessary. Check backlash.	18.2
Oil thermostatic valve	**Clean and inspect oil thermostatic valve.** Clean and check the thermostatic element, valve cone-casing and sealings.	18.5
Prelubricating oil pump	**Inspect the prelubricating oil pump.** Replace shaft seals and worn parts.	18.7
Electrical motor	**Electrical motor for prelubricating oil pump.** Replace roller bearings on electrical motor or latest after three (3) years in use.	
Lubricating oil automatic filter	**Replace lubricating oil filter candles.** Drain the filter housing. Clean the wire gauze. Replace the filter candles. Conduct visual inspection of all filter candles once a year. Replace the filter candles after latest 2 years in service or if Δp alarm occurs.	18N.1
Fuel system	**Check and adjust fuel system.** Check the settings of the fuel system. Check for possible leakage. Replace parts, if necessary.	17
Starting/smoke fuel limiter	**Check function of starting/smoke fuel limiter.**	22 23.1
Air starter	**General overhaul of air starter motor.** Conduct starter maintenance along with general engine maintenance or latest after 3 years. Replace bearings, solenoid valve and worn parts.	21.1 See manufacturers instructions.

04.12. Overhaul interval V1

Fuel	Overhaul interval	
	Average load > 75 %	Average load < 75 %
HFO 2	8000	10000
HFO 1	12000	14000
DO	16000	20 000

04.13. Interval: (8000 - 20000) See table 04.12. V7

Interval: (8000 - 20000) See table above		
Connecting rod	**Replace big end bearings.** Replace big end bearings. Inspect mating face and surface of serrations. Measure the big end bore, use form 2011V001.	11.4.2
	Inspect small end bearings Replace if necessary, use form 2011V007.	11.4.3, 06.2
Crankshaft	**Check thrust bearing clearance.** Check axial clearance	10.5.3
Cylinder heads	**Overhaul of cylinder head.** Dismantle and clean the underside, inlet and exhaust valves and ports. Pull out the exhaust gas seat rings, inspect cooling spaces and clean, replace the O-ring(s). If necessary, grind the valves and EX / IN seat rings (often lapping by hand is enough). Inspect the valve rotators. Replace the O-rings in the valve guides. Use the Cylinder Head Overhaul Report measurement record 2012V015.	12
Cylinder liners	**Inspect the cylinder liners.** Measure the bore using form No. 2010V002, replace liner if wear limits are exceeded. Hone the liners. Renew the antipolishing ring.	10.6
	Inspect all cylinder liners water side and replace O-rings. Pull all cylinder liners. If the deposits are thicker than 1 mm, clean all liners and the engine block water space. **Replace the O-rings** in the bottom part by new ones at every overhaul.	19.7 10.6
Injection pumps	**Overhaul of injection pumps.** Clean and inspect injection pumps, replace worn parts. Replace all seal rings and constant pressure valve. Check the erosion plugs, replace if necessary.	16.2.7
Pistons	**Inspect the piston.** Dismantle one composite piston for inspection of mating surfaces between piston skirt and piston crown. Inspect and clean oil spaces. Repeat the procedure with other pistons if necessary.	11.4.3

Interval: (8000 - 20000) See table above		
Piston, piston rings	**Inspect pistons and piston rings.** Pull, inspect and clean. Check the height of the ring grooves. Check the retainer rings of the gudgeon pins. Replace complete set of piston rings. Note the running-in program.	11.4.2
Main bearings	**Inspect the bearing shells of one main bearing.** Replace all bearing shells, if necessary.	10.4.2
Turbocharger TPS-chargers	**Inspect the bearings of radial type charger.** Replace bearings if necessary.	15.1.1 See manufacturers instructions.
Valve mechanism	**Check valve mechanism bearings.** Check tappets and rocker arms. Replace valve tappet roller bearing bush, if specified.	14.3.2 06.2

04.14. Interval: 16000 operating hours

V5

Interval: 16000 operating hours		
Fuel feed pump	**Inspect fuel feed pump.** General overhaul and replace shaft seals and gaskets.	
Governor drive	**Check the governor drive bearing.** Check governor driving shaft bearing clearance in situ.	22.3.1 06.2
Vibration damper	**Dismantle and check.**	11.1 See manufacturers instructions.
Viscous vibration damper	**Take oil sample from vibration damper.** Take oil sample for analysing.	11.1 See manufacturers instructions.
Camshaft	**Inspect camshaft bearings.** Replace if necessary.	14.3.2 06.2
Intermediate gears and bearings	Inspect gear teeth and measure backlash and axial clearance. Replace bearings at least every 32. 000 hrs.	13 06.2
Governor	**Governor general overhaul** at an authorized workshop latest after 5 years in use.	See manufacturers instructions.
	Check the function and adjustments of the governor. Replace worn parts.	22.3

04.15. Interval: 24000 operating hours

V8

Interval: 24000 operating hours		
Connecting rod	**Replace connecting rod screws.** Replace connecting rod screws at the latest every 24000 operating hrs. with new ones.	11.4.4 07
Crankshaft	**Inspect crankshaft.** Inspect the crankshaft bearing surfaces. Measure the crankpin diameter and ovality.	06.2
Engine fastening bolts	**Check tightening of engine fastening bolts.** Replace if necessary.	07.3
Overspeed trip device Elektro-pneumatic	**General overhaul of overspeed trip device.** Check function and tripping speed.	22.4 22.4.2
Turbocharger	**Replace turbocharger bearings.**	15.1.1 See manufacturers instructions.
Automation and control system	**Replace vibration dampers (rubber elements).** Replace the rubber elements for components such as connection boxes, control modules, connection rails and main cabinet. The vibration damper should be replaced latest every fourth (4) year.	23.3.1

04.16. Interval: 24000 operating hours or after 5 years

V6

Interval: 24000 operating hours or after 5 years		
Valve mechanism	**Replace rocker arm screws, yoke and adjusting screw nuts.**	14.1
Injection valve yoke	**Injection valve yoke tension screws.** Replace screws.	12
Exhaust gas piping	**Exhaust gas piping support, plates, nuts and screws.** Replace supports, nuts and screws.	20.1
Control mechanism	**Replace support bearing bushes and V-rings on fuel control shaft.**	22.1

04.17. Interval: 48000 operating hours

V1

Interval: 48000 operating hours		
Turbocharger	**Replace rotor.**	15.1.1 See manufacturers instructions.

05. Maintenance tools

V1

Maintenance of the engine requires the use of some special tools developed in the course of engine design. Some of these tools are delivered with the engine, others are available from the Wärtsilä's service stations.

The tools required for a particular installation varies depending on the application. The standard tool sets have been composed to meet the basic requirements.

Before starting a maintenance work, check that all necessary spare parts, consumables and maintenance tools are available. The required maintenance tools are stated in the maintenance instructions.

Tools available from Wärtsilä are listed in the Spare Parts Catalogue. Tools delivered with the engine are listed in the installation specific delivery list.

Regarding maintenance tools for the governor and the turbocharger, refer to the enclosed governor and turbocharger documentation.

05.1. About Spare Parts Catalogue

V1

The Spare Parts Catalogue presents a comprehensive selection of tools for the Wärtsilä engines. Each tool is specified by a code and a descriptive name. In order to facilitate the choice of tools for a specific service operation, the tools are grouped according to the engine part they are intended for. The tools for servicing a certain part are shown in a picture, where each tool is marked with its code. They are also listed in a table with tool codes and names.

Note!
Some of the tools listed in the Spare Parts Catalogue are only applicable for certain cylinder numbers and/or certain engine mounting equipment.

05.2. Ordering maintenance tools

V2

To order maintenance tools or spare parts:

1 **Find the required tools or parts in the Spare Parts Catalogue.** Note down the specifications (part number and name) from the Spare Parts Catalogue along with other ordering information, or fill in the Inquiry/Order List. See the table below for required ordering information. The engine type, engine specification and engine number are found on the engine name plate.

Table 05-1 Information required when ordering maintenance tools

Required information	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
Name of consignee	Engineer A. Clipper
	M/S Brigitte
	C/O Seaforwarding
	Sea Port, Hull
Purchaser	Shipowner Atlanta
	Head Square,
	Birmingham E.C.
Method of forwarding	Express air line

2 **Send the order to the Wärtsilä Service Office address printed on the Inquiry/Order List, or directly to Wärtsilä.** Addresses and telephone numbers are printed on the title page of this manual. All commercial terms are stated in the Inquiry/Order List.

Note!
All orders placed by telephone should be confirmed by email or letter.

When ordering special equipment or tools not included in the Spare Parts Catalogue or Instruction Manual, please state the manufacturer's type designation and serial number. If the data is not available, describe the tool as clearly as possible and enclose a picture.

06. Adjustments, Clearances and Wear Limits

V2

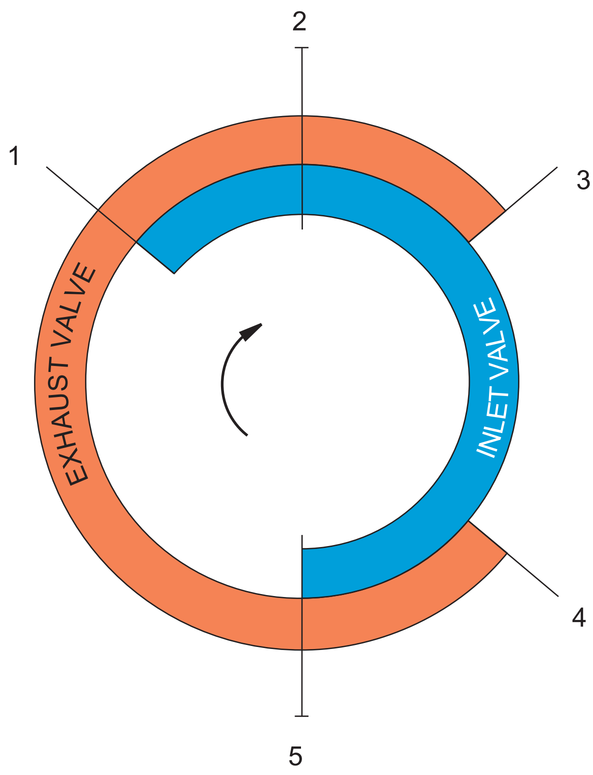
06.1. Adjustments

V8

Valve timing

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

Valve timing



1. *Inlet valve opens.* 2. *TDC.* 3. *Exhaust valve closes.* 4. *Exhaust valve opens.* 5. *BDC inlet valve closes.*

Fig 06-1

200601 V3

Other set values:

- Valve clearances, cold engine: inlet valves 0.4 mm, exhaust valves 0.8 mm.
- Fuel delivery commencement. See test records.
- Opening pressure of fuel injection valve 450±10 bar.

06.2. Clearances and wear limits at 20°C

V9

	Part, measuring point	Drawing dimension (mm)		Normal clearance (mm)	Wear limit (mm)
		Maximum	Minimum		
10	Main bearing clearance (also flywheel bearing)			0.190-0.294	
	Journal, diameter	210.000	209.971		209.900
	Journal, out of circularity	0.015			0.05
	Journal, taper	0.02/100			
	Main bearing shell thickness	7.420	7.405		7.36
	Main bearing housing bore	225.046	225.000		
	Assembled bearing bore	210.265	210.190		
	Thrust bearing, axial clearance			0.170-0.350	0.50
	Thrust washer thickness	13.850	13.830		
	Camshaft bearing clearance			0.125-0.215	
	Camshaft journal diameter	140.000	139.975		
	Camshaft bearing bush, thickness	4.945	4.930		
	Camshaft bearing housing, bore	150.046	150.000		
	Assembled bearing bore	140.190	140.125		
	Camshaft thrust bearing housing, bore	105.035	105.000		
	Assembled bearing bore	90.165	90.100		
	Camshaft thrust bearing clearance			0.100-0.187	
	Camshaft thrust bearing, axial clearance			0.25-0.55	
	Cylinder liner, diameter	200.046	200.000	top: 200.45 bottom: 200.25	
	Cylinder liner, out of cylindricity at TDC	0.02			0.20
	Antipolishing ring, wall thickness	4.25	4.20		4.05

	Part, measuring point	Drawing dimension (mm)		Normal clear-ance (mm)	Wear limit (mm)
		Maximum	Minimum		
11	Big end bearing clearance			0.145-0.230	
	Crankshaft, axial clearance			0.170-0.350	
	Crank pin, diameter	180.000	179.975		179.900
	Crank pin, out of circularity	0.015			0.05
	Crank pin, taper	0.03/100			
	Big end bearing shell thickness	4.950	4.935		4.90
	Big end bore, ovality	190.029	190.000		0.12
	Assembled bearing bore	180.205	180.145		
	Gudgeon pin bearing clearance			0.050-0.112	
	Gudgeon pin diameter	90.000	89.990		
	Small end bore	105.022	105.000		
	Assembled bearing bore	90.120	90.068		
	Connecting rod axial clearance in piston			0.2-0.6	
	Small end bearing bush, thickness	7.475	7.460		
	Piston gudgeon pin clearance			0.04-0.07	
	Piston gudgeon pin diameter	90.060	90.040		
	Piston ring height clearance: Compression ring 1 Compression ring 2 Oil scraper ring			 0.10-0.145 0.06-0.105 0.04-0.075	 0.4 0.35 0.35
	Piston ring groove height: Groove I Groove II Groove III	 6.12 5.08 6.05	 6.09 5.05 6.03		 6.40 5.35 6.30
	Piston crown M18 screw length	66.5	66.3		67.1
11B 11C	Balancing shaft 4L20 and 5L20 Intermediate gear axial clearance			0.10-0.20	
	Balancing shaft intermediate gear, bearing clearance			0.06-0.15	
	Axial clearance			0.10-0.20	
	Backlash balancing shaft intermediate gear/crankshaft gear			0.10-0.30	
	Backlash balancing shaft intermediate gear/balancing shaft gear			0.30-0.50	
	Backlash balancing shaft gear/balancing shaft gear			0.21-0.43	
	Drive shaft, axial clearance			0.15-0.40	
	Drive shaft, bearing clearance			0.090-0.169	
	Balancing shaft bearing clearance			0.090-0.169	

	Part, measuring point	Drawing dimension (mm)		Normal clearance (mm)	Wear limit (mm)
		Maximum	Minimum		
12	Valve guide diameter assembled	14.088	14.034		
	Valve stem diameter	14.000	13.982		13.95
	Valve stem clearance			0.04-0.10	0.20
	Valve seat deviation relative guide (maximum value)	0.10			
	Inlet valve seat bore in cylinder head	78.019	78.000		
	Exhaust valve seat bore in cylinder head outer bore inner bore	78.019 67.019	78.000 67.000		
13	**Camshaft drive intermediate gear** bearing clearance axial clearance			0.100-0.187 0.25-0.54	0.22 0.60
	Bearing diameter	90.165	90.100		
	Bearing journal diameter	90.000	89.978		
	Camshaft driving gear backlash:				
	Crankshaft gear wheel/large intermediate gear wheel			0.10-0.50	
	Small intermediate gear wheel/camshaft gear wheel			0.20-0.37	
	Base tangent length:				
	- crankshaft gear wheel, assembled	130.505	130.449		
	- large intermediate gear wheel	130.283	130.227		
	- small intermediate gear wheel	84.228	84.172		
	- camshaft gear wheel	140.331	140.275		
14	Valve tappet, diameter	54.970	54.940		
	Guide diameter	55.030	55.000		
	Diameter clearance			0.09-0.15	
	Tappet roller bore diameter	22.021	22.000		
	Tappet pin diameter	21.993	21.980		
	Clearance roller pin			0.007-0.041	
	Rocker arm bearing diameter	50.064	50.025		
	Bearing journal diameter	50.000	49.984		
	Bearing clearance			0.025-0.080	0.20
	Yoke pin diameter	19.935	19.922		
	Yoke bore diameter	20.021	20.000		
	Diameter clearance			0.065-0.099	0.15
16	Nozzle needle lift	0.45			0.55
17	Fuel feed pump backlash: Driving gear wheel to crankshaft gear wheel			0.24-0.47	

	Part, measuring point	Drawing dimension (mm)		Normal clearance (mm)	Wear limit (mm)
		Maximum	Minimum		
18	Lubricating oil pump diameter of shaft	49.92	49.895		
	Bush hole diameter, assembled	50.045	49.99		
	Bearing clearance			0.080-0.165	0.20
	Axial clearance: 4, 5 and 6L20			0.120-0.230	
	Axial clearance: 8 and 9L20			0.130-0.220	
	Backlash for pump gear wheels			0.432-0.736	
	Backlash for pump gear wheel/intermediate gear wheel			0.15-0.48	
	Intermediate gear, bearing clearance			0.06-0.15	
	Intermediate gear, axial clearance			0.10-0.20	
	Backlash for intermediate gear wheel/crankshaft gear wheel			0.10-0.30	
	Base tangent length over 2 teeth	43.37	43.258		
19	Water pump backlash for driving gear			0.26-0.55	
	Backlash for sea water pump driving gear/intermediate gear wheel			0.10-0.40	
	Backlash for sea water pump intermediate gear/crankshaft gear wheel			0.20-0.50	
	Base tangent length over 4 teeth	53.643	53.563		
21	Airstarter pinion wheel backlash			0.89-1.15	
22	Driving shaft for governor	22.0	21.987		
	Bearing for driving shaft	22.058	22.026		
	Bearing clearance			0.026-0.071	
	Axial clearance			0.10-0.50	
	Backlash for driving gear			0.07-0.25	
	Control shaft	20.000	19.967		
	Control shaft bearing	20.162	20.110		
	Clearance			0.110-0.195	

07. Tightening Torques and Instructions for Screw Connections

V2

07.1. Tightening torques for screws and nuts

V9

Note!
Tightening torques for hydraulically tightened connections are presented in their own section.

In the following sections from A on, the position numbers in the tables refer to the corresponding figures that represent the main components of the engine.

Threads and contact faces of nuts and screw heads should be oiled with lubricating oil unless otherwise stated. Locking fluids are used in certain cases.

Note!
Do not use Molykote or similar low friction lubricants for any screws or nuts due to risk of overtensioning.

Warning!
Always tighten to the torque specified in the tables. A loose screw connection may cause serious damages or human injury.

1 Nm = 0.102 kpm

Tightening torques

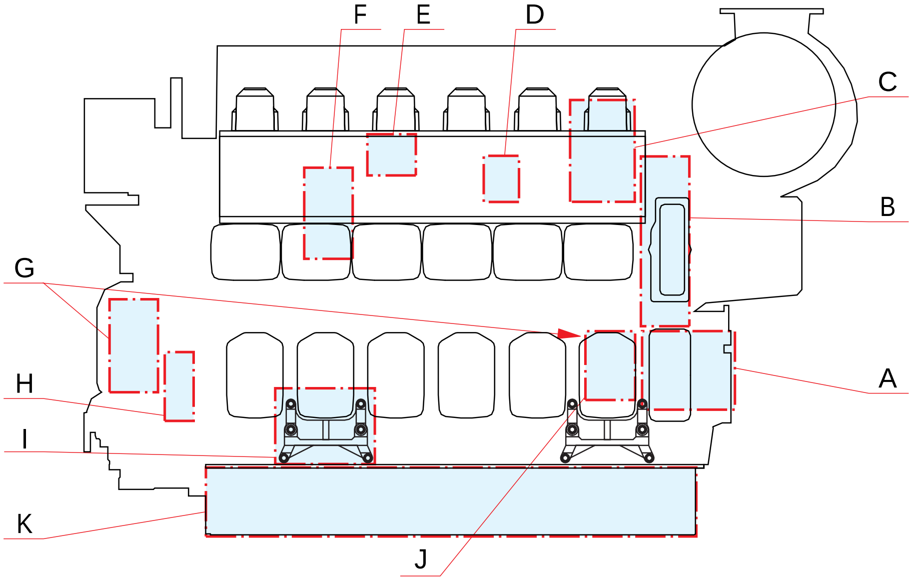


Fig 07-1

200774 V1

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

Screw dimension	Width across flats of hexagon screws (mm)	Key width of hexagon socket head screws (mm)	Torque	
			(Nm)	(kpm)
M5	8,5	4	5,4	0,55
M6	10	5	9.5	0.95
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

07.1.1. A: Crankshaft and flywheel

V8

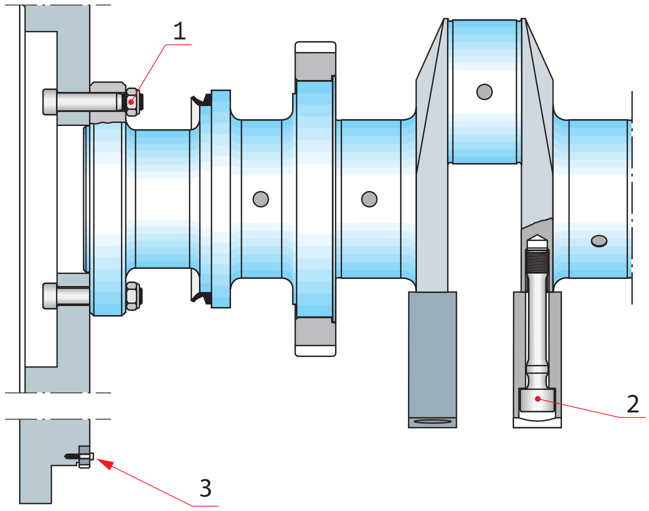


Fig 07-2

200756 V2

Pos.	Screw connection	Torque (Nm)
1.	Crankshaft flange screws (**fitted bolts**). Lubricate the contact faces of the screws and holes with **Molykote G-n Plus**, the threads with oil.	300
	Use the torque multiplier X-4.	91
	Crankshaft flange screws (**hexagon socket screws**). Lubricate the washers with **Molykote G-n Plus**, the threads with oil.	600±20
	Use the torque multiplier X-4.	182
2.	Screws for counterweight, M24 (**two counterweights per crank**) Lubricate with engine oil.	480±20
	Use torque multiplier X-4.	145
3.	Screws for the gear rim halves. **Apply Loctite 242 on threads**, see section 07.2.	49

07.1.2. B: Camshaft and intermediate gear

V6

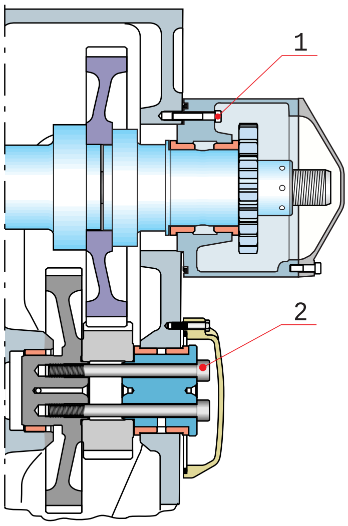


Fig 07-3

200771 V1

Pos.	Screw connection	Torque (Nm)
1.	Screws for housing, **apply Loctite 245**	25
2.	Screws for intermediate gear, 5xM20. Lubricate the threads and the screw head with oil.	530±15

07.1.3. C: Valve mechanism and multihousing

V8

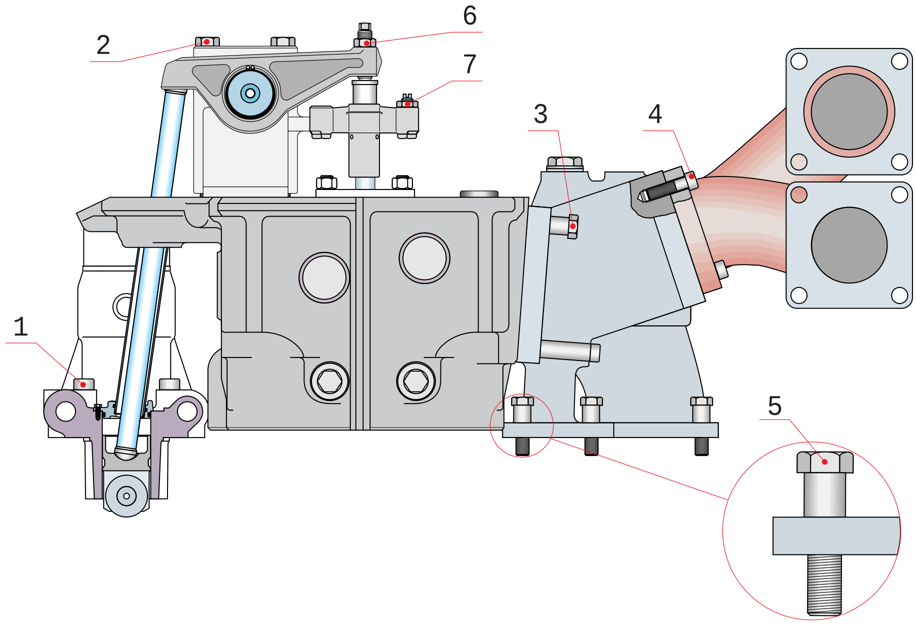


Fig 07-4

200790 V1

Posi-tion	Screw connection	Torque (Nm)
1.	Screws for valve tappet guide block and injection pump.	110±5
2.	Rocker arm console, fastening screws.	200±5
3.	Fastening screws, cylinder head/multiduct.	80
4.	Fastening screws, multiduct/exhaust manifold.	80
5.	Multiduct fastening screws with distance sleeves.	80
6.	Locking nut for valve clearance adjusting screw.	100
7.	Locking nut for valve yoke adjusting screw.	60

07.1.4. D: Injection pump

V7

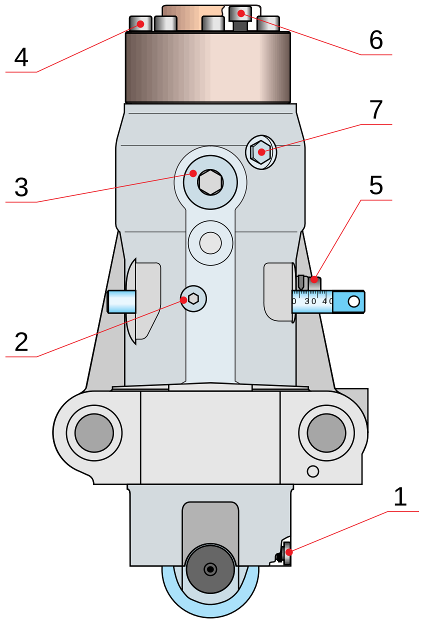


Fig 07-5

200772 V1

Pos.	Screw connection	Torque (Nm)
		Bosch PFR 1 CY 180V
1.	Side screw	14±1
2.	Grub screw	14±1
3.	Erosion plug **Apply Loctite 242 on threads,** see section 07.2	85±5
4.	Injection pump element fastening screws.	33±2
	Note! Tighten the screws crosswise in steps Lubricate threads with **Molykote G-n plus**	0..10..20..33
5.	Screw for fuel rack indicator	3,5±0,5
6.	Screws for pressure valve	33±2
	Note! Tighten the screws crosswise in steps Lubricate threads with **Molykote G-n plus**	0..10..20..33
7.	Vent screw	22±2

07.1.5. E: Fuel injection valve

V7

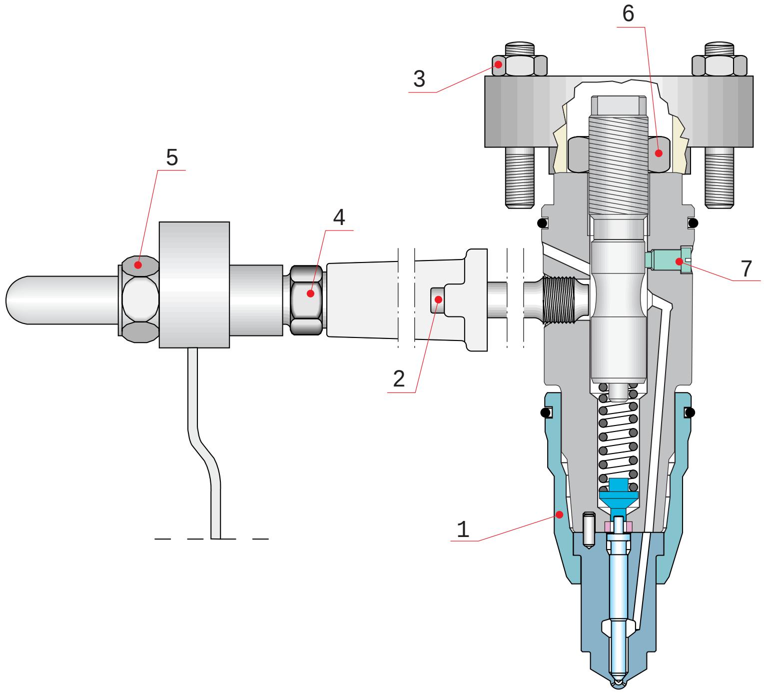


Fig 07-6

200779 V1

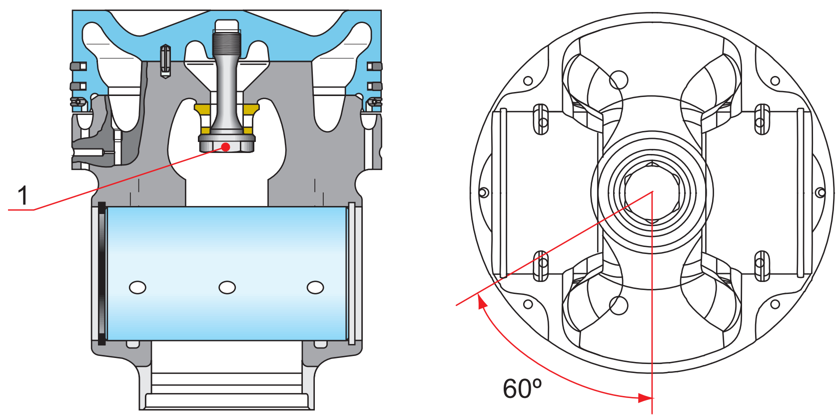
Position	Screw connection	Torque (Nm)
1.	Injection nozzle cap nut. Lubricate threads and contact face with **Molykote G-n Plus**.	270±10
2.	Screws for protecting sleeve.	25
3.	Injection valve fastening nuts, see section 16.4.4.	50±3
4.	Connection piece to nozzle holder, lubricate the connecting piece with oil.	65±5
5.	Injection pipe cap nuts to injection pump, lubricate the nuts with oil.	55±5
6.	Nut for pressure adjustment.	100±10
7.	Guide screw **Apply Loctite 241 on threads,** see Chapter 07: Use of locking fluid.	10+5

Note!
Injection valves of type 1 have an adjusting screw placed at the side of the valve, while injection valves of type 2 and 3 have an adjusting screw at top of the valve.

07.1.6. F: Piston

V5

Tightening the piston screw (One screw)



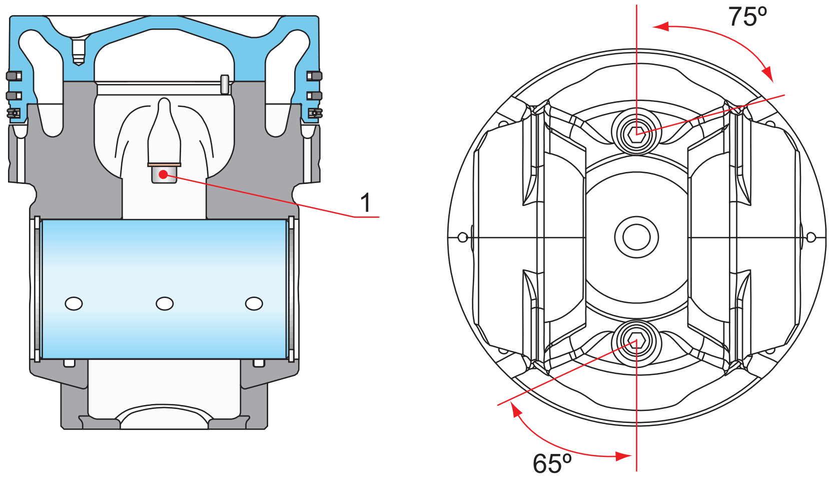
1. *Piston with 1 screw*

Fig 07-7

V1

	Piston with 1 screw	
Posi-tion	Screw connection	Torque (Nm) Angle (°)
1.	Screw for piston (M18x1.5):	
	New screw with old or new crown	
	1. Lubricate threads and contact surfaces with **Moly-kote G-N Plus**	
	2. Tighten the screw to	45 Nm
	3. Tighten the screw further	90°
	4. Loosen the screw	
	5. Tighten the screw again to	45 Nm
	6. Tighten the screw further	60°+5°
	7. Check with tightening torque, the screw may not turn further	130 Nm
	Note! When changing piston crown, renew the screw.	
	Old screw with old crown	
	1. Lubricate threads and contact surfaces with **Moly-kote G-N Plus**	
	2. Tighten the screw to	45 Nm
	3. Tighten the screw further	60°+5°
	4. Check with tightening torque, the screw may not turn further	130 Nm

Tightening the piston screw (Two screws)



1. *Piston with 2 screws*

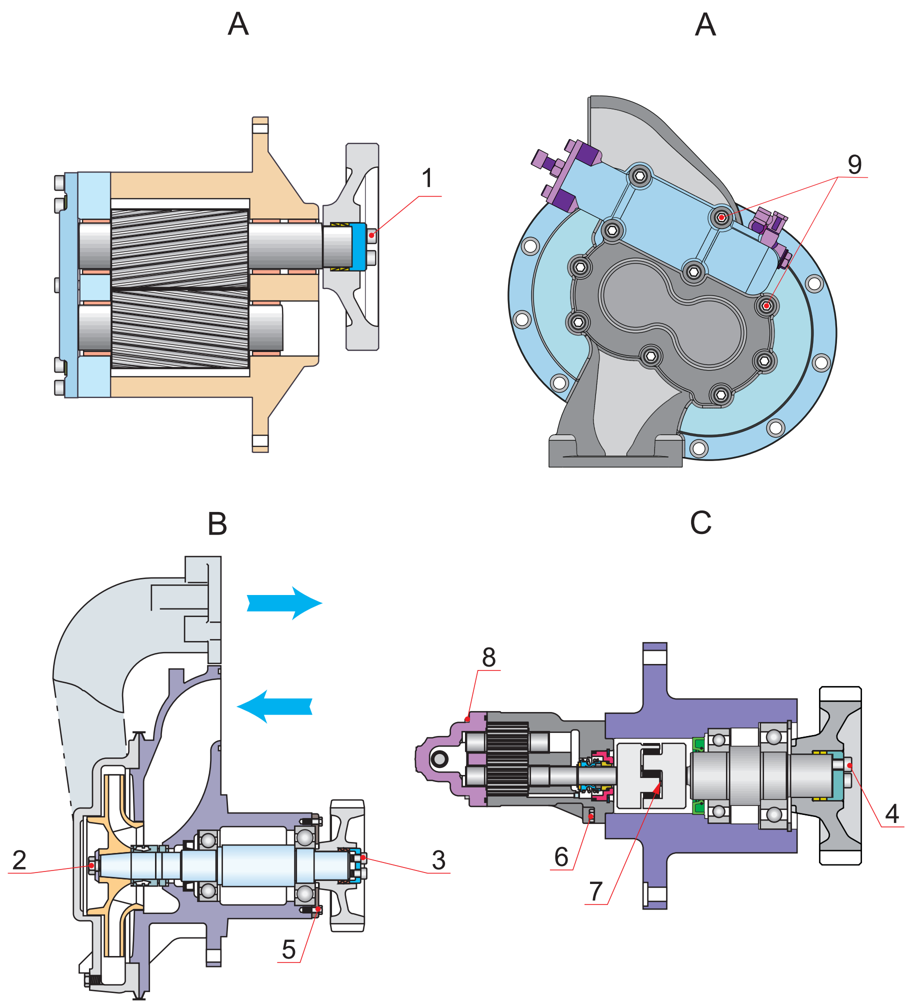
Fig 07-8

V2

	Piston with 2 screws	
Posi-tion	Screw connection	Torque (Nm) Angle (°)
1.	Screws for piston crown (M10):	
	New screws with old or new crown	
	1. Lubricate the threads and screw head with engine oil	
	2. Tighten screws to	10±1 Nm
	3. Tighten the screws a further	75°+5°
	4. Loosen the screws	
	5. Tighten the screws again to	10±1 Nm
	6. Tighten the screws further	65°+5°
	7. Check with tightening torque, the screw may not turn	50 Nm
	Note! When changing piston crown, renew the screw.	
	Old screws with old crown	
	1. Lubricate the threads and screw head with engine oil	
	2. Tighten the screws to	10±1 Nm
	3. Tighten the screws further	65°+5°
	4. Check with tightening torque, the screw may not turn further	50 Nm

07.1.7. G: Engine driven pumps

V6



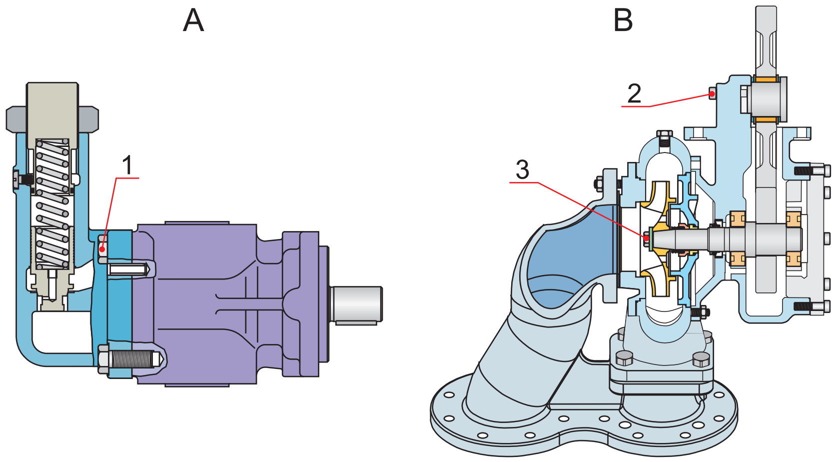
A. *Oil pump*, **B.** *Water pump*, **C.** *Fuel oil pump*

Fig 07-9

200770 V4

Pos.	Screw connection	Torque (Nm)
1.	Fastening screws for lubricating oil pump driving gear (connection with four Inbus Plus fastening screws). The screws are treated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	75±5
2.	Fastening screw for impeller of water pump. **Apply Loctite 243 on threads** , see section 07.2.	85±5
3.	Fastening screws for water pump driving gear (connection with three Inbus Plus fastening screws.). The screws are treated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	35±3
4.	Fastening screws for fuel oil pump driving gear (connection with three Inbus Plus fastening screws.). The screws are treated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	35±3
5.	Fastening screw for bearing housing cap. **Apply Loctite 243 on threads** , see section 07.2.	9.5±1
6.	Fastening screw for pump body.	25
7.	Fastening nut for coupling. **Apply Loctite 243 on threads** , see section 07.2.	27±3
8.	Fastening screw for valve cover.	25
9.	Fastening torque for oil pump cover	50

G: Engine driven pumps



A. *Prelubricating oil pump Kracht,* B. *Sea water pump*

Fig 07-10 200785 V2

Pos.	Screw connection	Torque (Nm)
1.	Fastenings screws for valve cover.	49
2.	Fastenings screws for shaft of intermediate gear.	50
3.	Fastening screw for impeller of sea water pump. Apply Loctite 243 on threads , see section 07.2.	85±5

07.1.8. H: Free end of crankshaft

V7

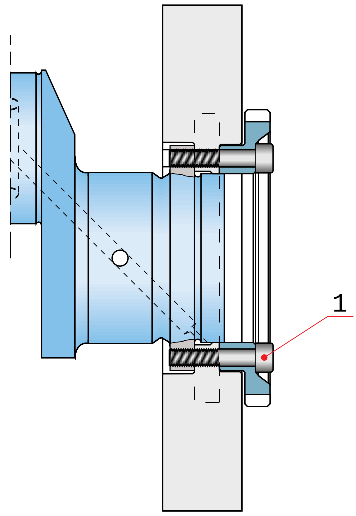


Fig 07-11

V1

Posi-tion	Screw connection	Torque (Nm)
1.	Screws (**M24**) for pump driving gear at free end of crankshaft. Lubricate screws with engine oil.	960±20
	Use the torque multiplier X-4.	290

07.1.9. I: Side screws for main bearings and screws for engine foot

V6

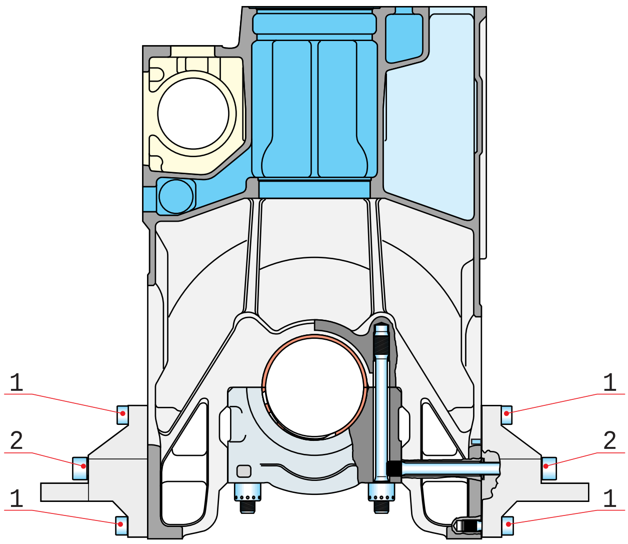


Fig 07-12

200777 V1

Pos.	Screw connection	Torque (Nm)
1.	Fastening screws for engine foot.	670±50
	Use the torque multiplier X-4.	205
2.	a) Pretightening of main bearing side screws, apply Molykote G-n Plus on contact face and engine oil on screw threads.	365
	b) Tightening to full torque of main bearing side screws.	990±50
	Use the torque multiplier X-4.	300

07.1.10. J : Intermediate gear for balancing shafts

V5

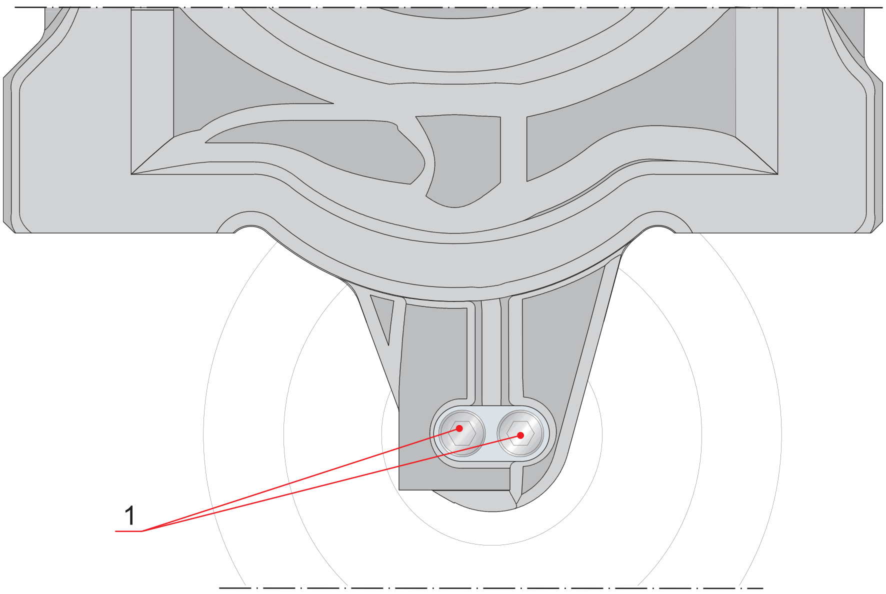


Fig 07-13

V1

Pos.	Screw connection	Torque (Nm)
1.	Screw, M10x100 8.8, for shaft.	50
1.	Screw, M10x100 10.9, for shaft.	67

07.2. Use of locking fluid

V1

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

07.3. Hydraulically tightened connections

V2

07.3.1. Pressures for hydraulically tightened connections

V4

Hydraulically tightened connections

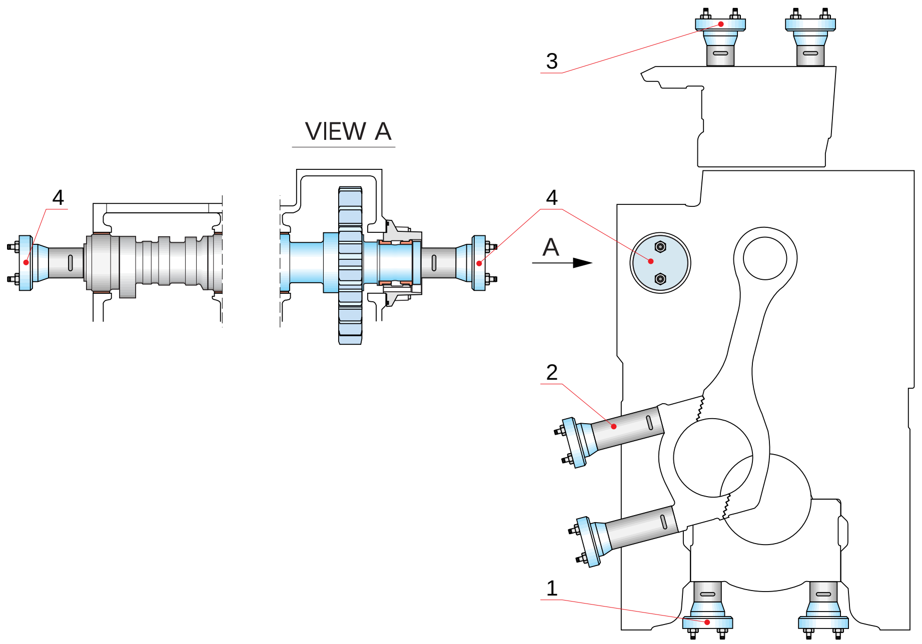


Fig 07-14

V1

Note!
Tighten the nuts in two steps according to the table below. .

Pos.	Screw connection	Torques (Nm)	Max. hydraulic pressure (bar)		
		Tightening of studs	1st step Tightening	2nd step Tightening	Loosening
1.	Main bearing nuts, M36 x 2	100±10	300	700	720
2.	Connecting rod nuts, M30 x 2	20±5	300	550	570
3.	Cylinder head nuts, M36 x 4	100±10	300	600	620
4.	Camshaft nuts, M42 x 2	Tighten by hand	300	560	580

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

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

07.3.2. Maintenance of hydraulic tool set

V2

The hydraulic tool set should be stored in a suitable place and corrosion protected. The set should be regularly checked and worn or damaged parts replaced. Special attention should be made on following components.

- Pressure gauge: Regularly calibration checked.
- Hydraulic couplings and hoses: Condition check.
- Hydraulic pump: Condition check.
- Hydraulic cylinder o-ring: Wear and condition check.

Note!
If the hydraulic cylinder o-ring has been exposed outside the cylinder the oil has to be removed from the cylinder before the cylinder with the o-ring can be re-installed. To return the o-ring with the oil in the cylinder will only damage the o-ring.

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

V2

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

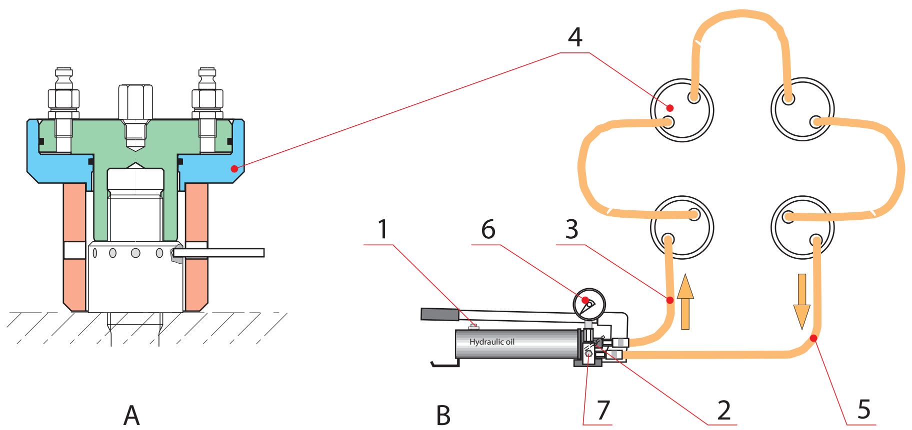
The components are coupled in series the pressure gauge being the last component thus securing that every cylinder is fed with the correct pressure.

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

- In the high pressure hydraulic tool set it is recommended to use a special hydraulic oil or in any case an oil with a viscosity of about 2°E at 20°C.
- During the filling of the container of the high pressure pump it is recommendable to couple the set according to scheme B, Fig 07-15. Before filling, open the release valve (2) and empty the cylinders (4) by pressing piston and cylinder together. After that, the container can be filled through the filling plug (1).
- After filling, vent the system by pressing in, with a finger, the centre pin of the female part of the last quick-coupling the coupling being disconnected from the pressure gauge. Keep on pumping until airfree oil emerges from the coupling.
- Check the pressure gauge of the hydraulic tool set regularly. For this purpose a comparison pressure gauge can be delivered. This pressure gauge can be connected to the plug hole (7) the outlet hose of the pump being connected direct to the pressure gauges.

  If, it is necessary to operate with the couplings not completely intact, it is advisable to open the air vent screw to assure that the passage is open to all cylinders before tightening the connection.

Hydraulic cylinder



1. Filling plug, 2. Release valve, 3. Pressure hose, 4. Cylinders, 5. Outlet hose, 6. Pressure gauge, 7. Plug hole.

Fig 07-15 200761 V1

Note!
Always connect the last end of the outlet hoses to the pressure gauge.

07.3.3. Dismantling hydraulically tightened screw connections

V2

1 **Attach distance sleeves and hydraulic cylinders** according to Fig 07-15 A. Screw on cylinders by hand.

2 **Connect the hoses** to the pump and cylinders according to Fig 07-15 B. Open the release valve (2) and screw cylinders in clockwise direction to expel possible oil.

3 **Screw the cylinders** in counter-clockwise direction about 3/4 a revolution (270°), M42x3 (camshaft) about 21/2 revolution (900°) otherwise the nut is locked by the cylinder and impossible to loosen.

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

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

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

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

07.3.4. Reassembling hydraulically tightened screw connections

V2

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

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

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

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

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

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

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

08. Operating Troubles, Emergency Operation

V2

08.1. Troubleshooting

V21

For preventive measures, see chapter 03 and chapter 04. Some operating troubles require prompt action. Operators should study this chapter so that they can respond quickly when problems occur.

	Trouble Possible reason	See chapter, section
1.	**Crankshaft does not rotate at starting attempt.**	
a)	The turning device is engaged. **NOTE!** Engine cannot be started when turning device is engaged. However, before starting, always check that turning device is disengaged.	11.1, 11.3, 21
b)	Starting air pressure too low, shut-off valve on starting air inlet pipe closed.	21
c)	Starting air solenoid valve faulty.	21
d)	Starting automation outside engine faulty.	03.1.2, 23.1
e)	Air starter faulty.	21.1
f)	Starting air pressure too high (> 10 bar) starting interlock.	21

2.	**Crankshaft rotates but there is no ignition**	
a)	Too low speed, see 1 b.	
b)	Automatic shut down device is not in start position.	23.1
c)	Load limit of control shaft or of governor is set at too low a value.	Fig 22-1
d)	Faulty overspeed trip device solenoid valve.	22.4
e)	Governor does not respond.	22.3
f)	Some part of fuel control mechanism jamming and prevents fuel admission.	22
g)	Fuel and injection system not vented, pipe connections between injection pumps and injection valves not tightened.	Fig 07-6 , 16.3, 17.3
h)	Fuel filter clogged.	17
i)	Three-way cock of fuel filter wrongly set, valve in fuel inlet pipe closed, fuel day tank empty, fuel feed pump not started or faulty.	17

2.	Crankshaft rotates but there is no ignition	
j)	Very low air and engine temperatures (preheat circulating water!) in connection with fuel of low ignition quality.	02.1
k)	Fuel insufficiently pre-heated or precirculated	Fig 02-2, 02.1.7
l)	Very low compression pressure. Inlet or exhaust valve jamming in open position. "Negative" valve clearance (strong blowing noise). 06.1	06.1
m)	Faulty governor.	22

3.	Engine fires irregularly, some cylinders do not fire at all	
a)	Jamming valves, inadequate fuel supply, too low temperatures, see 2 f, g, h, j, k, l, 4 d.	
b)	Injection pump control rack wrongly adjusted.	22.2.1
c)	Injection pump faulty (plunger or tappet sticking; delivery valve spring broken, delivery valve sticking).	16.2
d)	Injection valve faulty; nozzle holes clogged.	16.4
e)	Piston rings badly worn or damaged; too low compression pressure.	11.4.3
f)	In special cases, in engines which have to idle continuously for longer periods (several hours), for some reason, it is advisable to adjust the rack positions carefully (reduce rack position on those cylinders having the highest exhaust gas temperatures, increase on those cylinders which are not firing). This adjustment should be done in small steps and the difference between rack positions of the cylinders should not exceed 1 mm.	

4.	Engine speed not stable	
a)	Governor adjustment faulty (normally too low compensation).	22
b)	Some part of fuel control mechanism jamming and prevents fuel admission.	22
c)	Fuel feed pressure too low.	01.2
d)	Water in pre-heated fuel (vapour lock in injection pumps).	02.1.2
e)	External loading automation is faulty (for example: Controllable pitch propeller).	23.1

5.	Knocks or detonations occur in engine (if reason cannot be found immediately, stop the engine)	
a)	Big end bearing clearance too large (loose screws).	06.2, 07.3
b)	Valve spring or injection pump tappet spring broken.	12.3
c)	Inlet or exhaust valve jamming when open.	12.3
d)	Too large valve clearances.	06.1 12.2.5
e)	One or more cylinders badly overloaded, see 3 b.	
f)	Injection pump/valve tappet (multihousing) guide block loose.	Fig 07-4 16.1

5.	Knocks or detonations occur in engine (if reason cannot be found immediately, stop the engine)	
g)	Initial phase of piston seizure.	
h)	Insufficient preheating of engine in combination with fuel of low ignition quality.	Fig 02-2
j)	Fuel injection timing wrong.	13.1.2

6.	Dark exhaust gases	
a)	Late injection (wrongly set camshaft drive).	13.1.2
b)	See 3 b, c, d.	
c)	Engine overloaded (check the positions of the fuel injection pump racks).	
d)	Unsufficient 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 04.7 04.4 04.9 04.5

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. • compression rings. • compression rings turned upside-down. • ring scuffing (burning marks on sliding surfaces).	03.3.5, 06.2
b)	Blue-white 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 white exhaust gases due to water leakage from turbocharger or multiduct.	

8.	Exhaust gas temperature of all cylinders abnormally high	
a)	Engine badly overloaded (check injection pump rack positions)	Test Records
b)	See point 6 d.	
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 unsufficient. • engine room temperature abnormally high.	01.2, 15.2, 01.2, 01.3
d)	Excessive deposits in cylinder head inlet or exhaust ports.	12.2
e)	Exhaust pipe pressure after the turbine is high.	

9.	Exhaust gas temperature of one cylinder above normal	Test Records
a)	Faulty exhaust gas thermometer/sensor.	23.1
b)	Exhaust valve: • jamming when open. • "negative" valve clearance. • sealing surface blown by (burned).	12.3
c)	Faulty injection valve: • opening pressure much too low. • nozzle needle sticking open. • broken spring. • nozzle cracked.	16.4
d)	Late injection.	13.1.2
e)	Fuel supply insufficient (filter clogged).	01.2
f)	Injection pump faulty, fuel rack sticking in high load position.	16.2

10.	Exhaust gas temperature of one cylinder below normal	
a)	Faulty exhaust gas thermometer/sensor.	23.1
b)	See 2 f, h, 3 b, c, d. .	
c)	Leaky injection pipe or pipe fittings.	Fig 07-6
d)	When idling, see 3 f.	

11.	Exhaust gas temperatures very unequal	
a)	See 9 a, c, e.	
b)	Too low fuel feed pressure: too small flow through injection pumps. (see 2 h, i). May cause great load differences between cylinders although injection pump rack positions are the same. **Warning!** Causes high thermal overload in individual cylinders.	01.2
c)	See points 2 l, 3 b, c, d, e.	
d)	When idling, see point 3 f.	
e)	Exhaust pipe or turbine nozzle ring partly clogged.	15.1.2

12.	Lubricating oil pressure lacking or too low	01.2
a)	Check the pressure difference indicator.	23.1
b)	Faulty pressure gauge, gauge pipe clogged.	23.1
c)	Lubricating oil level in oil sump too low.	01.1, 18
d)	Lubricating oil pressure control valve out of adjustment or jamming.	18.3
e)	Three-way cock of lubricating oil filter wrongly set.	

12.	Lubricating oil pressure lacking or too low	01.2
f)	Leakage in lubricating oil suction pipe connections.	18
g)	Lubricating oil badly diluted with diesel oil, viscosity of oil too low. 02B	02B.1
h)	Lubricating oil pipes inside engine loose or broken.	18

13.	Too high lubricating oil pressure	
a)	See 12 b and d.	

14.	Too high lubricating oil temperature	01.2
a)	Faulty thermometer.	23.1
b)	Insufficient cooling water flow through oil cooler (faulty pump, air in system, valve closed), very high raw water temperature.	19
c)	Oil cooler clogged, deposits on tubes.	18.4
d)	Faulty thermostat valve.	18.5, 19.9

15.	Abnormally high cooling water outlet temperature, difference between cooling water inlet and outlet temperatures too large	01.2
a)	One of thermometers faulty.	23.1
b)	Circulating water cooler clogged, deposits on tubes.	19
c)	Insufficient flow of cooling water through engine (circulating water pump faulty), air in system, valves closed.	19.8
d)	Thermostat valve faulty.	19.9

16.	Water in lubricating oil	03.3.1
a)	Leaky oil cooler.	18.4
b)	Leakage at cylinder liner O-rings (always pressure test when cooling water system has been drained or cylinder liners have been dismantled).	10.6
c)	Faulty lubricating oil separator. See separator instruction book.	
d)	Leakage at LT cooling connection between engine block and free end cover.	19

17.	Water in charge air receiver (escapes through drain pipe in air cooler housing)	15.2.1
a)	Leaky air cooler.	15.2
b)	Condensation (too low charge air cooling water temperature).	Fig 03-1
c)	Leakage from multiduct.	20.1

18.	Engine looses speed at constant or increased load	
a)	Engine overloaded, a further increase of fuel supply is prevented by the mechanical load limiter.	Fig 22-1
b)	See 2 c, f, g, **h, i**.	
c)	See 4 c, d, 5 g, 19 d.	

19.	Engine stops	
a)	Shortage of fuel, see 2 h, i.	
b)	Overspeed trip device has tripped.	22.4
c)	Automatic stop device has tripped.	23.1
d)	Faulty governor or governor drive.	22.3

20.	Engine does not stop although stop lever is set in stop position or remote stop signal is given	
a)	Injection pump control rack wrongly set, see 3 b. Trip the overspeed trip device manually. If the engine does not stop immediately, block fuel supply as near to the engine as possible. Before restarting the engine, the fault must be located and corrected. Great risk of overspeed.	
b)	Faulty stop automation. Stop by means of stop lever.	23.1
c)	The engine is driven by generator or propeller or by another engine connected to same reduction gear.	

21.	Engine overspeeds and does not stop although overspeed trip device trips	
a)	Injection pump control rack wrongly set, see 3 b. Load the engine, if possible. Block fuel supply.	16.2
b)	An overspeeding engine is hard to stop. Therefore, regularly check the adjustment of the control mechanism (the injection pump rack positions). 1) The stop lever being in stop position or the overspeed trip device being tripped and the speed governor at maximum fuel admission. 2) The stop lever and the overspeed trip being in work position and the speed governor in stop position. This control should always be done when the control mechanism or the injection pumps have been touched.	22.1

08.2. Emergency operation

V2

08.2.1. Operation with defective air cooler

V7

If the water tubes of an air cooler are defective, the cooling water may enter the cylinders. If water or water mist flows out of the drain pipe at the bottom of the cooler housing, check whether it is cooling water or condensation. If condensation, reduce cooling (see Fig 03-1). If raw water, stop the engine as soon as possible and fit a spare cooler.

If no spare cooler is available, the following can be done as an emergency solution:

1 **Dismantle the cooler for repair and blank off the opening in the charge air cooler housing.** Connect the cooling water supply direct to the lubricating oil cooler. Repair the cooler, for example, by plugging the leaking tubes.

Note!
This will influence on the water flow to the lube oil cooler and the lube oil temperature will increase.

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

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

08.2.2. Operation with defective turbocharger V6

See chapter 15., section 15.1.5.

08.2.3. Operation with defective cams V6

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

1 **Injection pump cams:**

Slight damage:

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

Bad damage:

Lock the tappet roller of the injection pump in the upper position. See, Chapter 16: Injection System.

Caution!
Concerning torsional vibrations and other vibrations. See, Chapter 08: Torsional vibrations and other vibrations.

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

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

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

2 **Valve cams:**

Stop fuel injection to the cylinder concerned. See, Chapter 16: Injection System. Remove the valve push rods and cam followers of the cylinder. Replace the tubes covering the push rods.

Caution!
Concerning torsional vibrations and other vibrations. See Chapter 08: Torsional vibrations and other vibrations.

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

08.2.4. Operation with removed piston and connecting rod

V5

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

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

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

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

4 **Shut down injection pump.** See, Chapter 16: Injection System.

Caution!
Concerning torsional vibrations and other vibrations, see Chapter 08: Torsional vibrations and other vibrations.

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

If the turbocharger surges, reduce load further to avoid continuous surging.

Operation with piston and connecting rod of one or more cylinders removed should be performed only in absolute emergency conditions when there are no other options of proceeding under own power.

08.2.5. Torsional vibrations and other vibrations

V6

When running the engine with one cylinder or more out of operation, the balance of the engine is disturbed, and severe or even dangerous vibrations may occur. The vibration conditions are in practice dependant on the type of installation, but as general advice it can be said that when there are cylinders out of order, the following should be applied.

In installations with variable speed, if possible, the lowest speed should be used. See section 08.2.4.

09. Installation specific data

V1

Marine installations

This chapter is reserved for installation-specific data.

The installation-specific data may be found here or in the "Attachments" binder.

10. Engine Block, Oil Sump and Cylinder Liner

V2

10.1. Engine block and covers

V1

Data and dimensions
Material: Nodular cast iron
Weight (machined, dry):
1480 kg (4L20)
2080 kg (6L20)
2650 kg (8L20)
2950 kg (9L20)
Test pressure: 8 bar

The engine block is made of nodular cast iron and cast in one piece. It has a high rigidity and it is designed for minimum stress concentration and deformation. Part of the cooling water system, including the jacket water distributing pipes, as well as lubricating oil channels, and the charge air receiver are integrated in the engine block.

The main bearing caps, which support the underslung crankshaft, are clamped by two hydraulically tensioned screws from below and two screws horizontally (one horizontal screw only, for the thrust bearing cap). The bearing shells are axially guided by lugs to provide correct assembly. A combined flywheel/thrust bearing is located at the driving end.

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

The crankcase covers, as well as other light metal covers, tighten against the engine block by rubber sealings and four screws each. On the rear side of the engine, some of the crankcase covers are equipped with safety valves which relieve the overpressure in case of a crankcase explosion. The centrifugal oil filter is fixed to one of the covers. One cover is provided with an oil filling hole.

The end covers are made of cast iron. The covers tighten against the engine block by means of sealing compound.

The crankcase is furthermore provided with a vent pipe including a non-return valve. This pipe should be conducted away from the engine room.

10.2. Engine feet

V2

Data and dimensions
Material: Nodular cast iron
Weight: 27.3 kg

The engine is provided with four (six) bolted-on feet for its support. This arrangement provides excellent flexibility for optimisation of the installation. The feet are made of nodular cast iron.

10.3. Oil sump

V2

Data and dimensions

Material: Steel plates

Weight: 632 kg (4L20)

4L20 including balancing shafts

189 kg (6L20)

232 kg (8L20)

269 kg (9L20)

Oil volume: 270 l (4L20)

380 l (6L20)

490 l (8L20)

550 l (9L20)

The light, welded oil sump (casted for 4L20) is attached to the engine block from below and is sealed off by a rubber sealing. Suction pipes to the lube oil pump and separator, as well as the main lube oil distributing pipe for crankshaft bearings, are incorporated in the oil sump.

An oil dipstick is located in one of the crankcase covers. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level near the max. mark and never allow the level to go below the min. mark. The limits apply to the oil level in a running engine. One side of the dipstick is graduated in centimetre. This scale can be used when checking the lubricating oil consumption.

10.4. Main bearings

V1

Data and dimensions

Weight of bearing cap: 22 kg

The main bearing is a split type plain bearing of bi-metal type. The upper bearing shell has an oil groove but the lower bearing shell does not. The thrust bearing, located in the driving end, is of similar design.

10.4.1. Dismantling of a main bearing

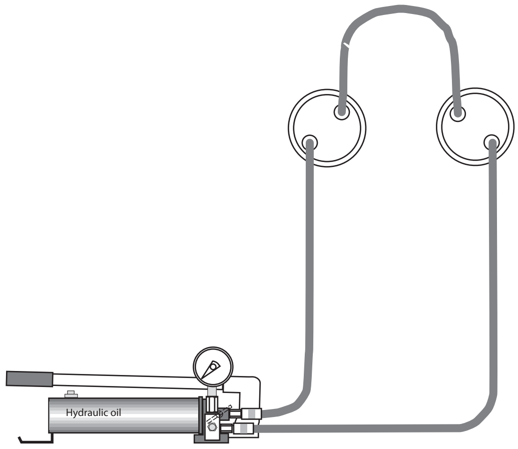
V6

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

2. **Loosen the side screws on the bearing** in question and on both adjacent bearings . Use the tool combination 822001, 803001 and 820009, see chapter 05.

3. **Loosen the nuts of the main bearing screws** on the bearing in question. Put the distance sleeve 861156 onto one of the main bearing screws . Insert the pin 861025 into the slot to fix the sleeve. Screw the hydraulic cylinder 861159 into position. Proceed in same way with the next main bearing screw. Open the main bearing nuts. See Fig 10-2.

Dismantling



1. *Screw on cylinder by hand.* **2.** *Connect hoses, open valve. Tighten cylinders by hand.* **3.** *Screw cylinders 180° counter- clockwise.* **4.** *Close valve, rise pressure.* **5.** *Open the nut about half a turn.* **6.** *Open release valve, remove tool.*

Fig 10-1 HYD2A V2

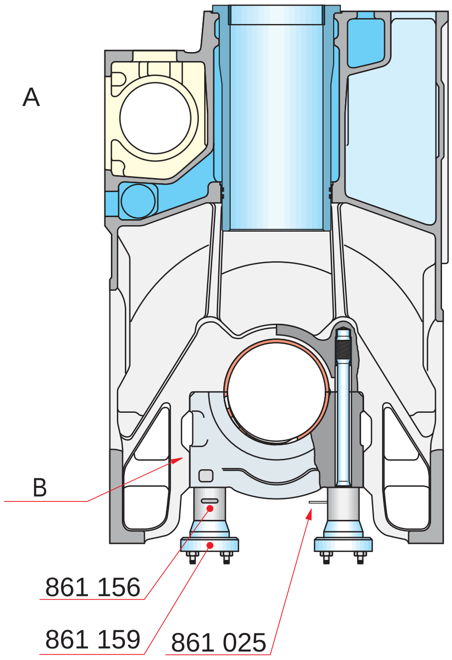
4 **Remove the hydraulic tool** and the distance sleeves.

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

6 **Unscrew the side screws of the main bearing cap.** Unscrew the side screw from the opposite, rear side. Hold the main bearing cap in place and unscrew the second side screw on operating side. Lower the main bearing cap.

7 **Remove the lower bearing shell.**

Dismantling and assembling of main bearing



A *Operating side,* B *Straight side.*

861 025 *Pin* 861 156 *Distance sleeve* 861 159 *Hydraulic cylinder.*

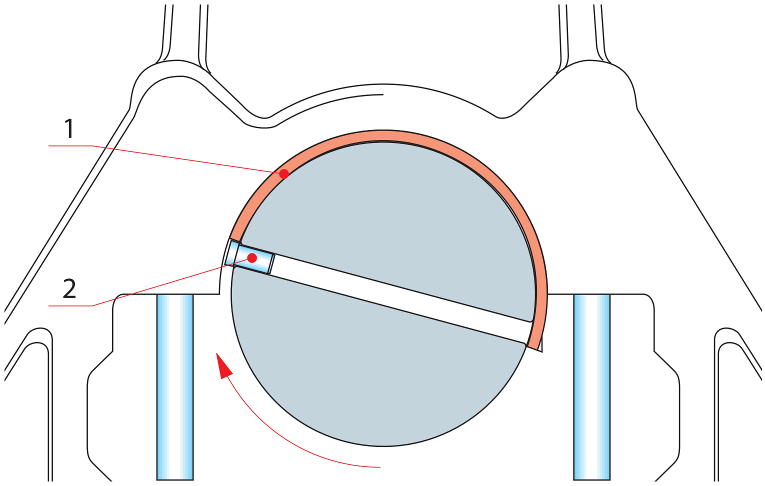
Fig 10-2 201052 V1

8 **Insert the turning tool** 851001 into the main bearing journal radial oil hole, see Fig 10-3. Turn the crankshaft carefully until the bearing shell has turned 180° and can be removed.

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

Note!
At least every third main bearing should be in place at the same time to support the crankshaft.

Use of turning tool for bearing shell



1.*Upper main bearing shell*,2.*Turning tool for main bearing (851 001)*

Fig 10-3 201053 V1

10.4.2. Inspection of main bearings and journals V5

Clean the bearing shells and check for wear, scoring and other damage. If a bearing is worn or damaged, renew both bearing shells and check the condition of the other bearings.

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

Note!
Mark the new bearings with the bearing numbers.

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

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

10.4.3. Assembling of main bearing

V6

1. **Clean the main bearing shells, the cap and the journal very carefully.**
2. **Remove the protecting tape from the journal oil holes.** Lubricate the journal with clean engine oil.
3. **Lubricate the bearing surface, back side and end faces of the upper bearing shell with clean lubricating oil.**

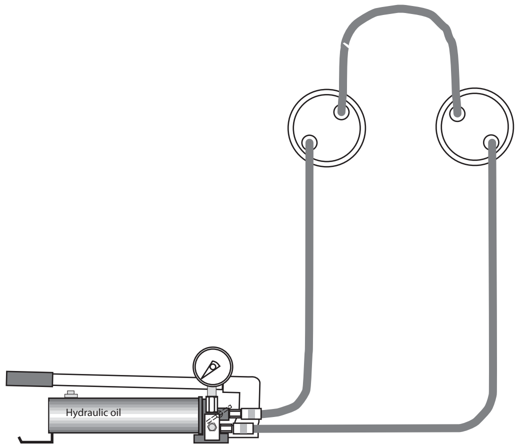
Note!
The bearing shell can be completely destroyed (deformed) during the assembly, if it is not lubricated carefully.

4. **Place the end of the bearing shell in the slot between the journal and the bearing bore, with the lug guiding in the oil groove.** Push it by hand as far as possible (recommended 2/3 of its length).
5. **Insert the turning tool 851001 into the main bearing journal radial oil hole.** Turn the crankshaft carefully until the bearing shell has turned into position. Take care that the bearing shell lug slides into the groove without being damaged.

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

6. **Remove the turning tool.**
7. **Lubricate the bearing surface, back side and both ends of the lower bearing shell with clean lubricating oil and place it in the bearing cap.**
8. **Clean the contact face between engine block and screw head carefully from dirt and paint.** Lubricate the surface with Molycote G-N Plus.
9. **Lift the bearing cap until the side screws, lubricate with engine oil and screw it by hand.** If necessary the main bearing cap can be lifted by help of the main bearing nuts. Turn the nuts by hand.
10. **Screw on the main bearing nuts by hand.**

Reassembling



1. *Screw on nuts, attach distance sleeve. Screw on cylinders by hand.* 2. *Connect hoses, open valve. Tighten cylinders by hand.* 3. *Close the valve and pump pressure to the stated value.* 4. *Screw the nuts until close contact to face.* 5. *Open the valve and remove tool set.*

Fig 10-4 HYD2A V2

11 **Pre-tighten the side screws on the operating side to stated torque.** See, chapter 07: Tightening Torques and Instructions for Screw Connections.

12 **Lift the distance sleeves into position 861156 on the bearing cap nuts and insert the pins 861025.** See, Fig 10-2.

13 **Lift the hydraulic tool 861159 into position and proceed with tightening of the main bearing nuts to stated torque.** See, chapter 07: Pressures for hydraulically tightened connections.

14 **Tighten the side screws on the operating side (straight side of bearing cap) to full torque.** See, chapter 07: Tightening torques for screws and nuts.

15 **Tighten the side screws on the opposite, rear side to full torque.**

16 **Mount the crankcase covers, that was removed.**

10.5. Flywheel/thrust bearing V1

10.5.1. Dismantling of flywheel/thrust bearing V4

1 **Remove the crankcase covers nearest to the flywheel.** Including the relief valve on the rear crankcase cover.

2 **Remove the rear half flywheel end cover then the operating side cover.**

3 **Loosen the thrust bearing cap side screw and adjacent main bearing side screws.** Use the tool combination 822001, 803001 and 820009.

Note!
The thrust bearing has only one side screw.

4 **Position the distance sleeves 861156 over the bearing cap nuts.**

5 **Insert the pin 861025 into the slot to hold the sleeve.**

6 **Screw on the hydraulic tool 861159.**

7 **Connect the hoses from the hydraulic cylinders to the high pressure pump.**

8 **Open the valve and tighten hydraulic cylinders using a ½ inch drive ratchet wrench and extension.**

9 **Rotate the cylinders back 180°, anticlockwise.**

10 **Close the valve and raise the pressure to the stated release pressure.** See Chapter 07: Tightening Torques and use of Hydraulic Tools

11 **Release the nut using the pin 861025 .**

12 **Open the valve and release the pressure.** Remove hydraulic cylinders, hydraulic holes, pin and distance sleeves.

13 **Remove the thrust bearing cap nuts.**

14 **Support the thrust bearing cap in place.**

15 **Remove the side screw using the tool combination 822001.**

16 **Lower the thrust bearing cap.**

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

18 **Insert the turning tool 851001 into the main bearing journal radial oil hole.**

19 **Turn the crankshaft using the turning device until the bearing shell has turned 180° and can be removed.**

20 **Remove the thrust washers.**

21 **Cover the two bearing journal radial oil holes.**

10.5.2. Inspection of flywheel/thrust bearings V1

Check the bearing shells in the same way as the main bearing shells. The thrust washers on the same side have to be replaced in pairs.

10.5.3. Assembling of flywheel-thrust bearing V5

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

2 **Remove the protecting tape from the journal oil holes.** Lubricate the journal with clean engine oil.

3 **Lubricate the bearing surface, back side and end faces of the upper bearing shell with clean lubricating oil.** The bearing shell can be completely destroyed (deformed) during the assembly, if it is not lubricated carefully.

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

5 **Insert the turning tool 851001 into the main bearing journal radial oil hole.** Turn the crankshaft carefully until the bearing shell has turned into position.

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

6 **Remove the turning tool.**

7 **Lubricate the running surface, and back side of the upper thrust washers with clean lubricating oil.** Push the washers into position by hand. To facilitate the mounting of the washers, the crankshaft can be axially moved in each direction.

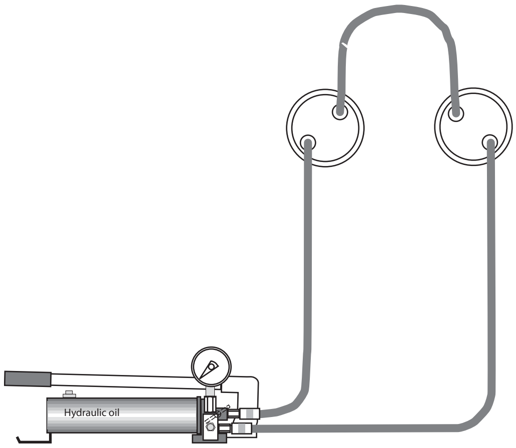
8 **Lubricate the bearing surface, back side and both ends of the lower bearing shell with clean lubricating oil and place it in the bearing cap.**

9 **Lubricate the running surfaces of the lower washers with clean lubricating oil.** Fix them into position on the guiding pins on the bearing cap.

10 **Lift the bearing cap until the side screws, lubricate with engine oil and screw it by hand.** If necessary the main bearing cap can be lifted by help of the main bearing nuts. Turn the nuts by hand.

11 Screw on the main bearing nuts by hand.

Reassembling



1. *Screw on nuts, attach distance sleeve. Screw on cylinders by hand.* 2. *Connect hoses, open valve. Tighten cylinders by hand.* 3. *Close the valve and pump pressure to the stated value.* 4. *Screw the nuts until close contact to face.* 5. *Open the valve and remove tool set.*

Fig 10-5 HYD2A V2

12 **Pre-tighten the side screws on the operating side to stated torque.** See, chapter 07: Tightening Torques and Instructions for Screw Connections.

13 **Lift the distance sleeves 861156 into position on the bearing cap nuts and insert the pins 861025.**

14 **Lift the hydraulic cylinder 861159 into position and proceed with tightening of the main bearing nuts.**

15 **Tighten the side screws on the operating side.** (Straight side of the bearing cap to full torque) See, chapter 07: Tightening torques for screws and nuts.

16 **Tighten the side screws on the opposite, rear side to full torque.** See, chapter 07: Tightening torques and Instructions for screw connections.

17 **Check axial clearance of the crankshaft.**

18 **Mount the flywheel end cover.** The operating side half has to be mounted first and then the back side half.

19 **Mount the cover for the oil pump intermediate gear shaft.**

20 **Mount all the oil pipes.**

21 **Mount the oil pump module and check the clearance.**

22 **Mount the crankcase covers, flywheel end side covers and rest of the oil pipes.**

10.5.4. Measurement of thrust bearing axial clearance

V1

1 **Lubricate the bearings** by running the prelubricating pump for a few minutes.

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

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

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

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

10.6. Cylinder liner

V1

Data and dimensions
Material: Special grey cast iron
Weight: 41 kg
Test pressure: 10 bar

The cylinder liner is made of special, wear resistant, cast iron. The liner is of the wet type. At the upper part the liners are sealed against the block metallically, and at the lower part by two O-rings.

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

10.6.1. Maintenance of cylinder liner

V1

Always when the piston is overhauled, the cylinder liner must be inspected. Check the bore for wear and other damages. The bore should be measured at three levels, both along and across the engine. If the bore is worn or glazed, the liner has to be honed. A high lube oil consumption may indicate that the bores are worn or that the surface of the bores are glazed.

Note!
Ovality of the cylinder liner bore cannot be corrected by honing only.

10.6.1.1. Honing of cylinder liner bore

V5

The pistons and connecting rods must be removed. Use covers or plastic film to protect all engine components from the debris which is caused during the process. Honing residues must be prevented from falling into the oil sump of the engine. For the honing process the following instructions are prescribed:

- The honing is to be carried out by means of "Plateau honing".
- Only ceramic hones with a coarseness of 80 and 400 should be used. The hones with a coarseness of 80 should be used until the polished areas in the cylinder liner are over scraping. The hones with a coarseness of 400 should be used for about 30 strokes to give the correct surface finish.
- The pitch angle of the honing lines in the cross hatch pattern should be about 30°, which is achieved by combining for example 40 strokes/min with a rotational speed of 100 RPM.

Pitch angle

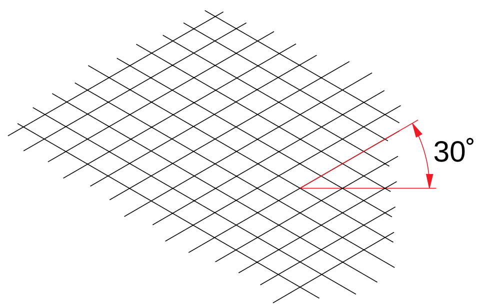


Fig 10-6

V1

- As coolant a honing oil is preferred, but a light fuel oil 2-15 cSt could also be used.
- After honing, the liner bore should be carefully cleaned by using a suitable brush, water (preferably hot) and soap or cleaning fluid, alternatively, light fuel oil. Then dry with a cloth and lubricate with engine oil for corrosion protection.

Note!
After honing of a cylinder liner, the piston rings have to be replaced with new ones.

Warning!
After a bore has been honed, follow the running in programme in chapter 03.

10.6.2. Removing of cylinder liner

V5

It is recommended that the crankshaft is turned to TDC and a piece of plastic is put straight through the crankcase over the crank pin, preventing remaining cooling water or dirt to enter the oil sump.

1 Drain the engine cooling water.

2 Remove the cylinder head, see chapter 12

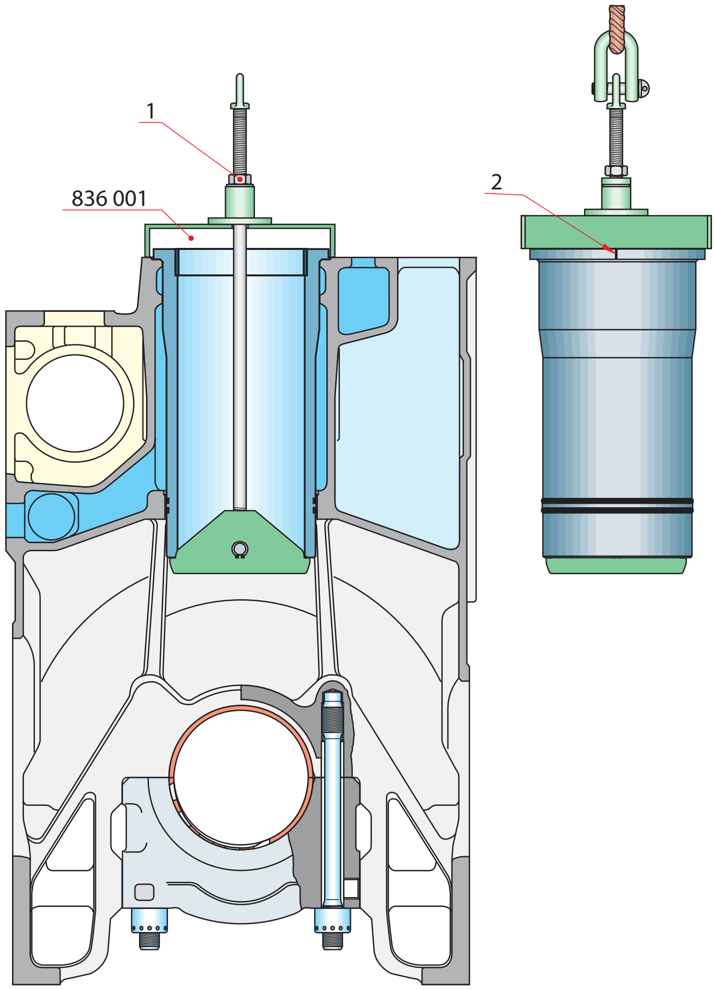
3 Remove the piston with connecting rod, see chapter 11

4 Mount the cylinder liner removing device 836001, according to Fig 10-7.

5 Tension the nut (1) of the pull screw until the liner is held between the removing device.

6 Lift the liner out of the engine block.

Removing and lifting of cylinder liner



1.*Nut*,2.*Distinct mark*,836001 *Extracting and lifting tool for cylinder liner*

Fig 10-7 201054 V2

10.6.3. Inspection of cylinder liner V1

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

10.6.4. Mounting of cylinder liner V6

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

1. **Check that all guide and contact faces** of the engine block and cylinder liner are clean and intact.
2. **Apply High-performance grease paste** e.g Gleitmo 805 or similar on engine block and cylinder liner contact surfaces accordingly to figure. See Fig 10-9.
3. **Mount a new shim for cylinder liner,** if specified for the engine. Check that the new shim has the same thickness as the replaced one. Apply High-performance grease paste e.g Gleitmo 805 on both sides of the shim.
4. **Mount the lifting device** for cylinder liner.
5. **Check that the O-ring grooves of the cylinder liner are clean,** and insert new O-rings.
6. **Lubricate the lower O-rings** with grease or clean lubricating oil.
7. **Lower the liner carefully into the bore** of the engine block. When the lowest O-ring touches the engine block, align the liner so that the mark on the liner is directed towards the driving end of the engine. Lower further and press liner into position by hand.
8. **Check the inner diameter of the cylinder liner,** at the places shown in picture.

Inner diameter

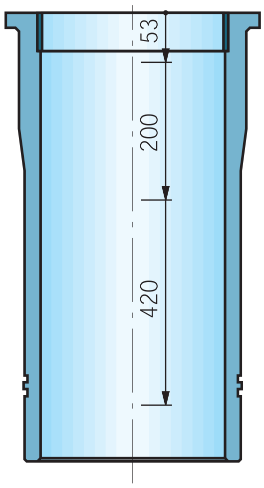
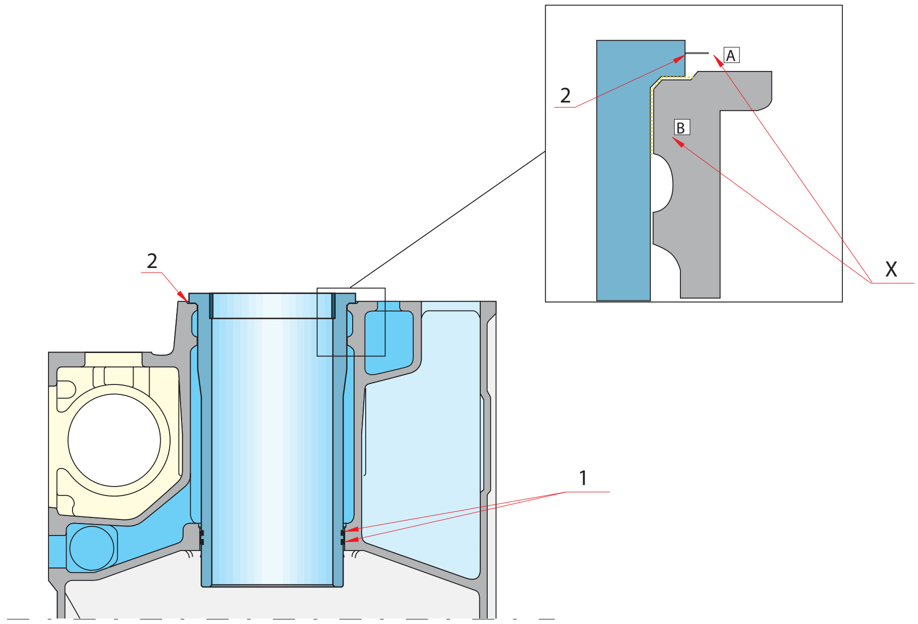


Fig 10-8

201050 V1

9. **Mount the piston with the connecting rod,** see chapter 11.
10. **Mount the cylinder head,** and refill the cooling water system, see chapter 12.
11. **Check the O-ring seals** from the crankcase side while circulating cooling water. Apply 3 bar static pressure.

Mounting of cylinder liner



1.*O-rings*,2.*Shim for cylinder liner*,X.*Apply grease paste from A to B*

Fig 10-9 201056 V2

11. Crank Mechanism: Crankshaft, Connecting Rod, Piston

V2

11.1. Crankshaft

V3

Data and dimensions
Material: Forged, alloyed steel
Weight:
1000 kg (8L20)

The crankshaft is forged in one piece and provided with two counterweights per cylinder. The counterweights are fastened with two screws each. 4-cylinder engines have either integrated or separate counterweights.

At the driving end of the engine, the crankshaft is equipped with a V-ring for sealing the crankcase. The axial clearance is controlled by a combined flywheel/thrust bearing. A shrink-fitted gear wheel for driving the camshaft is located at the driving end.

The main bearings are described in Chapter 10: Engine Block with Oil Sump and Cylinder Liner.

At the free end, there is a gear for driving the water pumps and the lubricating oil pump. Usually, a vibration damper is also installed. The damper can be either mechanical or viscous. See the instructions for the vibration damper provided separately, if the engine is equipped with one. In case there is no vibration damper, a tuning mass is used instead.

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

The lubricating oil is supplied through the side screw holes in the engine block to the main bearings. The oil flows further from the main bearing through the bores in the crankshaft to the connecting rod big end bearing and up in the connecting rod and piston. Due to a special design of the bores in the crankshaft, the flow to the connecting rod is intermittent. The oil is forced to flow in one direction only.

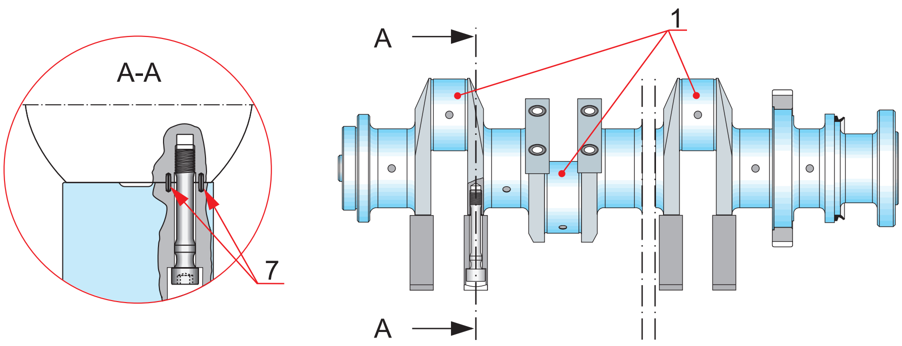
11.1.1. Balancing of crankshaft

V3

Data and dimensions
Material: Steel plate
Weight: 21 kg

The crankshaft is balanced with counterweights on the crank webs, two weights per cylinder journal. The counterweights are located by a guide pin and fastened to the web with two bolts. 4 cylinder engines have either integrated or separate counterweights.

Positions of counterweights



1. *Guide pin* 2. *Counter weights.*

Fig 11-1 V2

11.1.2. Crankshaft alignment

V5

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

2 **Set indicator at zero.**

3 **Read deflections when turning crank** to the rear side, TDC (top dead centre), operating side and BDC. Record readings in the measurement record WV98V036 "Crankshaft alignment".

Note!
During the alignment procedure the crankshaft should be turned in the anti-clockwise direction, only.

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

5 **Following limits of misalignment** are stated for an engine having normal running temperature (within 5 minutes after running at 60 % load or higher for 6 h or more):

a) on the same crank

The difference between two diametrically opposed readings must not exceed 0.07 mm after installing or realigning. Realignment is necessary if this limit is exceeded by more than 0.02 mm.

b) on two adjacent cranks

The difference between two corresponding readings must not exceed 0.04 mm. Realignment is necessary if this limit is exceeded, except for crankpin 1 and 2.

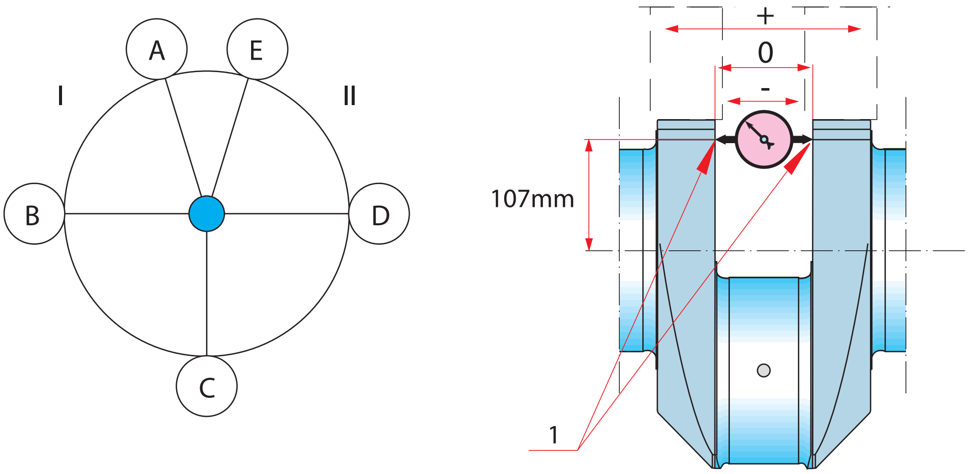
c) when the crank pin of cyl. 1 is at TDC (reading C)

The reading should be negative, max. -0.07 mm (-0.08 mm if flexible coupling with heavy flywheel e.g. 4L20 engine), if stiff or no coupling a small positive reading can be accepted max. +0.02.

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

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

Dial indicator position and reading



1.*Punched points,*I.*Operating side,*II.*Rear side (as seen from the flywheel end)*

Fig 11-2 201153 V1

11.2. Flywheel V2

Data and dimension
Material: Steel plate
Weight: about 350 kg

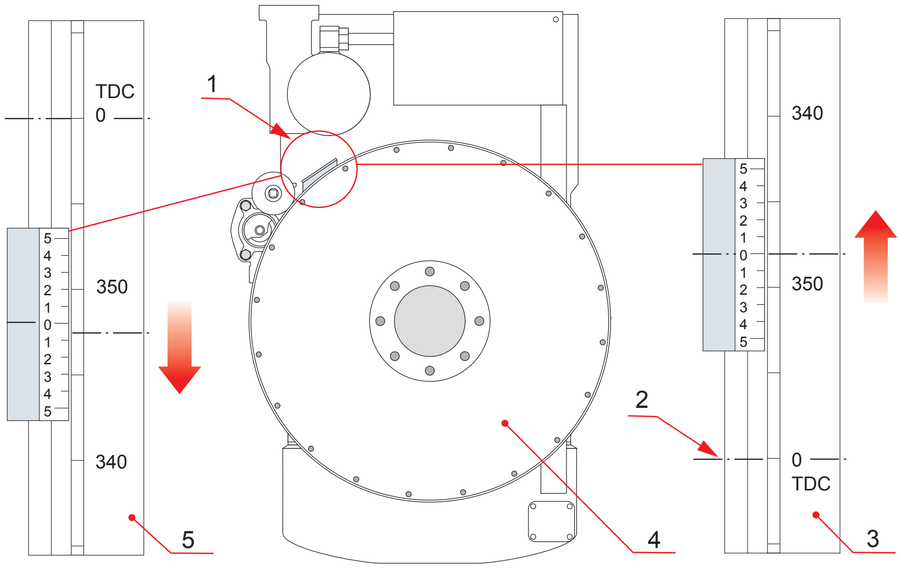
The steel flywheel is fitted to the crankshaft with four fitted screws and four normal screws. The correct position of the flywheel is determined by three smaller screws.

A gear rim is fitted to the flywheel.

A crank angle scale is stamped on flywheel. The scale starts from zero for the TDC of cylinder 1 and is divided in 360° crank angle. The TDC is marked for all cylinders.

The flywheel position indicator is marked with a scale to read the engine crank angles, at an accuracy of one (1) degree on the graduation of the flywheel.

Reading of flywheel indicator



1. *Flywheel Position indicator* 2. *TDC* 3. *Clockwise rotation* 4. *Flywheel* 5. *Anticlockwise rotation.*

Fig 11-3 V3

11.2.1. Chamfered gear rim V1

The gear rim is chamfered to improve the engagement of the air starter bendix and thus minimize the starting failures caused by a tooth to tooth contact.

The chamfering of the gear rim teeth is dependent of the rotating direction (clockwise, CW, or counterclockwise, CCW).

Chamfered gear rim

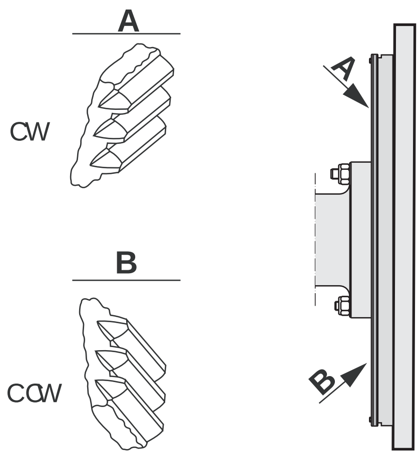


Fig 11-4

201187 V1

11.2.2. Replacing the gear rim

V6

If the gear rim is damaged or worn, it can be replaced without removing the flywheel. Follow the steps given below:

1 **Open the screws holding the gear rim and remove the gear rim from the flywheel.**

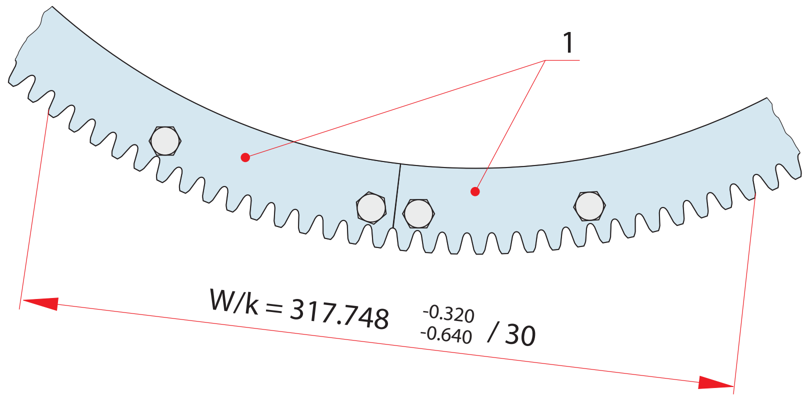
2 **Cut the ring in to the suitable pieces.** Ensure that the flywheel is not damaged during this operation.

3 **The spare part gear rim is delivered in two pieces, which can easily can be mounted on the flywheel.** Additional screw holes for the ring half ends are pre-machined at the factory.

4 **Mount the gear rim halves with (2 mm) feeler gauges between the two split halves and pre-tighten the fastening screws.**

5 **Measure the base tangent length over 30 teeth or chosen number of teeth, if no suitable calliper is available.** Compare the measured tangent length over the split area and tighten the fastening screws to stated torque. See, chapter 07: Tightening torques for screws and nuts.

Base tangent length over the number of teeth spanned



1. Gear rim half

Fig 11-5 201161 V2

11.3. Turning device V1

The crankshaft can be turned by a manual turning device operating on the flywheel. The turning device consists of a gear, which is operated with a ratchet. The rotational direction for turning can be reversed by altering the ratch position of the ratchet.

Note!
The engine must not be started while the turning gear is engaged.

11.4. Connecting rod and piston V1

Data and dimension
Material: Special steel, drop forged
Weight: 38 kg
Bearing type: Bi-metal bearing

The connecting rod is of the drop-forged type with H-section shaft. The big end is of "stepped split line" design and precision serrated at the mating surfaces. This design offers the maximum crank pin diameter but still makes it possible to pull the connecting rod through the cylinder liner.

The big end bearing shells are, for correct assembling, axially guided by lugs. The design of the crankshaft enables the use of a non-grooved upper bearing shell.

The two connecting rod screws are hydraulically tightened.

The gudgeon pin bearing bush is stepped to give a larger bearing surface on the more loaded lower side. It is lubricated via bores in the connecting rod.

The gudgeon pin is of the full floating design, secured axially with retainer rings. The oil flow from the connecting rod is passed through the gudgeon pin further up to the piston. The gudgeon pin has shrink fitted plugs in the ends.

11.4.1. General description of piston

V1

Data and dimension
Composite piston
Material skirt: Nodular cast iron or forged steel
Material crown: Forged steel
Screw: 10.9
Weight: 22 kg

The piston is of composite type with a forged steel or a nodular cast iron skirt and a forged steel crown screwed together. The piston skirt has a phosphate/graphite overlay.

The piston crown is cooled with lubricating oil by means of the cocktail shaker effect. The lubricating oil is led from the main bearing, through the bores in the crankshaft, to the big end bearing, and further through the bores in the connecting rod, gudgeon pin and piston skirt, up to the cooling space, from where it is drained back to the oil sump.

The pistons are provided with Wärtsilä patented skirt lubricating system.

The combustion chamber in the top of the piston is deep, preventing the fuel jets to touch the cylinder liner.

The compression ring grooves are hardened for better wear resistance.

Note!
Always handle the pistons with care. Do not damage or remove the phosphate/graphite overlay.

The piston ring set consists of two compression rings and one spring-loaded oil control ring. In this three-ring pack, every ring is specially dimensioned and profiled for the task it has to perform. The top ring is provided with a special wear resistant coating. The second compression ring is chrome-plated. The oil control ring is a spring-loaded, chrome-plated oil scraper ring.

The side to be upwards of the compression rings is always marked "TOP".

11.4.2. Removing and dismantling the piston and connecting rod

V5

Data and dimension
Weight: 75 kg

1 **Remove the cylinder head.** For instructions, see chapter 12 section 12.2.

a) Scrape off carbon deposits carefully from the slots of the anti-polishing ring and around the upper part of the cylinder liner.

b) Cover the piston top with a cloth or paper pressed tightly (by an old piston ring) against the cylinder wall to collect the deposits removed.

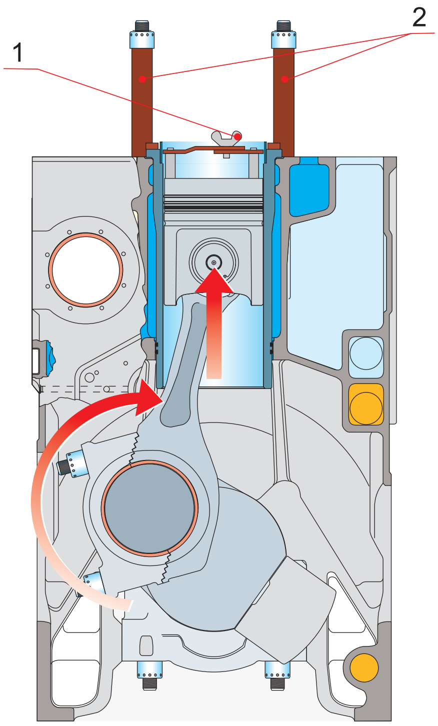
2 Remove the anti-polishing ring.

a) **Turn the engine.** The piston pushes the anti-polishing ring out.

Use the tool 836002 to extract the ring. Use 836003 to keep the liner in place during the extracting procedure.

3 **Clean the threaded hole in the piston crown.** Fasten the lifting tool 832002.

Removing the antipolishing ring



1. *Anti-polishing ring dismantling tool (836002)* 2. *Cylinder liner holders (836003)*

Fig 11-6

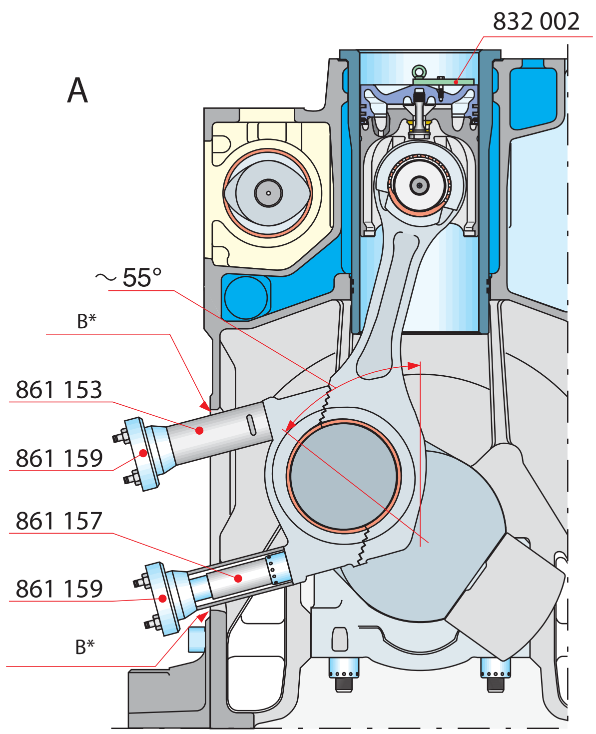
201176 V2

4 **Turn the crankshaft about 55° from TDC towards the operating side for the cylinder concerned.** See, Fig 11-7.

5 **Lift the distance sleeves 861153 into position on the connecting rod screws.** Screw on the hydraulic tools 861159 with extension pieces 861157.

Note!
Before and after applying the pressure on the hydraulic tool, check that there is clearance between the distance sleeves and the engine block. If necessary, turn the crankshaft slightly to get the clearance for both sleeves.

Dismantling of piston and connecting rod

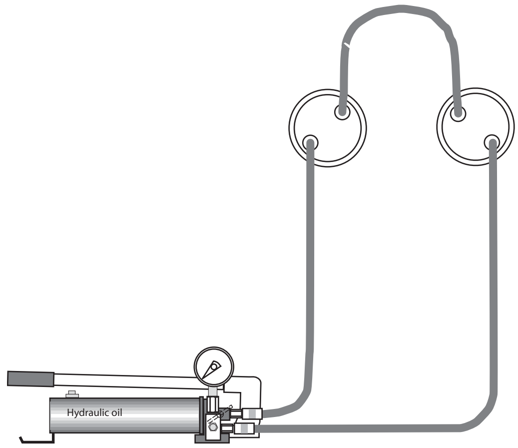


A *Operating Side* 861 153 *Distance sleeve* 861 157 *Extension piece* 861159 *Hydraulic Cylinder* 832 002 *Lifting tool for piston* B* *Check the clearance*

Fig 11-7 201175 V2

6 **Connect the hoses of the hydraulic pump, and open the connecting rod nuts.** See, section 07.3.

Dismantling



1. *Screw on cylinder by hand.* ***2.*** *Connect hoses, open valve. Tighten cylinders by hand.* ***3.*** *Screw cylinders 180° counter- clockwise.* ***4.*** *Close valve, rise pressure.* ***5.*** *Open the nut about half a turn.* ***6.*** *Open release valve, remove tool.*

Fig 11-8 HYD2A V2

7 Remove the hydraulic tool and the distance sleeve from the connecting rod studs.

8 Open the lower nut and remove the lower stud. Use the stud extracting tool 803011. The locking screw of the tool has left-hand threads.

9 Repeat the same procedure as above with the upper nut and stud. Lift the big end bearing cap together with the bearing shell out of the engine.

10 To remove the upper big end bearing shell, lift the piston a little. When lifting the piston, take care not to damage the crank pin or the cylinder liner wall.

11 Cover the crank pin oil holes with tape.

12 Lift the piston together with the connecting rod out of the engine. When lifting the piston, take care not to damage the cylinder liner wall.

13 Remove the retainer ring from the gudgeon pin hole in the piston on the side where the gudgeon pin drawing number is located. Use the pliers for the retainer ring, 843004.

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

14 Drive out the gudgeon pin from the opposite side. In low temperatures, the gudgeon pin may get stuck. Heating the piston to about 30°C for example, in oil.

15 **If the rings and grooves require for example cleaning or measuring, remove the piston rings.** Use the pliers 843003. Before removing them, note the position of the rings to ensure mounting in the same grooves. The design of the pliers prevents overstressing of the rings. Using other means may overstress the rings.

11.4.3. Maintaining the piston, piston rings and connecting rod bearings

V5

1 **Clean all the parts carefully.** Remove the piston rings. Remove carbon deposits from the piston and piston ring grooves. Special care should be taken not to damage the piston.

Caution!
Never use emery cloth on the piston skirt.

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

2 **Measure the height of the piston ring grooves.**

3 **Dismantle the composite piston for inspection of mating surfaces between the piston skirt and piston crown.** Inspect and clean oil spaces. See, section 07.1.6

Note!
Always fit new piston rings when a new cylinder liner has been honed or fitted.

4 **Check the gudgeon bearing bush and big end bearing bore.**

a) **When measuring the big end bearing bore, tighten the connecting rod cap and nuts to the stated pressure.**

b) **Determine the bearing shell wear by measuring the thickness. Use a ball anvil micrometer for this. See the wear limits in Chapter 06: Clearances and wear limits.**

c) **When replacing the big end bearing shells, always change both the upper and the lower bearing shells.**

Note!
Mark new bearings with the bearing number.

5 Inspect the piston combustion space visually.

a) Inspect at regular intervals and/or at every piston overhaul.

b) Check the combustion space for corrosion or burning marks.

Note!
If marks deeper than 2 mm are found, the piston should be replaced with new one.

11.4.4. Assembling and mounting of piston and connecting rod

V8

1 Mount the piston on a suitable support.

Note!
Use new screws when fitting new piston crowns. Because of the manufacturing method, it is not possible to measure the elongation of the M10 screws used with the two-screw piston crowns. For piston crown with one screw the measurement can be recorded in measurement record 2011V003.

Warning!
If elongation is suspected replace the screws

2 Lubricate the gudgeon pin and insert into the piston from the side marked with the drawing number. At low temperatures the gudgeon pin may stick, heating the piston to about 30°C in oil will ease pin fitment.

3 Mount the retainer ring.

Warning!
Never compress the retainer ring more than necessary. If the ring is loose in its groove fit a new ring.

4 Mount the piston rings using the pliers 843003, position the ring gaps 120° apart.

5 Attach the lifting tool 832002 to the piston crown.

6 Turn the crankshaft to 55° BTDC so that the journal of the cylinder being worked on faces the operating side crankcase opening.

7 Lift the piston and connecting rod.

8 **Lubricate the piston and place the clamp device for piston rings 843002 around the piston rings.** Check that the piston rings are correctly positioned in their grooves.

9 **Oil all the surfaces of the upper big end bearing shell.** Mount the bearing shell so that the lug fits into its groove in the connecting rod.

Caution!
Use of glue compound on a bearing shell is prohibited.

10 **Remove protecting cover from the crank pin oil holes and lubricate the crank pin with clean engine oil.**

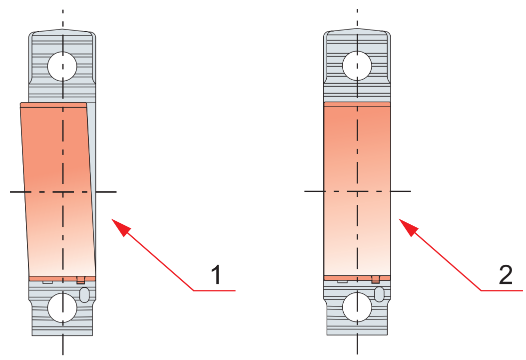
11 **Lower the piston and connecting rod carefully into the cylinder liner.** Remove the piston ring clamp 843002.

12 **Lower the piston further until the connecting rod is placed on the crank pin.**

13 **Oil all the surfaces of the lower big end bearing shell.** Mount the bearing shell so that the lug fits into its groove in the bearing cap.

14 **Check the bearing shell alignment.**

Checking the bearing shell alignment



1. *Incorrectly fitted,* 2. *Correctly fitted*

Fig 11-9 V3

15 **Fit the bearing cap.**

16 **Mount the lower and upper connecting rod screws.** Tighten using the stud remover tool 803011 to the specified torque. See Chapter 07: Tightening torques and use of hydraulic tools

Note!
Replace the screws every 24,000 operating hours at latest.

17 Lift the distance sleeves 861153 over the connecting rod nuts and screw on the hydraulic cylinder 861159 with extension piece 861157.

18 Connect the hoses from the hydraulic cylinders to the high pressure pump.

19 Open the valve and tighten the hydraulic cylinders using a ½ inch drive ratchet wrench and extension.

Caution!
Check the clearance between the distance sleeves and the engine block, before and after applying pressure to the hydraulic tool. If necessary turn the crankshaft slightly to get the clearance for both sleeves.

20 Close the valve, raise the pressure in two steps to the stated pressure. See Chapter 07: Tightening torques and use of hydraulic tools.

21 Tighten the nuts using the pin.

22 Open the pump valve and release the pump pressure.

23 Remove the hydraulic cylinders, hydraulic pipes, pin and distance sleeves.

24 Check that the connecting rod moves axially after tightening.

25 Mount the side covers.

26 Remove lifting yoke and disengage turning device.

27 Mount the anti-polishing ring and cylinder head. See Chapter 12: Removing and mounting the cylinder head.

12. Cylinder Head with Valves

V5

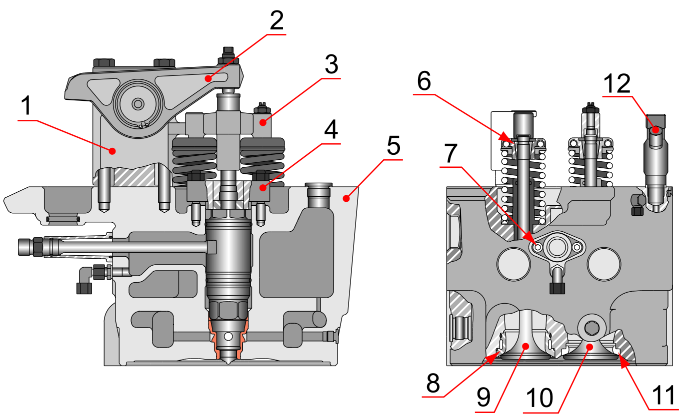
Data and dimensions
Material: Cast grey iron
Tensile strength:
250-300 N/mm^2
Weight: 92 kg
Combustion space
- design pres.: 200 bar
- test pressure: 225 bar
Water space
- test pressure: 10 bar
Operation temperature:
- water return: 95°C"

The cylinder heads are cast of special-quality grey iron. Each head includes two inlet valves, two exhaust valves, a centrally located injection valve and an indicator valve. The cylinder heads are individually tightened to the cylinder liner with four studs and hydraulically-tightened nuts. A metallic gasket seals the space between the cylinder liner and the cylinder head. The combustion air and the exhaust gas channels are connected to a common multi-duct, 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 advantage of four screws is not only the ease of maintenance but it also allows the design of large and correctly-designed channels for combustion air and exhaust gases. In a heavy-fuel engine the correct material temperatures are a crucial factor to ensure long lifetime of the components being in contact with combustion gases. Efficient cooling and a rigid design is best achieved with the "double deck" design in which the flame plate is relatively thin and the mechanical load is transferred to the strong intermediate deck. The most sensitive areas of the cylinder head are cooled by drilled cooling channels optimized to distribute the water flow evenly around valves and the centrally-located fuel injector.

The injection valve is described in chapter 16.

Cylinder head assembly



1. *Bearing bracket* 2. *Rocker arm* 3. *Yoke for valves* 4. *Yoke for injection valve* 5. *Cylinder head* 6. *Rotocap* 7. *Screws for connection piece* 8. *Exhaust valve seat* 9. *Exhaust valve* 10. *Inlet valve* 11. *Inlet valve seat* 12. *Indicator valve*

Fig 12-1

201259 V2

12.1. Functions of the cylinder head drilling

V3

The flame plate of the cylinder head is a part of the combustion chamber. During 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 multi-orifice injection valve and its sleeve are centrally mounted in the cylinder head. The sleeve holds the injection valve in position and separates the injection valve from the cooling water.

Each cylinder head is individually cooled by the water flow that enters the cylinder head from the cylinder jacket through a single bore. There are drilled cooling passages to the exhaust valve seats. After passing over the flame plate and the seat rings, the water flows out through a single bore into the multiduct. The cooling water flows out from the cylinder head directly to the multiduct. Any air or gas in the cooling water is vented from the top of the multiduct.

The valve mechanism is lubricated from the lubricating oil system. The oil is led through a pipe from the valve tappet guide in the multihousing to the rocker arm bracket. All other flows into the cylinder head are through drillings.

The controlled leakage from the injection valve is returned through the protection pipe.

The fuel pipe is also protected against hazardous leaks from the high pressure connection stud.

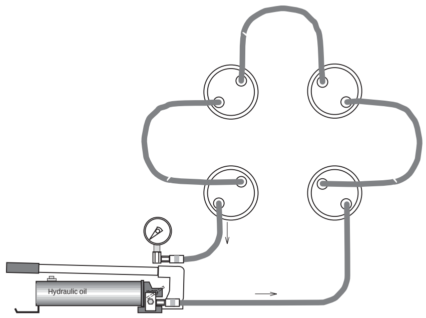
12.2. Removing the cylinder head

V6

1. **Drain the cooling water.**
2. **Open the indicator valves.**
3. **Remove the caps of the cylinder head screws.**
4. **Remove the cylinder head cover.**
5. **Turn the engine until both the inlet and exhaust valves are closed.** Remove the valve rocker arm bracket and the push rods.
6. **Remove the fastening screws of the multiduct.**
7. **Remove the injection pipe, the fuel leak pipe, and lube oil pipes, where necessary.** Protect all the pipe connections.

8 **Put on the distance sleeves 861156 and hydraulic cylinders 861159.** Loosen the cylinder head nuts.

Dismantling with hydraulic tools



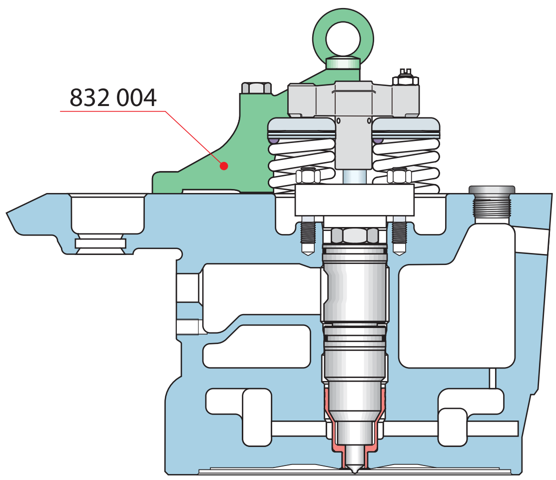
1. *Mount the cylinders by hand.* 2. *Connect hoses, open valve. Tighten cylinders by hand.* 3. *Turn the cylinders 180° counter-clockwise.* 4. *Close valve, rise pressure.* 5. *Open the nut about half a turn.* 6. *Open release valve, remove tool.*

Fig 12-2 HYD V1

9 **Remove the cylinder head nuts.**

10 **Lift off the cylinder head.** Use the lifting tool 832004.

Lifting the cylinder head



832 004 Lifting tool for cylinder head.

Fig 12-3 201255 V1

11 **Cover the cylinder opening with a piece of plywood or something similar.**

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

12.2.1. General maintenance of 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 chapter 02: Fuel, Lubricating Oil, Cooling Water.

Combustion spaces must be inspected carefully for possible wear. Valve seats and the injection valve sleeve should be inspected for possible water leakage and replaced if necessary.

Valve guides should be checked and replaced if worn. O-rings must be replaced with new ones at every overhaul.

The sealing surfaces between the cylinder head and cylinder liner should be inspected and reconditioned if necessary.

12.2.2. Mounting the cylinder head screws V1

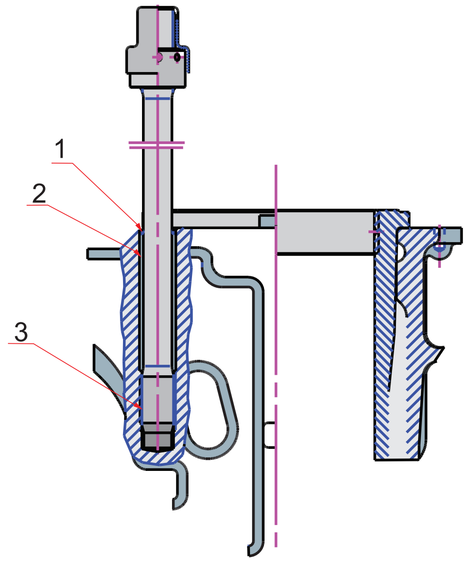
1 **Inspect the cylinder head screws for corrosion.**

- When corrosion pits with a depth of less than 0.1 mm is found, polish away the pits with a small hand grinder.
- If corrosion is deeper than 0.1 mm, change the screw.

Note!
Corrosion depth in threads can be hard to determine. Change the screws, whenever in doubt.

2 **Lubricate the threads of the screw.** Use a thin layer of Mobilarma 524 or corresponding corrosion protection agent.

Lubricating the threads of the screw



1. *O-ring* 2. *Compartment filled with Mobilarma 524* 3. *Threads of the screw lubricated with Mobilarma 524.*

Fig 12-4 V3

3 Mount the screw and tighten to a specified torque.

Caution!
Do not exceed the maximum tightening pressure.

Caution!
Change the cylinder head screws, if the maximum pressure is exceeded when using the hydraulic tool.

4 Fill the compartment between the screw and the engine block with Mobilarma 524 or corresponding corrosion protection agent.

a) When filling the corrosion protection agent leave about 2 mm space between O-ring and corrosion protection.

5 Mount the O-ring.

Note!
Change the O-rings at every piston overhaul.

12.2.3. Mounting the cylinder head

V8

1 **Clean the sealing surfaces.** Fit new cylinder head and multiduct gaskets.

2 **Fit new O-rings to the cooling water jacket and the push rod protecting pipe.**

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

4 **Attach the lifting tool 832004 to the cylinder head.**

5 **Lift on the cylinder head.** Pay special attention to the multiduct gasket, ensuring that it is intact and correctly mounted.

6 **Screw on the cylinder head nuts and tighten by hand.**

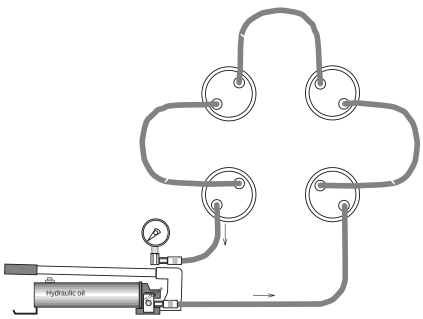
Note!
Before hydraulically tightening the cylinder head nuts, it is very important to ensure that multiduct sealing surface is properly aligned with the cylinder head sealing surface. Improper alignment can cause water leakage into the cylinder.

---

7 **Connect the multiduct, fit the screws and tighten by hand.**

8 **Put on the distance sleeves 861156, screw on the hydraulic cylinders 861159 and proceed with tightening of cylinder head nuts.** Tightening in two steps is recommended.

Assembling with hydraulic tool



1. *Mount the nuts, attach the distance sleeve. Mount the cylinders by hand.* **2.** *Connect hoses, open valve.* **3.** *Tighten the cylinders by hand.* **4.** *Close the valve and pump pressure to the stated value.* **5.** *Turn the nuts until close contact to face.* **6.** *Open the valve.* **7.** *Repeat steps 4, 5 and 6.* **8.** *Remove the tool set.*

Fig 12-5 HYD V1

9 **Tighten the multiduct screws to the torque stated in** 07.1.3.

10 **Connect the pipes, the fuel leak pipe, lubricating oil pipes and the injection pipe.**

11 **Fit the push rod protecting pipes.**

12 **Fit the push rod and the rocker arm bracket.**

13 **Adjust the valve clearance, see** section 12.2.5. For clearances, see section 06.1.

14 **Put on the cylinder head cover, remember to put new hose gasket for the cover.** Spot glue the gasket in place using Bostik-glue A3.

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

16 **Before starting, fill the engine cooling water system.** Turn the crank-shaft two revolutions, with the indicator cocks open.

Example

Glue points

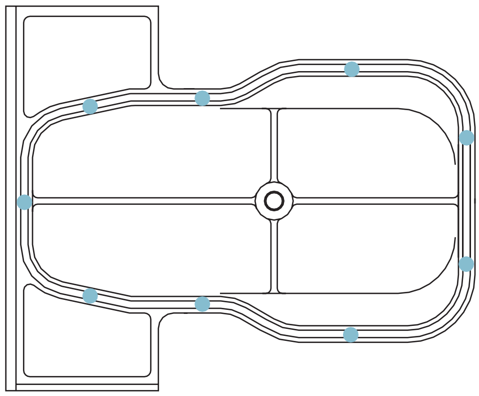


Fig 12-6 201256 V1

12.2.4. Valve clearance V2

Valve clearances, cold engine:	
inlet valves	0.4 mm
exhaust valves	0.8 mm

Note!
Before checking or adjusting valve clearance, allow the engine to cool for at least a couple of hours and ensure that the automatic start and the priming pumps are disconnected.

12.2.4.1. Checking the valve clearance V3

1 **Remove the cylinder head cover.**

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

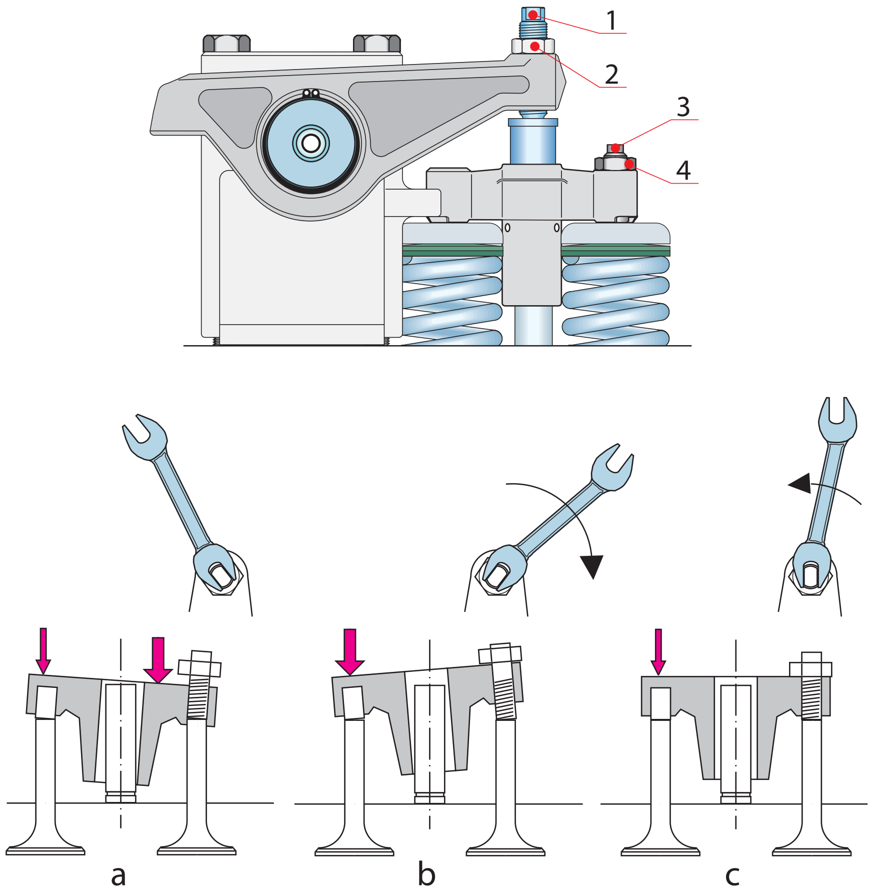
3 **Using a feeler gauge, check the valve clearance between the contact surfaces of the yoke and the rocker arm shoe.** There should be only slight resistance when the feeler gauge is slid in and out. If necessary, adjust according to section 12.2.4

4 **Refit the cylinder head cover.**

12.2.5. Adjusting valve clearance and yoke

V6

Adjusting valve clearance



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

Fig 12-7

201258 V1

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

2 Loosen the counter nuts of the adjusting screws on the rocker arm (2) and on the yoke (4). Turn the adjusting screws counterclockwise to provide ample clearance.

3 Press the fixed end of the yoke against the valve stem by pressing down the adjustable end.

a) Screw down the adjusting screw (3) until it touches the valve end.

b) Note the position of the spanner (position a).

c) Press down the fixed end.

d) Keep on screwing down while the yoke tilts, until the guide clearance is on the other side and the fixed end of the yoke starts lifting from the valve stem.

e) Note the position of the spanner (b).

4 Turn the adjusting screw counterclockwise to the middle position "c" between "a" and "b". Lock the counter nut of the adjusting screw.

5 Put a feeler gauge corresponding to the valve clearance between the contact surfaces of the yoke and the rocker arm shoe.

a) Tighten the adjusting screw (1) until the feeler gauge can be moved to and fro only with slight force.

b) Hold the adjusting screw, and tighten the counter nut. Check that the clearance has not changed while tightening.

12.3. Exhaust and inlet valves and seat rings V2

Data and dimensions
Material:
High quality steel
Diameter
-inlet valve: 73 mm
-exhaust valve: 66 mm

Valve seat ring
Material: High quality steel
Angle
-inlet seat: 20°
-exhaust seat: 30°

The cylinder head has four valves fitted, two inlet valves and two exhaust valves. All the valves are made of surface-treated heat resistant steel. The 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. The valve guides have an O-ring (sealing against the valve stem), which is located at the top of the guide bore.

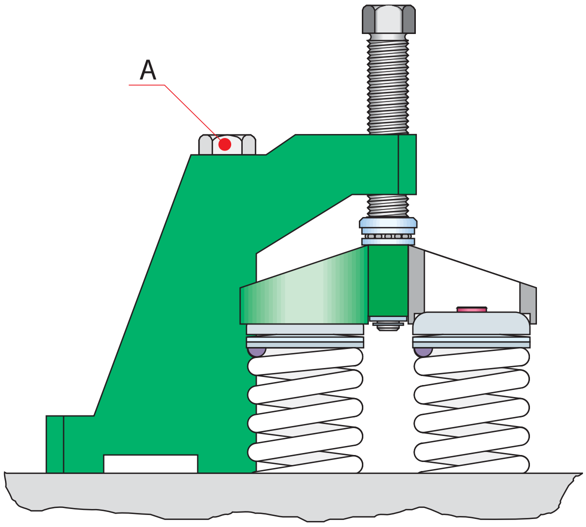
The valves are provided with one valve spring per valve and valve rotating devices or valve spring retainers.

The valve seat rings are fitted in the cylinder head for both inlet and exhaust valves. The exhaust valve seat rings are water cooled and therefore provided with one or two O-rings per seat.

12.3.1. Dismantling valves V4

1 Fit the tool 846010 according to Fig 12-8.

Tool assembly for dismantling valves



A. *Fastening screw*

Fig 12-8 201252 V1

2 **Compress the springs** about 15-20 mm with the screw.

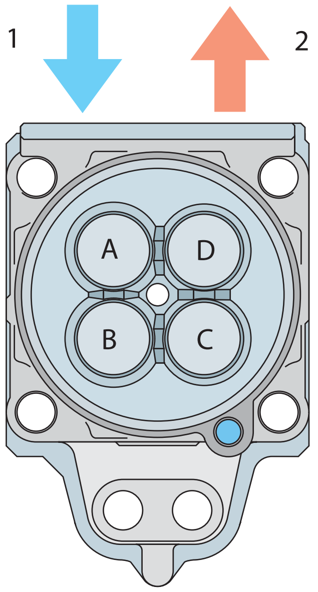
3 **Knock at the centre of the valve discs** with a soft piece of wood, plastic hammer or similar, so that the valve cotters come loose and can be removed.

4 **Unload the tool.**

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

6 **Note the marks on the valves** or mark them according to Fig 12-9 so they can be re-installed into the same guide if they are in good condition.

Marking of the valves (view from the underside)



A. *Inlet valve,* B. *Inlet valve,* C. *Exhaust valve,* D. *Exhaust valve*

1. *Air in,* 2. *Ex out*

Fig 12-9 201254 V1

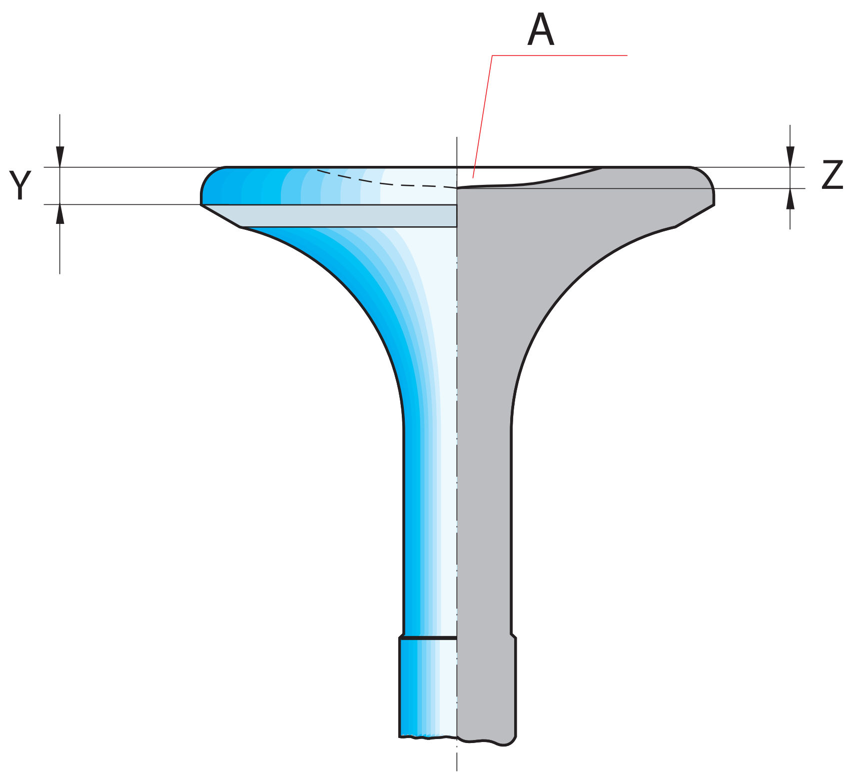
12.3.2. Checking and reconditioning of valves and seats

V5

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

2 **Check the wear and erosion on the valve head** according to Fig 12-10. The margin width "Y" should be more than 4.5 mm (nominal 5.5 mm) and dimension "Z" should be less than 1 mm. If the values exceed these limits the valve must be replaced.

Control of burning-off on valve



A *Burnt area*

Fig 12-10 321256 V1

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

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

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

12.3.3. Lapping

V5

If slight pits exist on the sealing faces, they can be lapped by hand:

1. **Fit the turning tool to the valve.**
2. **Apply a thin layer of lapping compound to the sealing surface of the valve; No.1 for coarse lapping, No.3 for fine lapping.**
3. **Rotate the valve back and forth towards the seat using turning tool 841001.** Lift the valve from the seat at intervals while lapping.
4. **Remove the smallest possible amount of material, as the sealing faces have hardened during operation and are valuable.** It is not necessary to grind off all pits.
5. **Clean the valve and the seat carefully after lapping.**

12.3.4. Machine grinding

V5

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

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

Valve

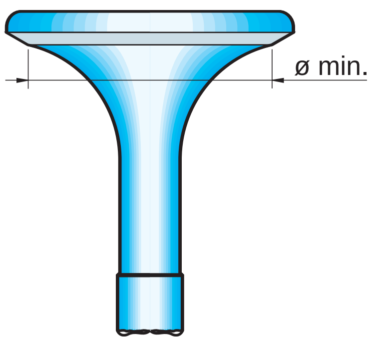
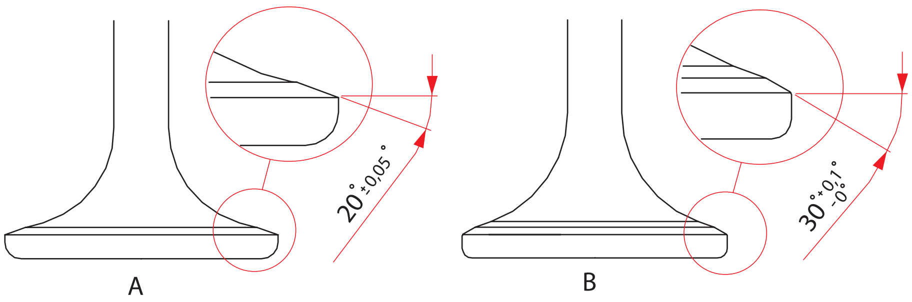


Fig 12-11 201257 V2

1. **Seat face of the inlet valve:** The seat angle of the inlet valve is 20° with a tolerance of ± 0.05°. Minimum allowable inner diameter of sealing surface after grinding is 52 mm; after that, the valve must be replaced by a new one.
2. **Seat face of the exhaust valve:** There are two alternative types of exhaust valve (Stellit and Nimonic). The seat angle of the exhaust valve is 30° with a tolerance of -0° - +0.10° (to achieve contact with

the seat ring at the inner edge of the valve seat.) The minimum allowable inner diameter of sealing surface after grinding is 48 mm; after that, the valve must be replaced with a new one.

Seat face of the valves



A. *Inlet*, B. *Exhaust*

Fig 12-12 201262 V1

3 **Seat ring for the inlet valve:** The seat angle of the inlet valve seat ring is 20° with a tolerance of ± 0.05°. The seat can be ground until the outer seat diameter is 78 mm; after that, the ring must be replaced with a new one.

4 **Seat ring for the exhaust valve:** The seat angle of the exhaust valve seat ring is 30° with a tolerance of 0° - +0.10°. The seat can be ground until the valve contact section mark has disappeared. If the section mark disappears at machining, it is recommended to replace the ring. Aim to get a contact to the seat ring at the inner edge of the valve seat.

Exhaust valve seat ring

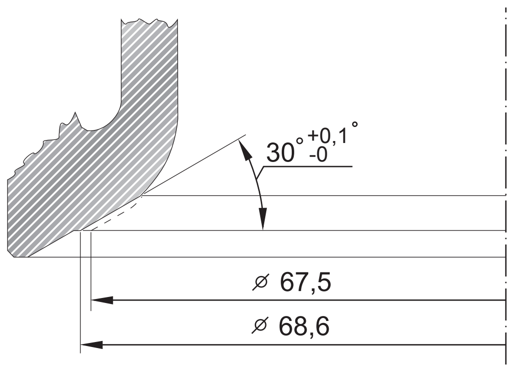


Fig 12-13 201261 V2

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

12.3.5. Change of seat ring

12.3.5.1. Removing the old seat rings with the hydraulic extractor

V5

The seat rings can most conveniently be removed with a special hydraulic extractor, which can be ordered from the engine manufacturer. If the extractor is not available, a scrapped valve can be used. See 12.3.5.2.

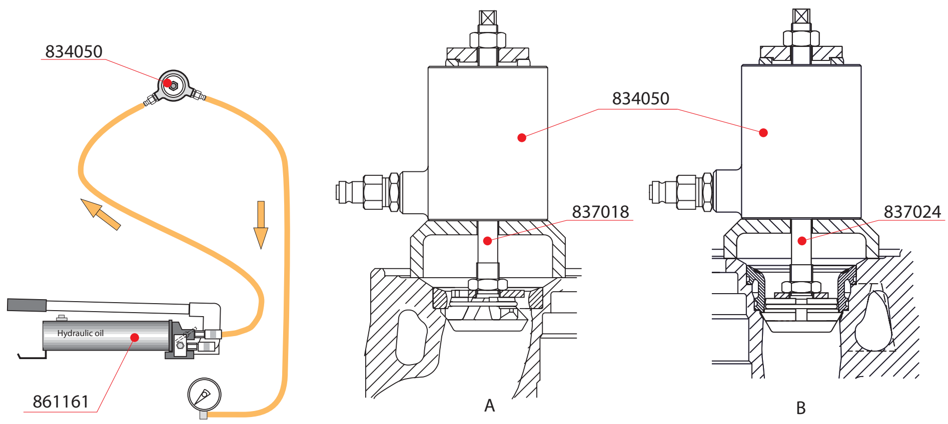
1 **Assemble the extractor** according to Fig 12-14. Notice the difference in assembly for the inlet and exhaust seat.

2 **Tension the extractor** by tightening the axial screw.

3 **Pressurize the extractor** to withdraw the seat ring.

4 **Open the pump valve to release the pressure,** disconnect the hoses and dismantle the extractor.

Example **Removing an old seat ring**



A. *Inlet*, B. *Exhaust*

Fig 12-14 201263 V1

12.3.5.2. Removing the old valve seat with using the scrapped valve

V3

The seat rings can most conveniently be removed with a special hydraulic extractor, which can be ordered from the engine manufacturer. If the extractor is not available, a scrapped valve can be used.

1 **Weld a scrapped valve to the seat** using electric beam welding. For ease of welding, machine the valve head to a diameter of 55-60 mm.

Note!
Protect the flame plate and the joint surfaces of the cylinder head when welding.

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

12.3.5.2.1. Fitting a new inlet valve seat ring

V8

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

2 **Before fitting the valve seat, chill the seat in liquid nitrogen to -190°C, and ensure that the cylinder head temperature is at least 20°C.** If liquid nitrogen is not available, put the seat in a freezer, and heat the entire cylinder head so that the seat head temperature difference is at least 120°C.

Note!
Heat up the entire cylinder head, not only the seat bore.

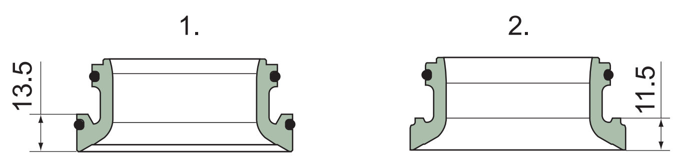
3 **Check the eccentricity of the sealing face in relation to the valve guide.** If it exceeds 0.1 mm, grind the seat surface in a seat grinding machine.

12.3.5.2.2. Fitting a new exhaust valve seat ring

V8

There are two types of exhaust valve seat rings, depending on the installation.

Exhaust valve seat rings



1. *Exhaust valve seat ring with two O-rings.* 2. *Exhaust valve seat ring with one O-ring.*

Fig 12-15

201260 V2

Note!
The seat rings are not interchangeable because of different pocket and seat geometry.

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

2 **Check the bore diameter in the cylinder head.** See, chapter 06: Clearances and wear limits at 20°C.

3 **Cool the seat ring between -20 and -25 °C prior to fitting.**

Caution!
Temperature lower than -25 °C may damage the O-ring(s) during assembly.

4 **Heat up the entire cylinder head to 100°C by means of either steam or a gas burner.** If steam is used it may be easier if the steaming is done within a closed box.

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

5 **Mount the O-ring(s) on the cooled valve seat.**

6 **Apply soap-water solution to lubricate the O-ring(s).**

7 **If the exhaust valve seat ring is mounted with one O-ring:**

- Clean with Loctite 7063.
- Apply Loctite 620 to the cylinder head. Loctite must only be applied to the larger bore (Ø 78) without O-ring. Not to the smaller bore where the O-ring fits.

For more information about the use of Loctite, see section 12.3.6

8 **Mount the exhaust valve seat using one of following methods:**

- Put the seat rings into a guide bush and press in the seat with a guided arbor. It is also possible to use a special tool (837032) which can be ordered from the engine manufacturer.
- Insert the seat ring using an old scrapped exhaust valve. Do not use an exhaust valve which is to be reused. Knock/push on the valve until the seat ring is correctly seated.

Note!
It is recommended that the exhaust seat O-rings are always replaced when overhauling the cylinder head.

Note!
Mounting of a exhaust valve seat ring should 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 should be ground in a seat grinding machine.

10 **Pressure test the cylinder head water side before mounting with a test pressure of 10 bar.** Use pressure test tool (847004 and 847005) for blocking the water holes of cylinder head.

12.3.6. Use of Loctite products for locking the seats and centre sleeves

V4

1 **After the "hot" cylinder head washing, the seat pockets must be cleaned,** with hot water and/or a wet cloth, to remove possible anti-corrosion chemicals and to achieve a pH value close to pH7.

2 **Before assembling the cooled seat,** use Loctite 7063 to remove any frost, dirt or protective chemicals. This neutralizes the surface close to pH7.

Note!
Power cleaner or similar should not to be used.

3 **Apply the Loctite 620 to the surface,** to which a sleeve or seat ring is to be locked. Loctite 620 must be use because of the high temperature performance. It needs a 1 hour curing time.

Note!
Do not apply Loctite to an O-ring (use soap-water solution).

12.3.7. Reassembling the engine valves

V3

1 **Check the valve springs.** If there is any cracking, corrosion or wear, fit new springs.

2 **Put new seal rings** in the valve guides.

3 **Lubricate the valve stems** with engine oil.

4 **Put in the valves** and check for free movement.

5 **Put on the springs** and rotators. Replace the valve rotators if they are worn or damaged.

6 **Compress the springs** with the tool set.

7 **Put in the valve cotters** and unload the springs.

8 **Check that the valve cotters fit properly.**

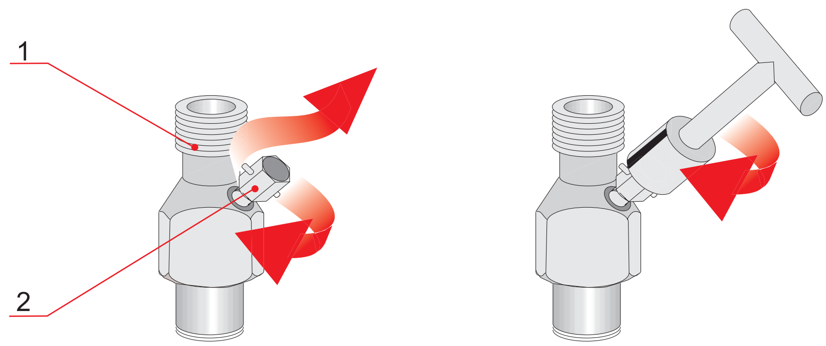
9 **Check the function of the valve rotators.** Mark the valve disc and cylinder head with a felt-tip pen and check that the valve moves when the stem is gently tapped with a mallet.

12.4. Operation and maintenance of the indicator valve

V5

The inside construction of the indicator valve is such that the pressure in the cylinder tightens it. The valve is designed so that the cylinder pressure causes the valve to seal. Consequently the force needed to close the valve is relatively low. The valve cock screw has a left-hand thread. The opening and closing of the valve is shown inFig 12-15. Use the special T-wrench808001 to open and close the valve.

Open and close indicator valve



1. *Thread* 2. *Valve cock screw.*

Fig 12-16 321255 V2

1 **When starting the engine,** Close the indicator valves. Use only a minimum force that the sealing surfaces seat properly. The cylinder pressure will push them tightly together.

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

3 **When opening the indicator valve** for measuring the cylinder pressure, use of force must be avoided.

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

5 **Apply a high temperature lubricant** (up to 1000°C) to the valve stem threads when you feel that they are sticking.

Note!
Use the special T-handle wrench to open and close the indicator valve.

12.4.1. Cylinder firing pressure checking

V3

Warning!
The area around a running engine is hazardous and due attention must be given to rotating parts and hot surfaces. Note that hot, high pressure gases will be ejected if an indicator valve is opened while the engine is running.

1 **Remove the heat shield** from the indicator valve concerned and connect the peak pressure indicator. Make sure that it is properly connected before opening the indicator valve.

2 **Open the indicator valve** Read instructions in section 12.4. The valve is opened by turning the cock anti-clockwise.

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

Note!
The value to be recorded in the data record is (P_{av}) which is the average of the peak firing pressures from at least 32 cycles. Cylinder pressure readings will be practically worthless unless the corresponding engine loads are recorded.

Before measuring, adjust the settings of the equipment according to above. See the instrument manufacturer's instructions for details.

4 **Close the indicator valve** (see section 12.4) and remove the peak pressure indicator.

5 **Refit the heat shield.**

12A. Testing the cylinder tightness

V5

Note!
Test the cylinder tightness immediately after the engine has stopped.

A tool can be used to control the cylinder and valve tightness.

1 Turn the appropriate piston to ignition TDC (all valves closed) for the cylinder concerned.

12A.1. Connecting the tool for Wärtsilä 20

V12

1 Connect the tool to the indicator valve in open position.

Testing the cylinder tightness

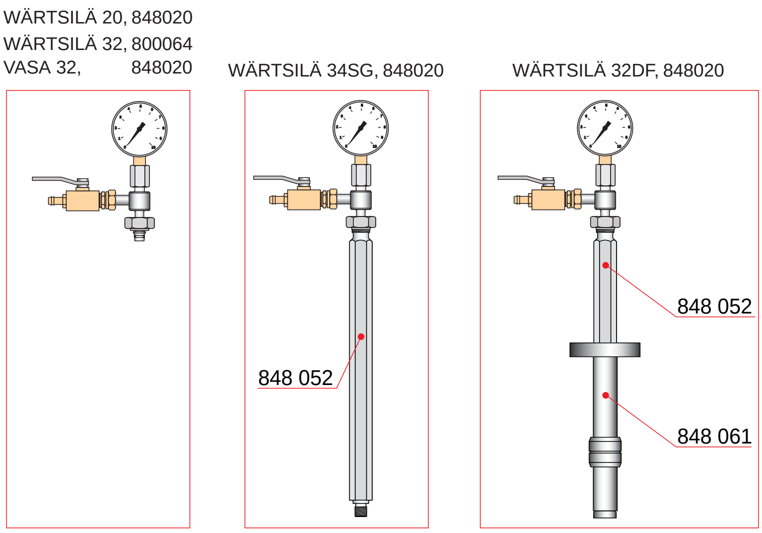


Fig 12A-1

321260 V1

2 Measure the cylinder tightness. See, section 12A.2.

12A.2. Measurement

V3

1 Connect air to the tool with a pressure of 6-7 bar (= normal working air pressure).

2 Open the valve on the tool and record the pressure.

3 Close the valve.

4 Measure the time (in seconds) it takes for the pressure to drop to 0.5 bar .

- If the pressure from the beginning was 6 bar and it takes more than 10 sec. for the pressure to drop to 0.5 bar, the result is acceptable.
- If the pressure drops directly to 0 bar, it is possible that one or more valves are sticking or the valve(s) are burnt.

  A sticking valve will be indicated by the immobility of the valve when the engine is turned.

  A burnt valve can normally be seen from the exhaust temperature. If the valve clearance is zero, it will also cause a direct pressure drop.
- Carbon particles that were trapped between the valve and the seat when the engine was stopped, could also prevent the valve from closing properly thus causing a direct pressure drop. If this is suspected, the engine should be run for a few minutes and the test repeated.
- If a blow-by between the cylinder liner and piston is suspected e.g. due to the fast fouling of filters or high crankcase pressure, it is best to test all the cylinders and compare the readings.

  For example: From a six cylinder engine you get a serial: 12, 17, 15, 4, 19 and 18 seconds.

  This shows that cylinder No. 4 is the one where blow-by is to be suspected.

  This conclusion can be verified by listening for leaking sounds inside crankcase during testing.
- If time restrictions only allow the overhaul of one piston, the piston of the cylinder with the worst blow-by should be dismantled and inspected. The result of the inspection will give some indication of the general engine condition.
- When testing the cylinder after an overhaul, a rapid pressure drop can be observed. This is because the pistons have not been run-in.

Note!
Keep pre-lubricating pump running during test.

Note!
The turning gear should be engaged during test.

- In general, the location of leakage can be found by listening when the air valve is open.

Note!
The general condition of an engine is indicated with the test device, but the operation data records are more important. Overhaul the engine at the recommended intervals; do not wait until a test such as this indicates a fault.

13. Camshaft Driving Gear

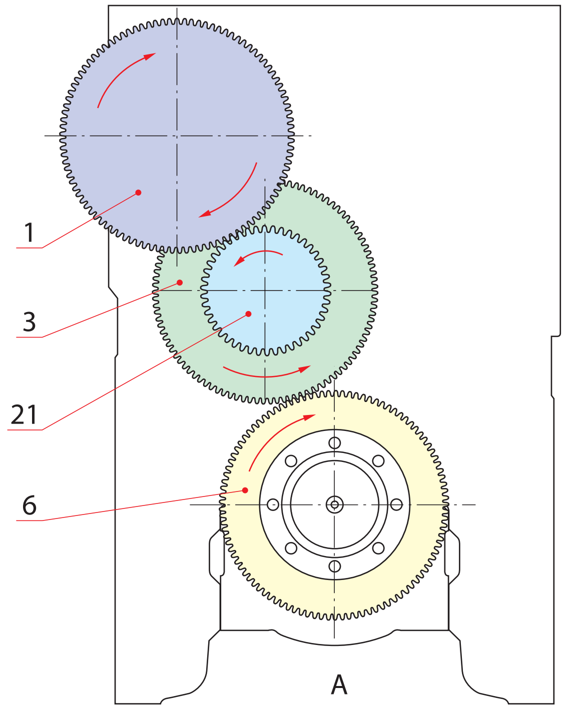
V5

The camshaft is driven by the crankshaft through a gearing. The gearing consists of a gear wheel ring (6), which is press fitted to the crankshaft, and two intermediate gears (3 and 21) and a camshaft driving gear (1), seeFig 13-1.

The bearing shafts of the intermediate wheels are journalled in the engine block. The camshaft driving wheel (1) is fastened between the end of the camshaft and the extension. For the speed governor drive a helical gear wheel is located at the end of the camshaft. Lube oil nozzles provide for lubrication and cooling of the gearing.

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

Camshaft driving gear



1.*Drive gear for camshaft,*3.*Bigger intermediate gear for camshaft drive,*6.*Gear wheel for crankshaft,*21.*Smaller intermediate gear for camshaft drive*

A.*Flywheel end*

Fig 13-1

201354 V2

13.1. Intermediate gears and camshaft gear V5

The intermediate gear wheels are case hardened. The wheels have a common shaft and are fixed to each other by a friction connection. The lubrication for the bearings is arranged through drillings in the shaft and in the wheels from a distributing pipe.

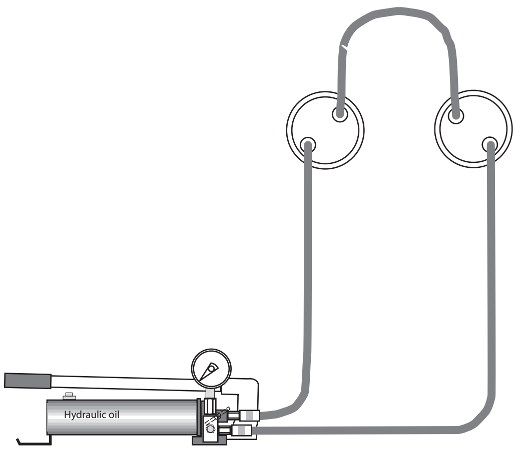
The basic adjustment of injection timing is done with the gear wheel (1) for camshaft (Fig 13-4). By loosening the round nut (14) of the camshaft, the friction connection of the gear wheel to the camshaft is released. The timing can be adjusted if the crankshaft is rotated in relation to the camshaft.

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

13.1.1. Maintenance of camshaft gearing V5

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

Dismantling with hydraulic tool



1. *Screw on cylinders by hand.* 2. *Connect hoses, open valve. Tighten cylinders by hand.* 3. *Screw cylinders about two and half a turn backwards.* 4. *Close valve, rise pressure.* 5. *Open the nut about two and half a turn.* 6. *Open release valve, remove tool.*

Fig 13-2 HYD2A V2

13.1.2. Basic adjustment of valve timing

V7

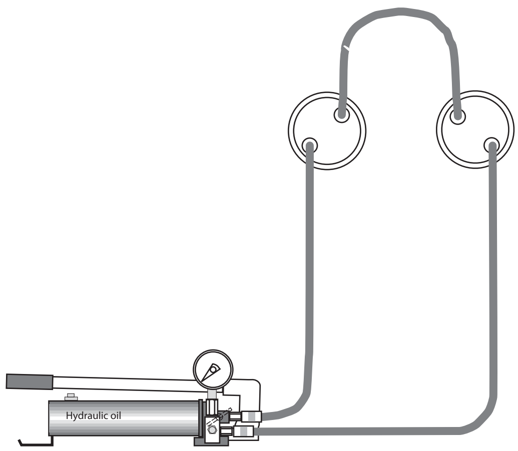
Basic adjustment of the valve and injection timing is done by changing the relative position of the camshaft and gearwheel (1). If the position is changed, the position of the camshaft is changed in relation to the crankshaft.

Note!
The relative position between the camshaft and crankshaft is adjusted at the factory and should not be changed unless it is absolutely necessary.

1 **Remove the camshaft end cover (13).**

2 **Turn the crankshaft until the position of correct injection timing is reached.**

Reassemble with hydraulic tool



1. *Screw on nuts, attach distance sleeve. Screw on cylinders to the bottom by hand.*2. *Connect hoses, open valve. Tighten by hand.* 3. *Close the valve and pump pressure to the stated value.* 4. *Screw the nuts until close contact to face.* 5. *Open the valve and remove tool set.*

Fig 13-3

HYD2A V2

3 **Install the hydraulic tool 861169 on the screw (12).**

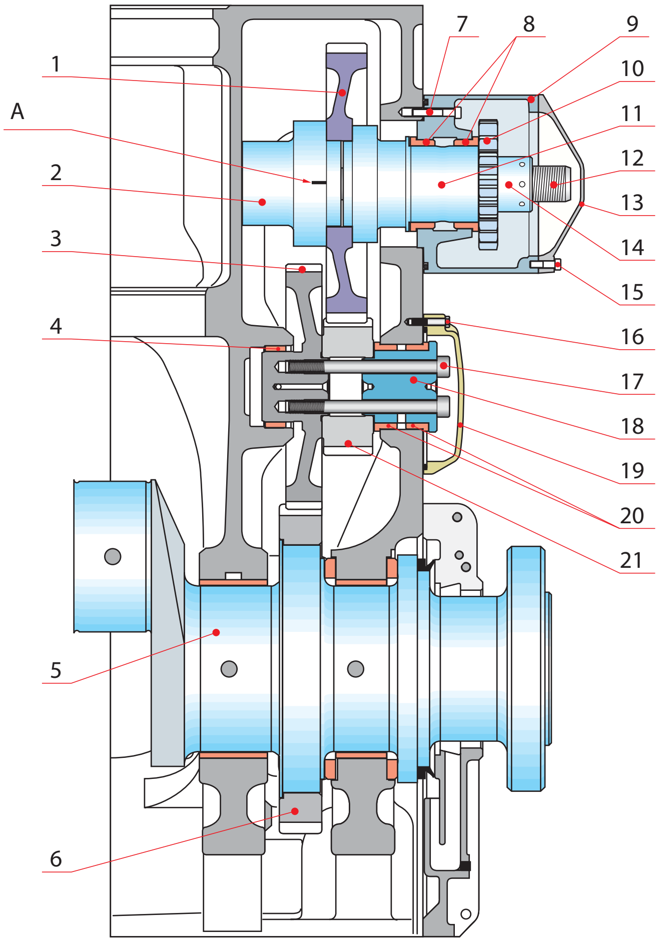
4 **Loosen the nut using correct hydraulic pressure and turn the crankshaft.** The intermediate and camshaft gear wheel should then rotate while the camshaft should stand still. See, Chapter 07: Hydraulically tightened connections.

5 **Tighten the screw connection and re-check the injection timing.** See, Chapter 16: Control of fuel injection timing.

6 **Remove the hydraulic tool and install the camshaft end cover.**

Note!
The round nut (14) of the camshaft is guided against a shoulder in the gear wheel for governor drive (10). When tightening the camshaft screw, pay close attention to fix the nut correctly against the guiding face in order to prevent damaging the parts.

Camshaft driving gear



1. *Gear wheel for camshaft* 2. *Extension shaft* 3. *Intermediate gear wheel* 4. *Bearing bush* 5. *Crankshaft* 6. *Gear wheel for crankshaft* 7. *Screw* 8. *Screw* 9. *Housing* 10. *Gear wheel for governor drive* 11. *Extension shaft* 12. *Screw* 13. *Cover* 14. *Screw* 15. *Guiding pin* 16. *Screw* 17. *Screw* 18. *Shaft* 19. *Cover* 20. *Bearing bush* 21. *Intermediate gear wheel.*

A. *Indicating mark*

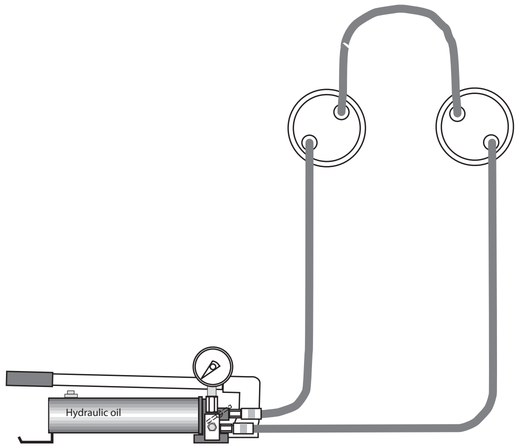
Fig 13-4 201353 V1

13.1.3. Removing of camshaft driving gear V5

1 **Remove the gearing covers** and the adjacent camshaft cover.

2 **Turn the crankshaft** to TDC at firing for cylinder No. 1.

Dismantling with hydraulic tool



1. *Screw on cylinders by hand.* 2. *Connect hoses, open valve. Tighten cylinders by hand.* 3. *Screw cylinders about two and half a turn backwards.* 4. *Close valve, rise pressure.* 5. *Open the nut about two and half a turn.* 6. *Open release valve, remove tool.*

Fig 13-5 HYD2A V2

3 **Remove the governor unit** and speed pick-ups.

4 **Remove the governor drive cover plate (13)** . See Fig 13-4, and disconnect oil supply pipe.

5 **Open the nut (14)** and remove the drive gear for the governor (10).

6 **Open the screws (7)** and remove the complete governor drive assembly.

7 **Remove the end piece (11).**

8 **Remove the camshaft gear wheel (1).**

9 **Remove the intermediate gear wheel cover (19)** and spray nozzles.

10 **Remove the extension shaft (2).**

11 **Open the fastening screws (17)** and remove the shaft piece (18) and the small intermediate gear wheel (21).

12 **Remove the big intermediate gear wheel (3).**

13.1.4. Mounting of the camshaft gearing

V7

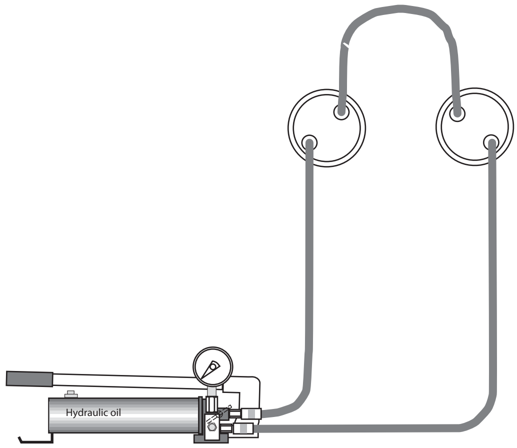
Note!
Turn the crankshaft to TDC at ignition for cylinder No.1 before proceeding with the job.

1. **Lubricate the bearing bushes (4) and (20).** See, Fig 13-4.
2. **Lift the big intermediate gear wheel (3) into position.**
3. **Insert the small intermediate gear wheel (21) onto the collar of the big intermediate gear wheel.**
4. **Insert the shaft piece (18) and hand tighten the fastening screws (17).**
5. **Insert the extension piece (2).** Ensure that the indicating mark (Fig 13-4) is visible and is in a horizontal position.
6. **Lift the camshaft gear wheel (1) into position.** Ensure that the camshaft gear wheel is mounted with the deeper side towards the screw connection.
7. **Insert the end piece (11).**
8. **Insert the housing of the governor drive.** Replace the O-ring with a new one and tighten the screws (7) to stated torque.
9. **Insert the gear wheel for governor drive (10) and the screw (12) into position.** Insert and hand tighten the nut (14).

Note!
Insert the nut carefully onto the guiding collar in the gear wheel for the governor drive before installing the hydraulic tool onto the screw.

10. **Tighten the screw (17) for the intermediate gear wheel to stated torque.**

Reassembling with hydraulic tool



1. *Screw on nuts, attach distance sleeve. Screw on cylinders to the bottom by hand.*2. *Connect hoses, open valve. Tighten by hand.* 3. *Close the valve and pump pressure to the stated value.* 4. *Screw the nuts until close contact to face.* 5. *Open the valve and remove tool set.*

Fig 13-6 HYD2A V2

11 Lift the hydraulic tool onto the screw and rise the pressure to 300 bar and tighten the nut.

12 Check the valve timing. See, section 16.2.6.

13 Tighten the nut to the full stated pressure. See, section 07.3.

14 Mount the governor unit and the speed pick-ups.

15 Install the covers for the gearing and the camshaft.

16 Mount all the covers and the oil pipes.

Note!
Check the valve timing before the engine is started.

13.2. Crankshaft gear ring V2

The gear wheel ring (6) is press fitted to the crankshaft. Removing and mounting the gear ring requires special knowledge and should be conducted by authorized personnel only.

14. Valve Mechanism and Camshaft

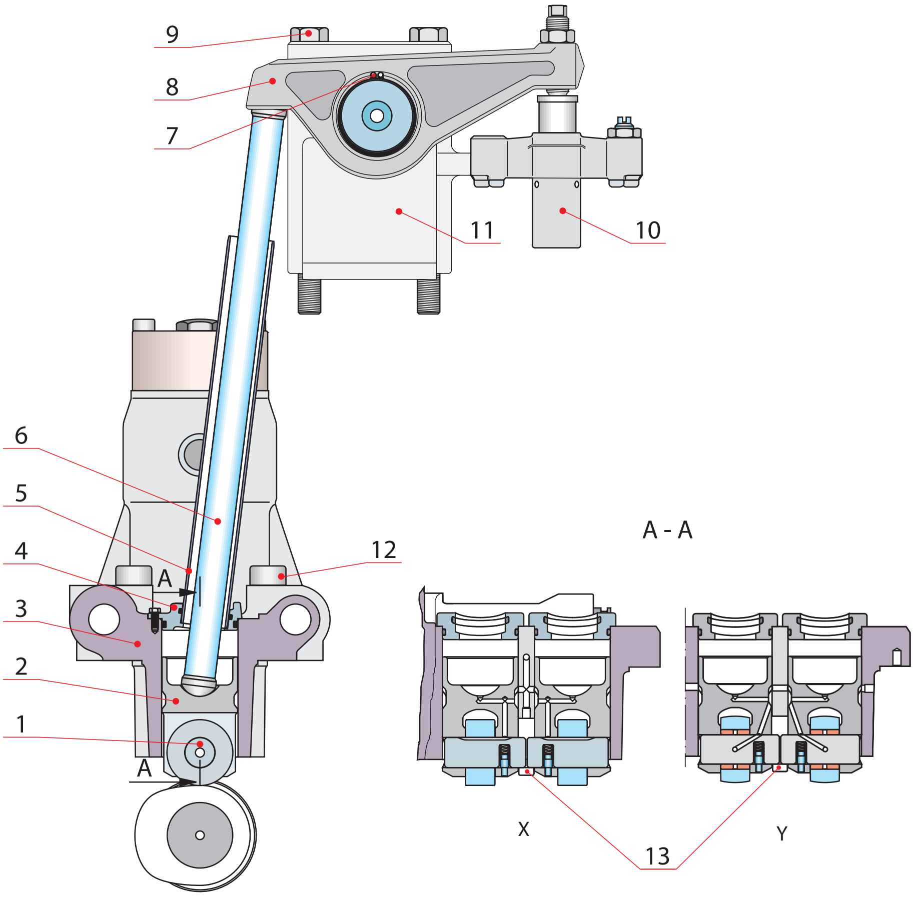
V2

14.1. Valve mechanism

V7

The valve mechanism transfers the cam motion to the valves. The valve mechanism consists of piston type valve tappets (2) moving in a common guide block casing; the multihousing (3), tubular push rods (6) with ball joints, nodular cast iron rocker arms (8) journalled on a rocker arm bearing bracket (11), yokes (10) guided by a yoke pin in the cylinder head.

Valve mechanism



1. *Roller pin,* 2. *Valve tappet,* 3. *Multihousing,* 4. *Cover for valve tappet,* 5. *Protecting sleeve,* 6. *Push rod,* 7. *Retainer ring,* 8. *Rocker arm,* 9. *Screw,* 10. *Valve yoke,* 11. *Rocker arm bracket,* 12. *Screw,* 13. *Securing screw*

X. *Without floating bearing bush,* Y. *With floating bearing bush*

Fig 14-1 201458 V2

14.2. Function of valve mechanism V3

The movement of the valve tappets is governed by the cam profile. The valve tappets transfer the movement through push rods to the rocker arms. The rocker arms operate the inlet and exhaust valves through a yoke.

The bracket for the rocker arms is made of nodular cast iron and is fastened to the cylinder head by two long screws. The steel journal is press fitted into the bracket. The positioning of the journal is important for the oil supply to the valve mechanism.

The rocker arms act on the valve yokes, which are guided by an eccentrically placed yoke pin. To compensate for heat expansion a clearance must exist between the rocker arm and yoke. All adjustments are made on a cold engine, and this work procedure is explained in chapter 12. Each valve yoke operates two valves simultaneously.

The valve mechanism is lubricated from the main flow with pipe connections. All other flows in the cylinder head are through drilled bores. Oil to the valve yokes passes through the rocker arm bracket in an intermittent flow controlled by the bore in the rocker arm. Oil will only flow through the rocker arm when it is in the open-valve position. Oil which is passed to the yoke lubricates the yoke tappet and by splashing through the bores also lubricates the valve rotators. Oil is returned to the crankcase in a free flow through the protective sleeves of the push rod.

Note!
The intermittent supply provides a minimal oil flow to the valve mechanism. The oil flow to a cylinder head with all valves closed is "shut off". To completely check the oil flow to a cylinder head during pre lubrication, the engine must be rotated during pre-lubrication.

14.3. Maintenance of valve mechanism V8

Normally, the valve mechanism need no maintenance, but the components should be checked for damage and wear at the intervals stated in chapter 04. See chapter 06 for adjustments and wear limits. If the valve mechanism is dismantled, the components should be marked and later reassembled in the same position to avoid unnecessary wear.

14.3.1. Dismantling of valve mechanism V8

1. **Remove the covers of the valve mechanism and camshaft from the cylinder concerned.**
2. **Turn the crankshaft to a position where the valve tappet rollers of the valves and the injection pump are on the base circle of the cam.**
3. **Unscrew the screws (9) and remove the rocker arm bearing bracket from the cylinder head.**
4. **Remove the retainer rings and rocker arms.** To remove the retainer rings, use pliers 843004.

5 **Remove the push rods injection pipe, fuel leak pipes and the protecting sleeves.**

6 **Remove air pipe and lube oil pipes.** Loosen the control shaft bracket. Disconnect the fuel rack.

7 **Open the fuel pipe connection between the multi-housings concerned.** Use circlip pliers to slide the fuel retainer ring to one side. Move the fuel line connecting sleeves clear of the adjacent fuel pipes.

8 **Loosen the fastening screws 12, remove the high pressure connecting piece and protecting sleeve.** Remove the housing (3).

9 **Remove the securing plate.** The valve tappets can now be withdrawn. Before dismantling, mark the parts so that they can be reassembled in their original positions.

10 **The tappet roller and pin can now be separated by depressing the retainer into the pin and slide out.** The tappet should be covered, as the retainer is under spring loaded tension.

14.3.2. Inspection of valve mechanism parts

V5

1 **Clean the rocker arm bore and the journal and measure for wear.** When cleaning, pay special attention to the oil holes.

2 **Clean and inspect all parts of the valve tappet.** When cleaning, pay special attention to the oil holes.

3 **Check for wear by measuring the tappet, the housing bore and the roller.**

4 **Change the O-rings of the cover (4) if they are damaged or hard.**

14.3.3. Assembling the valve mechanism

V9

1 **Lubricate the parts of the valve tappet with clean engine oil and assemble.** Observe the marks for correct positioning.

2 **Insert the valve tappets into the multi-housing and mount the securing plate (13).**

3 **Mount the cover for valve tappet.**

4 **Mount the complete housing onto the engine and tighten the screws to the stated torque according to Chapter 07: Tightening Torques and Instructions for Screw Connections.**

5 **Connect the fuel pipes between the multi-housings concerned.** Move the fuel line connecting sleeves on the adjacent fuel pipes. Use circlip pliers to slide the fuel retainer ring into its groove.

6 **Connect the air pipe, injection pipe, fuel leak pipes and lube oil pipes.** Mount the control shaft bracket and connect the fuel rack.

7 **Grease the O-rings, insert the protecting sleeves (5) and push rods (6) into the guide block.**

8 **Mount the yoke.** For adjusting the yokes, see section 12.2.5.

9 **Lubricate the rocker arm bore and mount the rocker arms (8) on the bracket.**

10 **Apply the retainer rings (7) by using pliers 843 004.** Check the axial clearance and free rotation of rocker arms.

11 **Mount the rocker arm bracket on the cylinder head and tighten the screws (9) to the stated torque.** See, Chapter 07: Tightening torques for screws and nuts.

Note!
The rocker arm bracket has to be centred.

12 **Check the valve clearance according to Chapter 06: Adjustments.** Mount the covers.

14.4. Camshaft

V7

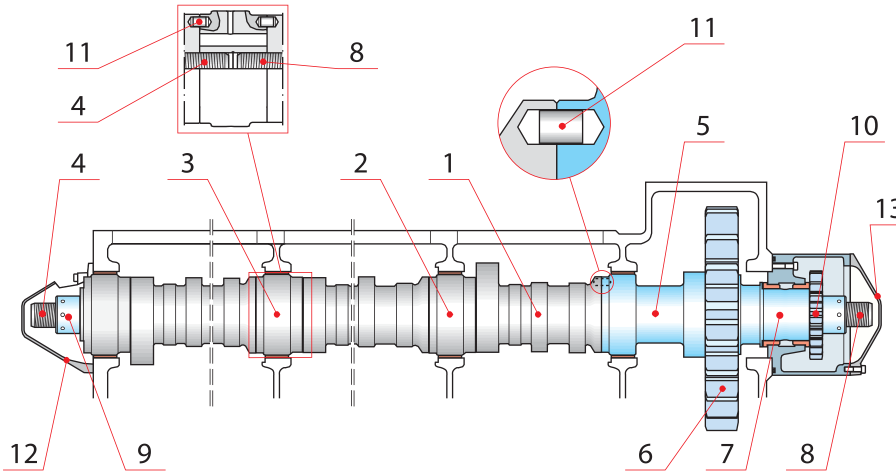
Data and dimension
Material: Special steel, case hardened
Weight: Camshaft piece 14,6 kg
Bearing piece 8,6 kg

The camshaft is built up of one-cylinder camshaft pieces (1) and separate bearing pieces (2).

The drop forged camshaft pieces have integrated cams, the sliding surfaces of which are case hardened. The camshaft is driven by the crankshaft through gears at the driving end of the engine. At this end the camshaft is provided with a helical gear for driving the speed governor.

The camshaft has an axial bearing at the driving end. The oil supply is arranged to the axial bearing from the driving end of the engine. The camshaft has a bore, through which oil is supplied to every camshaft bearing and from there up to the multihousing. The rotational speed of the camshaft is only half of the engine speed.

Camshaft



1. *Camshaft piece,* 2. *Bearing piece,* 3. *Bearing piece,* 4. *Screw,* 5. *Extension piece,* 6. *Drive gear,* 7. *End piece,* 8. *Screw,* 9. *Nut,* 10. *Gear,* 10. *Guide flange (ProAct actuator),* 11. *Guide pin,* 12. *Cover,* 13. *Cover.*

Fig 14-2 201459 V2

14.4.1. Removing of camshaft piece

V9

1 **Remove the camshaft covers.** See Chapter 16. Remove the rocker arm brackets and the injection pumps for the cylinders concerned. Before removing the injection pumps remove the control shaft completely or support it well.

2 **Remove the cover 12 from the free end of the camshaft.** And also the cover 13 from the driving end of the camshaft, if necessary.

3 **Loosen the nut of the screw 4 or 8 depending on the cylinder concerned.** Note the position of the camshaft piece, using the hydraulic tools 861158 and 861169. See Chapter 07 for correct pressure.

Note!
When undoing the camshaft connection the hydraulic jack has to be turned to the bottom, then undone for two and a half turns. The nut is to be undone opened for two and half turns and the pressure released slowly.

4 **Separate the camshaft piece concerned from the bearing pieces by using a suitable lever.** Pay attention not to damage the tappet rollers or camshaft pieces when moving the shaft axially.

5 **Remove the screw from the camshaft.**

6 **Remove the camshaft piece carefully via the camshaft doors.**

14.4.2. Mounting of camshaft piece

V8

1 **Clean and lubricate the camshaft bearing bush and the bearing surface of the bearing piece with clean engine oil.** Carefully insert the bearing piece into the bearing housing. Pay attention to the position of the bearing piece.

2 **Insert the guide pins into the bearing piece and fit the snap rings.** The shorter section of each pin should protrude from the bearing piece.Fig 14-2

3 **Install the camshaft piece between two bearing pieces and onto the guiding face of the bearing pieces.** Check the position of the guide pins. Check the position of the guide pins. Insert the M42*3 screw and pre-tighten it by hand.

4 **Move the camshaft pieces axially with a suitable lever.** Hand tighten the nut.

5 **Check the injection timing prior to tightening the camshaft driving gear nut wheel to full torque.** See Chapter 16

6 **Install the hydraulic tool.** Rise the pressure in two steps, first to 300 bar and tighten the nut. Then tighten the nut to a pressure according to Chapter 7. See Fig 14.3. Note the clearance between the pressure plate and sensors.

Note!
When tightening the camshaft connection keep the hydraulic jack to the bottom.

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

8 **Mount the injection pumps, injection pipes and rocker arms.**

9 **Mount the covers.**

10 **Check the valve clearances.** See section 12.2.5.

14.5. Camshaft bearings

V7

When the camshaft has been removed, the inner diameter of the bearing bush can be measured in situ, by using a ball anvil micrometer. The maximum diameter is stated in section 06.2. If the maximum diameter for one camshaft bearing bush is exceeded, all camshaft bearing bushes should be replaced. A special tool is available for this purpose, see Fig 14-3.

14.5.1. Changing of camshaft bearing bush

V6

1 **Lubricate the new bearing bush with clean oil on the outer surface and put it on the guide sleeve.** The distinct mark must be positioned downwards and towards the flywheel end.

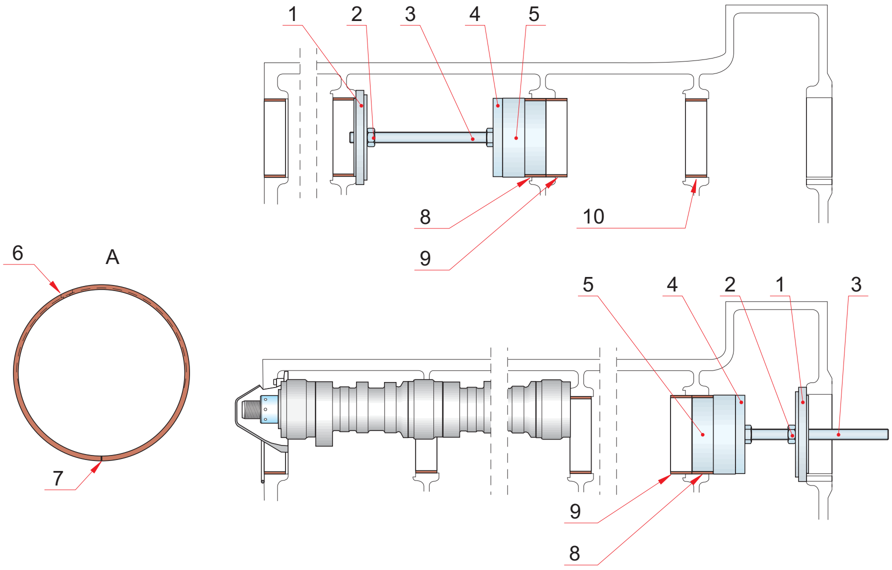
Note!
The bearing bush without the oil groove can be used only in the camshaft bearing bore No.1.

2 **Put the thrust discs (1 and 4) and the thrust screw in place.** Now tighten the nut by hand until the new bearing bush meets the old one.

3 **Tighten the nut to press out the old bearing bush.** Simultaneously mount the new bearing bush in place.

4 **Unscrew the nut and dismantle the tool.**

Changing of camshaft bearing bush



1. *Thrust disc,* 2. *Nut,* 3. *Thrust screw,* 4. *Thrust disc,* 5. *Guide sleeve,* 6. *Oil hole,* 7. *Distinct mark,* 8. *Bearing bush, new,* 9. *Bearing bush, old,* 10. *Bore no. 1*

A. *Bearing bush*

Fig 14-3 201455 V2

14.5.2. Changing of camshaft bearing bush No.1

V6

1 **Lubricate the new bearing bush with clean oil on the outer surface and put it on the guide sleeve.** The distinct mark must be positioned downwards and towards the flywheel end. See Fig 14-3.

2 **Put the thrust discs (1 and 4) and the thrust screw in place.** Now tighten the nut by hand until the new bearing bush meets the old one.

3 **Tighten the nut to press out the old bearing bush.** Simultaneously mount the new bearing bush in place.

4 **Unscrew the nut and dismantle the tool.**

15. Turbocharging and Air Cooling

V1

15.1. Turbocharger

V6

Data and dimensions
Weight (dry):
- TPS 52 230 kg
Material:
- Casings: special cast iron
- Turbine: special heat resistance steel
- Compressor: light metal alloy or titanium alloy
- Bracket: cast iron

The turbocharger utilizes the energy of the engine exhaust gas to feed more air to the engine, thereby offering advantages such as boosted engine power output and thriftier fuel consumption.

The exhaust gas discharged from the cylinders of the engine are led through the exhaust manifold into the turbocharger and accelerated in the turbine housing before the passages of the turbine wheel. The turbine rotates at a high speed and turns the compressor wheel mounted on the same shaft as the turbine wheel. The compressor takes air, often through a filter, from the engine surroundings and compresses it to a higher pressure. A higher pressure results in a higher density of the air which means that a larger amount of air is forced into the cylinder and correspondingly a larger amount of fuel can be burnt. This increases the effective pressure during the combustion and thus increases the output.

During the compression of the air in the turbocharger, the air is heated up mainly due to the compression and partly due to losses in the compression work in the compressor. The hot and compressed air flows through an air cooler. When the air is cooled, the density of the air is further increased.

The turbocharger can be divided into two basic sections: The turbine wheel that is driven by the exhaust gas and the compressor wheel which forces intake air through the air cooler and into the cylinder. The turbine wheel is of the radial turbine type, i.e. the gas enters the turbine axially and leaves it radially. The shaft connecting the turbine wheel to the compressor wheel is supported by two bearings between the turbine and compressor wheel. The compressor is of radial type, i.e. air enters the turbine radially and leaves it axially.

The bearings are lubricated with lubricating oil from the engine lubricating system.

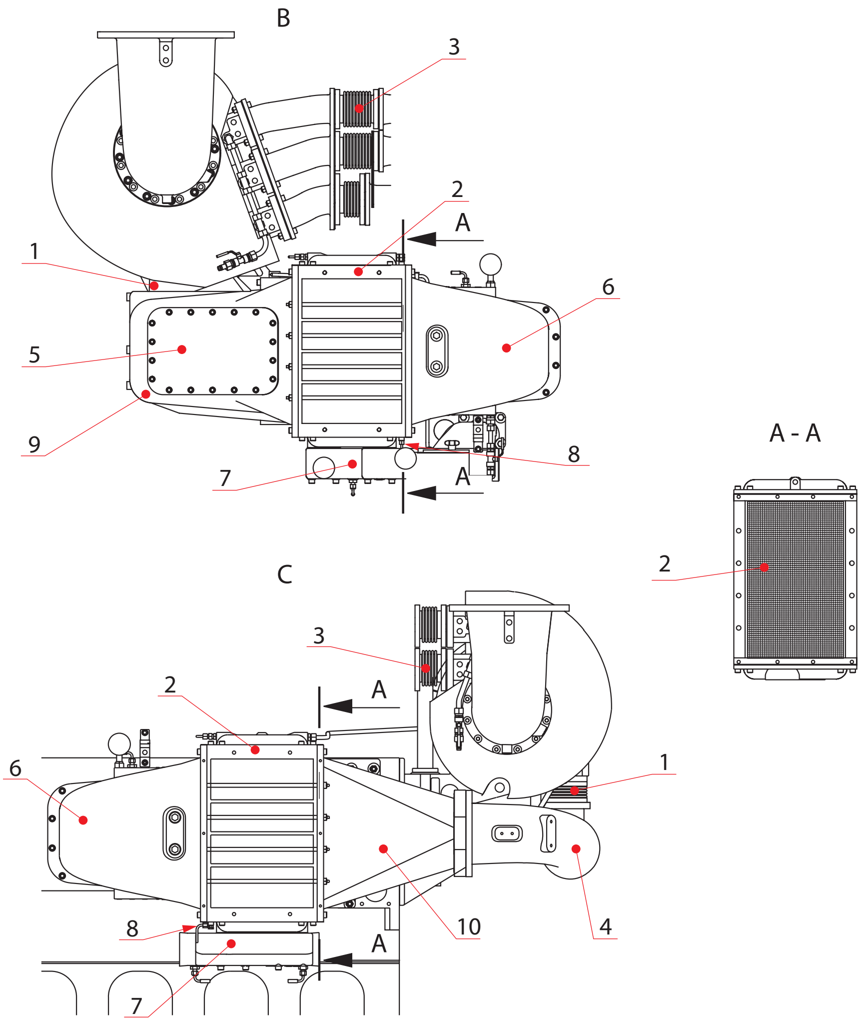
The air outlet housing of the turbocharger is connected to the air duct of the engine through a piece of metal bellows (1), which allows thermal expansion of the air duct. The air duct is designed to reduce the speed of the air in an efficient way before it enters the air cooler. The air duct is provided with guiding vanes for an equal distribution of air over the whole air cooler surface. The air duct is fixed in position to the air cooler housing.

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

The exhaust pipes from the engine are also connected to the turbocharger through metal expansion bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions.

The turbocharger is equipped with cleaning devices for cleaning of both the compressor and the turbine by water injection.

Turbocharger and charge air cooler assembly



1.*Bellows*, 2.*Air cooler*,3.*Bellows*,4.*Charge air pipe*,5.*Cover*,6.*Air inlet piece*, 7.*Water connection*,8.*Drain pipe*,9.*Air box*,10.*Diffuser*

B.*TC at the driving end (LD)*,C.*TC at the free end (LF)*

Fig 15-1 201571 V2

15.1.1. Turbocharger maintenance

V7

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

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

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

15.1.2. Water cleaning of the turbine

V7

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

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

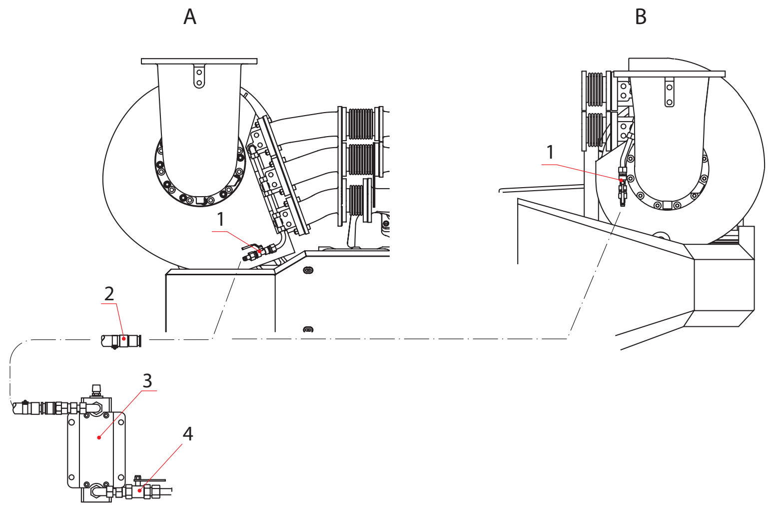
During long time of operation, periodic water cleaning prevents the build-up of significant deposits on the turbine blades and nozzle vanes. This cleaning method does not work on very dirty turbines which have not been washed regularly.

If the normal water cleaning of the turbine does not effect much on the exhaust gas temperature level, hard deposits have probably been built up on the nozzle ring and the turbine blades in the turbocharger and they have to be cleaned mechanically. For that purpose the rotor and the nozzle ring have to be removed from the turbocharger.

At water cleaning the water must be injected into the exhaust system with the engine running at reduced output (see 15.1.3, step 1). The disadvantages of reducing the output occasionally is not significant compared with the advantages of cleaning.

The necessary water flow is basically dependent upon the volume of gas and its temperature. The flow should be adjusted so that the major part of the water is evaporated and escapes through the exhaust. It is important that all of the water does not evaporate, since the cleaning effect is based upon the water solubility of the deposits and the mechanical effect of the impact of the water drops. Additives or solvents must not be used in the cleaning water. The use of salt water is prohibited.

Water cleaning of the turbine



1. *Valve* 2. *Quick-coupling* 3. *Flow meter* 4. *Valve.*

A. *TC at the driving end,* B. *TC at the free end*

Fig 15-2 201570 V2

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 (3) to a suitable value, see table below.

Table 15-1 Water cleaning of turbine

Turbocharger size	Water flow (l/min)
TPS 48	6
TPS 52	8
TPS 57	10

Cleaning should take place regularly according to chapter 04, Maintenance Schedule. Depending on the results obtained, the interval between two washings may be increased or reduced.

15.1.3. Turbine cleaning procedure

V8

The flow meter enables accurate control of the amount of water injected. Before cleaning the turbine, it is advisable to record the below parameters for later use to assess efficiency of the cleaning; recording at two or three different loads will give a more accurate evaluation basis for the influence of the washing.

- Charge air pressure
- Exhaust gas temperatures after the cylinders
- Exhaust gas temperatures before and after the turbocharger, provided that measurement equipment is installed
- Turbocharger speed
- Engine load

Note!
The charge air pressure is not allowed to drop below 0.2 bar during the entire washing procedure.

1 **Stabilise the temperatures.**

a) **For constant speed operated engines run the engine at approx. 25-30% load for 10 minutes.** Maintain this load during the entire washing procedure. Recommended temperature before turbine should remain between 400°C and 450°C.

b) **For variable speed operated engines run the engine at approx. 10-15% load (465-530 rpm of nominal 1000 rpm) for 10 minutes.** Maintain this load during the entire washing procedure. Recommended temperature before turbine should remain between 400°C and 450°C.

2 **Open valve (1) to confirm free passage.**

3 **Connect the water hose to the quick coupling (2) as in Fig 15-2**

4 **Open the water supply valve (4) before the flow meter (3) and immediately adjust the water flow according to the table shown above, wash 30 seconds.** Stop washing by closing the valve (1).

Warning!
Water injection time and the exhaust gas temperatures are to be carefully observed. Continuous (heavily exceeding 30 seconds) water flow may cause a failure of the turbocharger. Too high exhaust gas temperatures (>450°C) may result in impermissible thermal stresses.

5 **Run the engine for 10 minutes to stabilise the temperatures.**

6 **Open the 2-way valve and wash for another 30 seconds.**

7 **Run the engine for 10 minutes to stabilise the temperatures.**

8 **Repeat steps 6 and 7 once more.** Washing water should now have been injected three times.

a) **After the washing, run the engine for 10 minutes at least at 25-30% load to stabilise the temperatures.**

If three times washing is not sufficient to clean the turbine (based on the operating parameters) it is recommended to further perform two additional washing sequences.

Washing the turbine more than three times also indicates that it is advisable to shorten the intervals between each cleaning occasion.

15.1.4. Water cleaning of the compressor

V7

The compressor can be cleaned during operation by injecting water. The method is suitable if contamination is not too far advanced. If the deposit is very heavy and hard, the compressor must be cleaned mechanically.

The injected water does not act as a solvent. The cleaning effect is achieved by the physical impact of the drops on the deposit. It is therefore advisable to use clean water containing no additives either in the form of solvents or softening agents that could be precipitated in the compressor and form a deposit.

Regular cleaning of the compressor prevents or delays the formation of deposit but does not eliminate the need for normal overhauls, for which the turbocharger has to be completely dismantled.

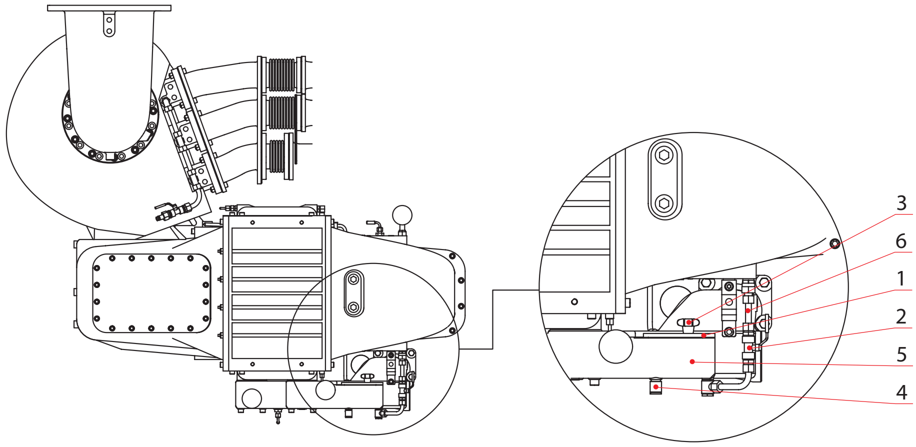
Through an inlet pipe, pressured air can enter the dosing vessel. The water is injected to the compressor through the pipe (4), see Fig 15-3 or Fig 15-4 depending on the location of the turbocharger.

The water must be injected while the engine is running and at the highest possible load, that is, at a high compressor speed.

For an efficient washing, it is important to inject all the water required within 4-10 seconds. This water quantity is 0.4 dm^3.

For water injection, the water should first be measured with the measuring cup and the same measured water is pressurised later (for example by charge air). Under no circumstances may the injection nozzle be connected to the water main flow through tap or a large tank because this would allow an uncontrolled quantity of water to enter the turbocharger and the diesel engine.

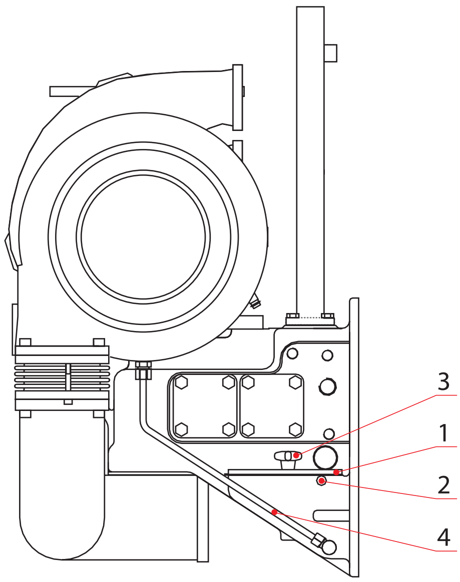
Water cleaning of compressor, TC at the driving end



1. *Cover* 2. *Valve* 3. *Knob* 4. *Water pipe* 5. *Water cup* 6. *Inlet pipe*

Fig 15-3 201568 V2

Water cleaning of compressor, TC at the free end



1. *Cover* 2. *Button* 3. *Knob* 4. *Water pipe*

Fig 15-4 201558 V2

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

The cleaning device for the compressor is used as follows:

1. **Record the charge air pressure, cylinder exhaust gas temperatures, charger speed, for later use to assess efficiency of the cleaning.**
2. **Loosen knob (3) and remove cover (1).**
3. **Fill the vessel with water up to 1 cm below the rim.**
4. **Re-fit cover (1) and tight screw knob (3).**
5. **Turn valve (2) or press button (2).** This admits compressed air from the air receiver to the vessel and forces the water through a pipe (4) to the compressor.
6. **Repeat the readings taken in step 1 to compare the efficiency of the washing.** The success of injection can be recognized by the change in charge air pressure and in the exhaust gas temperature.

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

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

15.1.5. Operation with damaged turbocharger

V7

In case of a serious breakdown of the turbocharger, if the situation does not allow the immediate repair or exchange of the turbocharger, the engine can temporarily be operated up to about 15% of the nominal output of the engine with the blanking device fitted.

Caution!
Blocking the rotor is not recommended as it blocks the flow path for the exhaust gases. Remove the rotor cartridge completely, and fit the blanking device according to the instructions in the turbocharger manual.

Caution!
As the turbocharger is out of function, the thermal load on the engine components increases. Therefore, observe the exhaust gas temperatures carefully during the operation with blanked turbocharger.

Note!
The exhaust gas temperatures after the cylinder heads must not exceed 500°C.

If the engine is operated for longer periods with exhaust temperatures close to 500°C with the blanked turbocharger, there is a risk of piston seizure. This is due to the hot temperatures internally the piston (cooling gallery) causing the lube oil forming deposits in the cooling gallery. This results in a poorer cooling effect with more thermal expansion of the piston, one of which in turn can lead to piston seizure.

During operation, also follow closely that the lube oil temperature is kept at the level of normal operation.

Also other engine components are exposed to the higher thermal loading.

After the turbocharger rotor cartridge has been removed and the blanking device fitted according to the instructions in the turbocharger manual, proceed in the following way:

1. **Remove air inlet piece (6) and disconnect the cables for sensors of the charge air inlet piece.** See, Fig 15-1.

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

3. **When the engine is loaded follow carefully that the exhaust gas temperatures do not exceed 500°C.** It is to be noted that the exhaust gas temperatures will increase by time and that the operator should first let the temperatures be stabilized at a certain load before the load is increased to the maximum allowable. The maximum allowable load in any case is about 15% of the nominal output of the engine.

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

15.2. Charge air cooler

V9

Data and dimension
Material
- Tubes: copper alloy
- Water boxes: cast iron
Weight : 160 kg (dry)
Test pressure: 8 bar (water side)

The charge air cooler is mounted between the air duct and air inlet piece, see Fig 15-1.

The cooler is of a tube type. The tubes are provided with thin fins to get a more efficient cooling of the air. The cooling water circulates in the tubes, while the compressed air passes between the fins on the outside of the tubes.

The top of the air cooler acts as a venting of the air cooler water side.

15.2.1. Charge air cooler maintenance V8

1 **Condensate from the air is drained through a small hole/pipe (8) at the bottom of the air cooler, see** Fig 15-1. Examine regularly that the draining pipe is open by checking the air flow when running.

Warning!
If water keeps on dripping or flowing from the draining pipe for a longer period (unless running all the time in conditions with very high humidity) the cooler insert may be leaky and must be dismantled and pressure tested.

2 **At longer stops, the cooler should be either completely filled or completely empty, as a half-filled cooler increases the risk of corrosion.** If there is a risk of sinking water level in the system when the engine is stopped, drain the cooler completely. Open the air vent screw to avoid vacuum when draining.

3 **Clean and pressure test the cooler at intervals according to Chapter 04: Maintenance Schedule.** If the receiver temperature cannot be held within stipulated values at full load.

4 **Always when cleaning, check for corrosion.**

15.2.2. Cleaning of charge air cooler air side V1

Cleaning of the air side should be done early enough to avoid forming of soot and oil on the fins, which form a hard deposit layer that is difficult to remove, as well as a build-up of products that form sulphuric acid (condensation) when left on the fins and tubes for some time.

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

15.2.2.1. Ultrasonic cleaning V1

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

15.2.2.2. Chemical cleaning V1

We recommend chemical cleaning of the air side, while cooler is removed, see section 15.2.3.

15.2.2.3. Recommended detergents

V1

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

Recommended cleaning detergents	
Supplier	**Product designation**
Basol Ltd.	Basol 77
Clensol Ltd.	Industrial Clegris
Drew Ameroid Marine Division Ashland Chemical Company One Drew Plaza Boonton, NJ 07005, USA	Ameroid ACC-9
Henkel KGaA Düsseldorf	P3-Grato 90
Houseman Ltd The Priory, Burnham Slough SL1 7LS, UK	Cooltreat 651
Maritech AB Box 143 S-29122 Kristianstad, Sweden	H.D. Powder W.1.H.D.S. phenol
Nalco Chemical Company One Nalco Centre Naperville, Illinois 60566-1024 USA	Nalfleet ACC
Nalfleet Marine Chemicals PO Box 11 Winnington Avenue, Northwich Cheshire, CW8 4DX, UK	Nalfleet ACC
Vecom Holding BV PO Box 27 3140 AA Maassluis, Holland	Vecom B-85

15.2.3. Cleaning of air cooler insert

V9

Cleaning of the water and air side heat exchange surfaces is imperative for a long and trouble free operation of the engine and must be done at regular intervals.

1 **Remove the shield plates.**

2 **Remove the water connection and pipes when the cooling water is drained.** Disconnect the cables for sensors of the charge air cooler assembly.

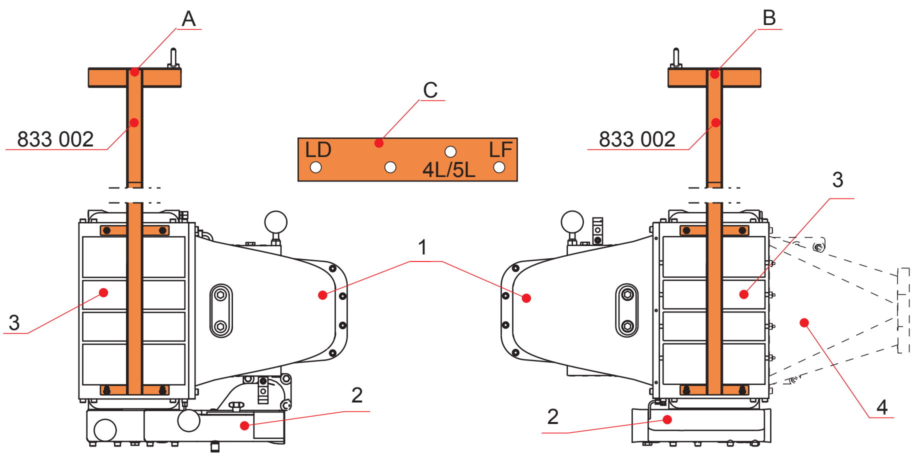
3 **Apply the lifting tool 833002 and check location of the lifting eye bolt (LD/LF/4L/5L).**

4 **Loosen the fastening screws of the air inlet piece (1) from the engine block.** Observe that two screws are inside of the air inlet piece.

5 **Remove the remaining cooler flange screws.** On the LD-engine: Open the cover (5) and remove the fastening screws of the air cooler inside of the air box (9), Fig 15-1.

6 **Lift of the air cooler (3), air inlet piece (1) and water connection (2) assembly.** On the LF-engine: The diffuser (4) may also be removed at the same time to make removal and mounting of the air cooler assembly easier.

Lifting of the air cooler assembly



A.TC at the driving end (LD), B.TC at the free end (LF), C.Location of the lifting eye bolt.

1. *Air inlet piece* 2. *Water connection* 3. *Air cooler* 4. *Diffuser*

Fig 15-5 201572 V4

7 **Remove the air inlet piece and water connection from the air cooler.**

8 **Clean the air side of the cooler by immersing it in a chemical cleaning bath for at least 24 hours.** We recommend that cleaning tank should be equipped with perforated pipes on the bottom for the best cleaning effect, see Fig 15-6. During cleaning, steam or pressurized air should

be connected to the pipes to get a good circulation. When cleaning is completed, the cooler should be flushed by applying a powerful water jet.

Note!
If the water jet attacks the cooling tubes vertically, i.e. in parallel to the fins, a pressure of 120 bar is suitable to be applied at a distance of two meters from the fin surface.

Caution!
Wrong use of water jet may cause damage to the fins, which results in an increased pressure drop over the air cooler.

9 **Clean the water side by detaching the headers from the cooler bundle.** Immerse the tube bundle into a chemical cleaning bath for at least 24 hours. Upon completion, follow the recommendations given for the air side.

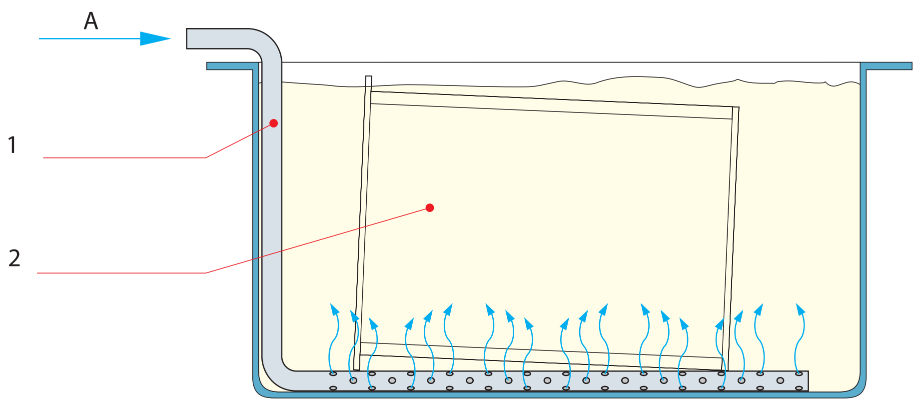
10 **Check the gaskets before reassembling the water connection.**

11 **Apply sealing compound to the sealing faces.** See, section of the spare parts catalogue for charge air cooler assembly.

12 **Mount the air cooler assembly on the engine.**

13 **Vent the cooler and check the tightness when starting up.**

Air cooler cleaning tank



A. *Steam of air*

1. *Perforated pipes* 2. *Cooler insert*

Fig 15-6 201565 V1

16. Injection System

V3

16.1. Injection pump

V8

Data and dimensions
Multihousing:
- material: special cast iron
- weight: 25 kg
Injection pump element:
- weight: 4.5 kg
Injection press: 1500 bar
Plunger: coated
Delivery valve opening press.: 22 ± 2 bar
Constant pressure valve, opens when the pressure difference is: 120 ± 10 bar

The engine is fitted with one injection pump per cylinder. The injection pump is located in a "multihousing". The multihousing incorporates:

- A housing for the injection pump element,
- A fuel supply channel along the whole engine,
- A fuel return channel from each injection pump,
- Guides for the valve tappets,
- A lubricating oil supply to the valve mechanism.

The multi-housing concept permits a reliable and compact design. It eliminates fuel and oil piping and generally simplifies maintenance.

The injection pumps are one-cylinder pumps with built-in roller tappets. The valve tappets are integrated in the same multihousing. The return fuel is drained at atmospheric pressure, through the integrated channel, back to the low pressure fuel circuit. .

Each injection pump is equipped with an emergency stop cylinder that is coupled to an electro-pneumatic overspeed prevention system.

16.1.1. Function of injection pump

V10

The injection pump supplies pressurized fuel to the injection nozzle. It has a mechanism to regulate the fuel supply according to the engine speed and load. The pumps are controlled by the governor.

The plunger Fig 16-1, is pushed up by the camshaft via the roller tappet and pulled back by the tappet spring, reciprocates in the element on a predetermined stroke to feed fuel under pressure.

The plunger also controls the amount of fuel injected by adjusting the position of the helical edge relative to the discharge port. The plunger has an obliquely cut groove (lead) on its side. When the plunger is at the lowest position or bottom dead centre, fuel flows through the inlet port into the element bore. Rotation of the camshaft moves the plunger up. When the top edge of the plunger step is lined up with the ports, the plunger begins to compress the fuel. As the plunger rises further, the helix is eventually exposed to the discharge ports and the pressurized fuel is delivered through the lead to the ports. When the helix is no longer exposed to the discharge port, the supply is cut off. By rotating the plunger, it is possible to alter the proportion of stroke during which the helix is exposed to the port. Thus the amount of fuel delivered during each plunger stroke can be controlled. The length of stroke during which fuel is delivered is called the effective stroke and is regulated by the fuel governor via the fuel racks. The fuel racks are meshed with the control sleeve which in turn is attached to the plunger. A linear movement of the racks is thus converted to a rotation of the plunger.

The element is of a mono-block design with integrated fuel delivery valve and constant pressure valve. The ports are of a special design to prevent cavitation.

The delivery valve, provided at the top of the element, performs the function of discharging the pressurized fuel to the injection pipe. The fuel compressed to a high pressure by the plunger forces the delivery valve to 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 constant pressure valve from the high pressure injection pipe to instantly lower the residual pressure between the delivery valve and the nozzle. This draw-back effect improves the termination of an injection on the nozzle and prevents after injection dripping, and improves injection regularity by preparing the line for the next injection.

The multihousing is provided with two erosion plugs, which can easily be replaced when necessary.

16.2. Maintenance of injection pump

V8

We recommend that the engine is run with light fuel for 5 minutes before overhauling the injection pump. During maintenance utmost cleanliness must be observed. It is unnecessary to remove the control shaft unless every injection pump is to be removed. When the injection pump is dismantled, the components should be marked so that to avoid unnecessary wear, they can later be reassembled in the same position.

16.2.1. Removal of injection pump

V9

1 **Shut off the fuel supply to the engine and stop the prelubricating pump.**

2 **Remove the covers of the valve mechanism and camshaft from the cylinder concerned.**

3 **Turn the crankshaft to a position where the valve tappet rollers of the valves and the injection pump are on the base circle of the cam.**

4 **Remove the rocker arms block, pushrods and the protecting pipes.**

5 **Remove the injection, fuel leak and lube oil pipes where necessary.** Disconnect the fuel rack if necessary remove control shaft.

6 **Undo the fuel pipe connections between the multihousings concerned.** Use circlip pliers to slide the fuel retainer ring to one side. Move the fuel line connecting sleeves clear of the adjacent fuel pipes. See Fig 16-1.

7 **Cover immediately all openings with tape or plugs to prevent dirt from entering the system.**

8 **Loosen the flange nuts and lift off the pump.**

9 **Cover the bore in the engine block.**

16.2.2. Mounting of injection pump

V14

1 **Check and clean the pump.** Also clean the plane and the bores of the engine block.

2 **Check the O-rings of the insert part and lubricate with vaseline or engine oil.** Check that the fuel cam is not in the lifting position.

3 **Fit the pump and tighten the screws for the flange to the stated torque.** See Chapter 07,Fig 07-4and Fig 07-5.

4 **Remove tape and plugs from all openings.** Check that the exhaust and inlet cams are not in the lifting position.

5 **Fit the protecting pipes, push rods, rocker arms bracket and adjust the valve clearances.** See Chapter 12, Fig 12-7. Assemble necessary pipes.

6 **Close the fuel pipe connections between the multihousings concerned.** Use circlip pliers to slide the fuel retainer ring.

7 **Assemble the injection pipe and tighten nuts to rated torque.** See Chapter 07.

8 **Check that the fuel rack moves freely.**

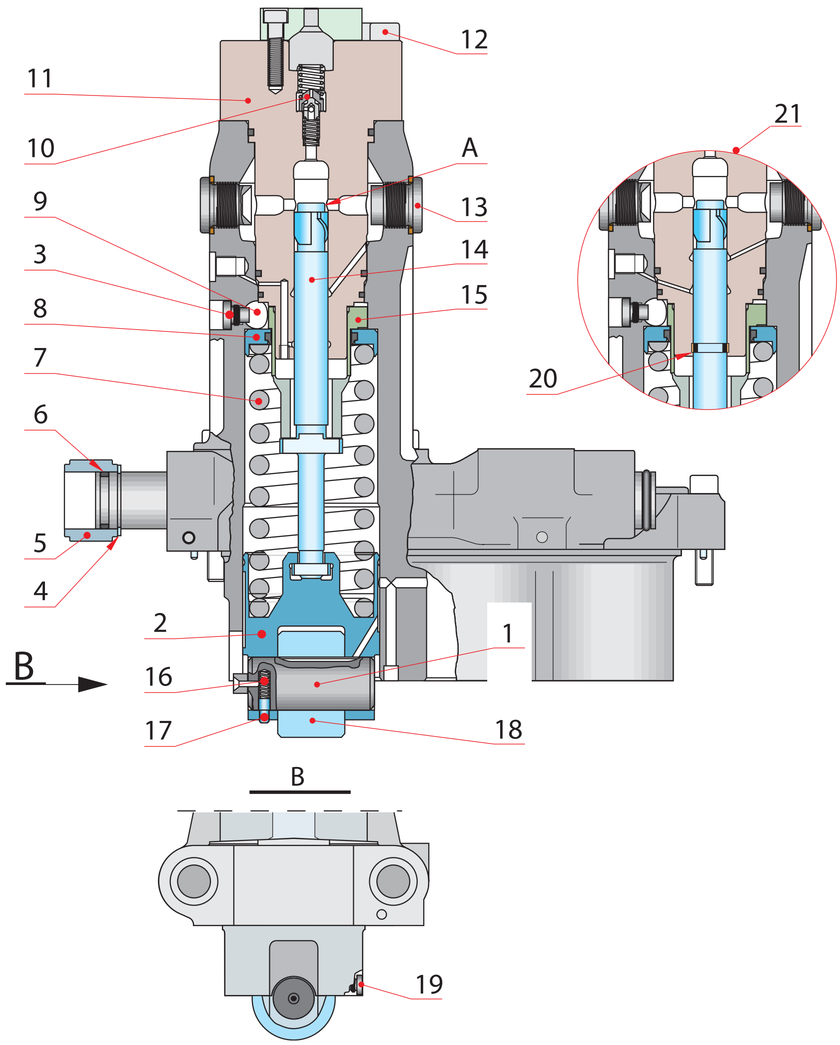
9 **Connect the fuel rack to the control shaft.** Assemble the control shaft if removed.

10 **Rotate the control shaft and check that all pumps follow the shaft movement.** Check the fuel rack position of all pumps, see Chapter 22.

11 **Open fuel supply to the engine.** Vent the fuel system according to the instructions in Chapter 17. The injection pump is provided with a venting plug.

12 Mount the covers.

Injection pump



1. *Tappet pin.* 2. *Tappet.* 3. *Plug.* 4. *Retaining ring.* 5. *Sleeve.* 6. *O-ring.* 7. *Spring.* 8. *Spring plate.* 9. *Fuel rack.* 10. *Fuel delivery valve/Constant pressure valve.* 11. *Pump element.* 12. *Screw.* 13. *Erosion plug.* 14. *Plunger.* 15. *Control sleeve.* 16. *Spring.* 17. *Pin.* 18. *Tappet roller.* 19. *Guide screw.* 20. *Seal ring/O-ring.* 21. *Alternative Design.*

Fig 16-1 201668 V2

16.2.3. Removal of injection pump element V10

Most maintenance operations can be done without removing the multihousing from the engine. We recommend that the engine is run with light fuel for 5 minutes before overhauling the injection pump. During maintenance utmost cleanliness must be observed.

1. Shut off fuel supply to the engine and stop the prelubricating pump. Open the covers.
2. Remove the injection, fuel leak and lube oil pipes where necessary. Disconnect the fuel rack.
3. Cover immediately all openings with tape or plugs to prevent dirt from entering the system.
4. Turn the crankshaft so that the injection pump tappet is in the bottom position and the roller resting on the base circle of the cam.
5. Loosen the flange screws until they are free from the threads.
6. Mount the extracting tool 846022 so that the tool flange is against the screw heads. Tighten the nut until the element is held by the tool.
7. Lift the pump element.
8. Remove the extracting tool.
9. Remove the plug and remove the fuel rack.
10. Remove the plunger by turning it about 90° using the tool 846023.
11. Cover the opening in the multihousing immediately with clean cloth.

Note!

The delivery valve must only be serviced by authorized personnel.

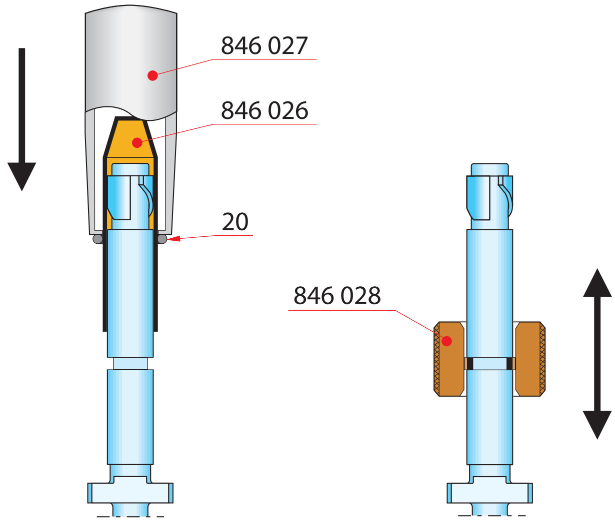
16.2.4. Changing of plunger sealing rings

V9

Note!
The sealing rings must always be renewed if they are removed from the groove on the plunger.

1. Remove the old rings, by cutting them off without damaging the plunger surface.
2. Place the protecting sleeve (846026) on top of the plunger to cover the sharp edges of the helix.
3. Lightly lubricate the protecting sleeve, O-ring, sealing ring and the plunger with light fuel oil.

Sealing ring assembly and calibration of rings



846026. Protecting sleeve 846027. Application rod 846028. Calibrating sleeve 20. O-ring / Seal ring

Fig 16-2 201669 V2

4 **Push the O-ring with the application rod (846027) over the protecting sleeve, down along the plunger and place it by hand in the groove.**

5 **Push the sealing ring with the application rod over the protecting sleeve, down along the plunger and place it by hand in the groove.**

6 **Remove the protecting sleeve.** Use the test sleeve (846028) to check that the seals are correctly fitted in the groove.

16.2.5. Mounting of injection pump element V9

1 **Check and clean the element.**

2 **Fit new O-rings and lubricate.**

3 **Clean the housing.** Pay special attention to the O-ring sealing surfaces.

4 **Insert the plunger.** Control sleeve with the tool 846023.

5 **Check that the control sleeve is in correct position.** Mount the fuel rack and plug . Check that the fuel rack moves freely.

6 **Assemble the element into the housing.** Be careful when connecting the plunger into the element.

7 **Tighten the fastening screws diagonally in steps to the stated torque.** See, Chapter 07: Tightening torques and use of hydraulic tools.

8 **Check that the fuel rack moves freely.**

9 **Rotate the control shaft.** Check that all pumps follow the shaft movement and check the fuel rack positions of all pumps, see Chapter 22: Control mechanism.

10 **Remove the protecting tapes or plugs.** Connect the pipes and the injection pipe. Tighten the nuts to torque.

11 **Open the fuel supply to the engine.** Vent the fuel system according to the instructions in Chapter 17: Fuel system.

16.2.6. Control of fuel injection timing

V10

For normal adjustment of injection timing the prelift can be measured mechanically by a special tool 869001.

Control of fuel injection timing is necessary only if major components have been changed, for example, the camshaft intermediate gear or one or more camshaft pieces.

1 **Remove the camshaft cover at the cylinder in question.**

2 **Turn the crankshaft until the pump tappet roller is on the basic circle of the camshaft.** Approximately 20° before the ignition TDC.

3 **Mount the checking tool 869001 and adjust the dial indicator tool 848041 to zero.**

4 **Turn the flywheel in the rotating direction until the tappet rises 7 mm.**

5 **Read the flywheel position.** If the position is according to test records, go to step 13.

6 **Remove the camshaft end cover.** Install the hydraulic tool 861169 on the screw, see Chapter 13: Basic adjustment of valve timing.

7 **Loosen the nut by using correct hydraulic pressure.** See, Chapter 07: Hydraulically tightened connections and release the pressure.

8 **Turn the flywheel to the correct position.**

9 **Tighten the screw connection.**

10 **Turn the crankshaft until the pump tappet is on the basic circle.**

11 **Adjust the gauge to zero.**

12 **Turn the flywheel in the rotating direction until the tappet lifts up to 7 mm.** Check the position of the flywheel.

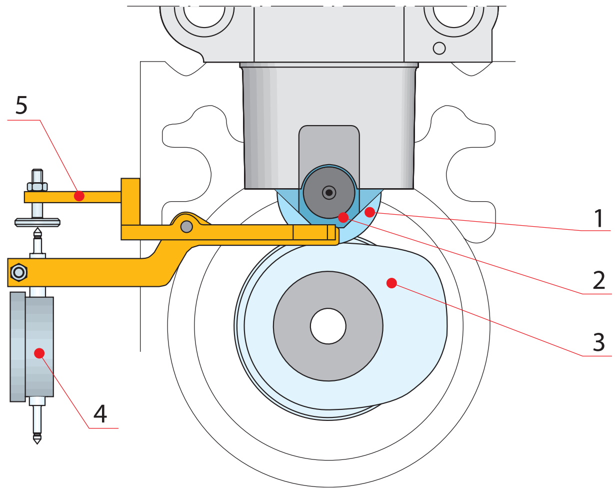
13 **Unmount the checking tool.**

14 **Reassemble the cover of the intermediate gears.**

15 **Reassemble the camshaft cover.**

Note!
Changing of the camshaft gear position will affect all cylinders.

Checking of injection timing



1. *Tappet roller* 2. *Tappet* 3. *Camshaft* 4. *Dial indicator* 5. *Injection timing tool*

Fig 16-3 201663 V2

16.2.7. Injection pump overhaul V8

The multihousing should be removed from the engine and properly cleaned.

Note!
The element cylinder, plunger and delivery valve assembly are matched and they must be kept together during the overhaul.

1. **It is recommended that the pump is firmly held in a vice while it is being dismantled.**
2. **Remove the injection pump element.** See, Chapter 16: Removal of injection pump element.
3. **Renew sealing rings on the injection pump plunger.** See, Chapter 16: Changing of plunger sealing rings.
4. **Turn the pump up side down.**
5. **Support the roller tappet with the tool 846016 and unscrew the guiding screw.** See,Fig 16-1.
6. **Release the spring tension and remove the tool.**

7 **The roller tappet and the spring can now be removed.**

8 **Remove the spring plate and control sleeve.**

9 **Depress the roller pin locking pin and withdraw the roller pin.** Cover the locking pin as it is under spring loaded.

10 **As the valve tappet is also fitted into the multihousing, we recommend that it is checked at the same time.**

11 **Wash the components in absolutely clean diesel oil and lubricate the internal parts with engine oil.** Pay special attention to the grooves and bores for leak fuel and lubricating oil. Clean protective latex gloves should be worn when handling components.

12 **Normally, further dismantling is not necessary.** Ensure that the components from different pumps are not mixed together, where appropriate apply identifying marks. The components must be protected against rust, and in particular, avoid touching the plunger running surfaces with bare fingers.

13 **Lubricate the roller and roller pin before assembling them.**

14 **Renew the sealing ring.** Insert the control sleeve and the spring plate into the housing.

15 **Lubricate the tappet roller.** Assemble it into the housing together with the spring.

16 **Support the tappet roller with the tool 846016 by keeping the slot for guiding screw in the correct position.**

17 **Depress the tappet roller until the slot is aligned with the hole.**

18 **Screw in and tighten the guiding screw to stated torque.** See, Chapter 07: Tightening Torques and Instructions for Screw Connections.

19 **Turn the pump and assemble the injection pump element.** See, Chapter 16: Mounting of injection pump element.

20 **Unless the pump is immediately mounted on the engine, it must be well oiled and protected by a plastic cover or similar.** The fuel ports and injection line connection must always be protected by plugs or tape.

16.3. Injection line

V8

The injection line consists of two parts, the connection piece, which is screwed sideways into the nozzle holder, and the injection pipe.

The connection piece seals with plain metallic surfaces which are to be checked before mounting. Always tighten the connection piece to correct torque before mounting the injection pipe; even if only the injection pipe has been removed, because the connection piece may have been inadvertently loosened when the pipe was unscrewed.

The injection pipe is covered by a shield to protect the engine environment from fuel leaks. The injection pipes are delivered complete with connection nuts assembled. When assembling the high pressure pipe, the connection piece should be held with a tool.Always tighten the connections to the correct torque.

Protect dismantled injection line components against dirt and rust.

16.3.1. Checking the tightening of injection pipe connections

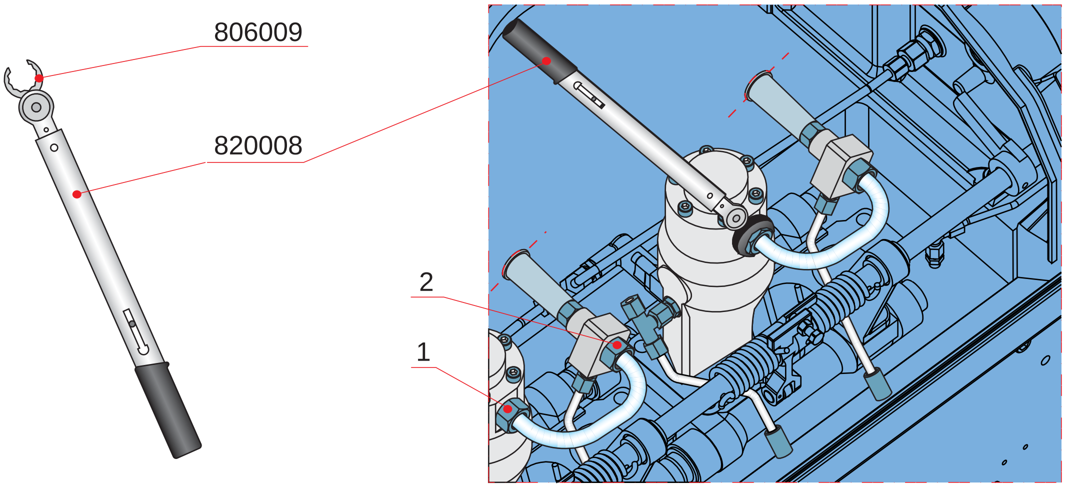
V3

When a new or overhauled engine has been running for 50 hours and while the engine is hot, re-check the tightness of the fuel pipe connections.

Warning!
Fuel that leaks, spills or sprays onto hot surfaces can cause fires.

Warning!
A high pressure fuel oil spray from any broken or leaking injection pipe may cause serious injuries.

Tightening of injection pipe connections



1./2. *Injection pipe cap nut,* 806009. *Crowfoot wrench,* 820008. *Torque wrench.*

Fig 16-4 V1

1. **Open and remove the Hot Box covers.**
2. **Tighten the cap nuts of injection pipe to specified torque.** Use the crowfoot wrench (806009) with a torque wrench (820008) and check the tightening of injection pipe cap nuts.
3. **Repeat the above procedure with the remaining injection pipes.**
4. **Mount the Hot Box covers after checking the tightening of all injection pipes.**
5. **Check for leaks after starting the engine.**

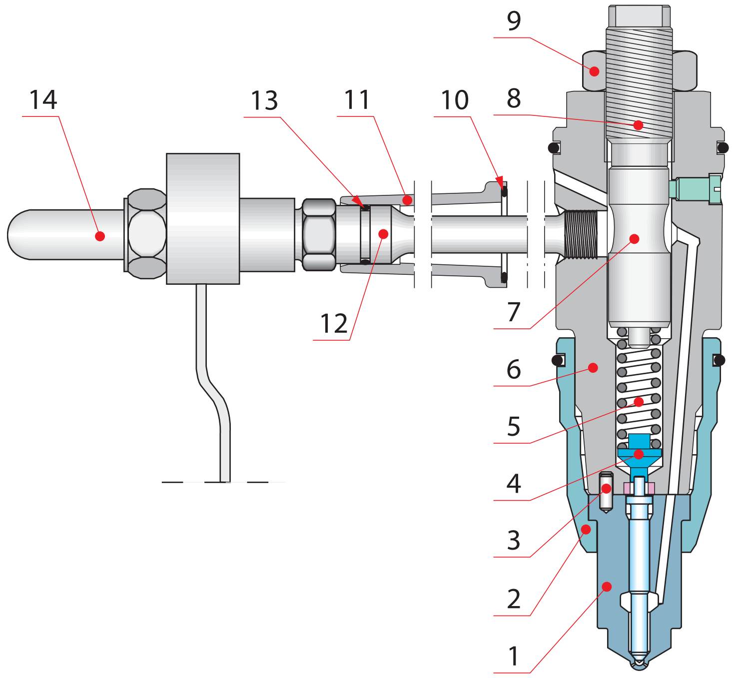
16.4. Injection valve V8

Data and dimension
Orifices: 8 pcs
Orifice dia.: 0.38 mm
Angle: 148°
Opening press: 450 bar

The injection valve is centrally located in the cylinder head and includes the nozzle holder (6) and the nozzle (1), seeFig 16-5. The fuel enters the nozzle holder from the side through a connection piece screwed 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. The pressure at which the nozzle operates can be corrected by turning the adjusting screw (8) in the injection valve.

Injection valve



1. Nozzle, 2. Nozzle nut, 3. Dowel pin, 4. Push rod, 5. Spring, 6. Injection valve housing, 7. Thrust bolt, 8. Adjusting screw, 9. Nut, 10. O-ring, 11. Protecting sleeve, 12. Connection piece, 13. O-ring, 14. Injection pipe

Fig 16-5 201665 V1

16.4.1. Removing of injection valve

V12

1 Remove the cylinder head cover.

2 Remove the injection pipe.

3 Remove the rocker arms.

4 Unscrew the connection piece and loosen the protecting sleeve if necessary.

5 Remove the fastening nuts of the injection valve.

6 Lift out the injection valve by using tool 846024.

7 Protect the fuel inlet hole of the injection valve and the bore in the cylinder head.

16.4.2. Overhauling of injection valve

V13

1 **Inspect the nozzle immediately after removing the injection valve from the engine.** Carbon deposits (trumpets) may indicate that the nozzle is in poor condition, or the spring is broken. Clean outside of the nozzle with a brass wire brush. Don't use steel wire brush.

2 **Check the function and condition of the nozzle, that is, the opening pressure and seat tightness.** It is recommended to use a pneumatic fuel valve test pump (864012) in order to judge spray characteristics with realistic pumping rates. It is recommended to use an oil mist separator (864018) with the test device to avoid unnecessary health hazards. Optionally a hand pump tester (864012) with an accumulator device can be used for checking the nozzle function and condition.

Note!
The detailed instructions of using the pneumatic fuel valve test pump (864012) are delivered with the pump.

Caution!
Use the injector testing device only in a well ventilated place, preferably with a suction line close to the test device.

3 **Put the holder tool for injection valve (846030) in a screw vice.** Insert the injection valve into the tool with nozzle downwards.

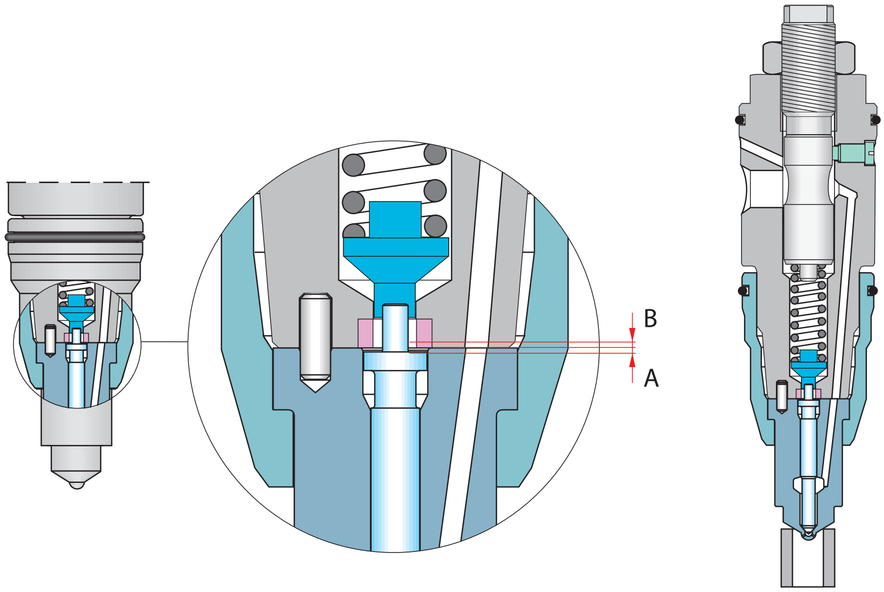
4 **Remove the nozzle from the holder by turning the injection valve housing counter-clockwise until the cap nut is loosen.** Keep the nozzle together with the holder body, don't let it follow up with the nut. If there is coke between the nozzle and the nut, the dowel pins may break and damage the nozzle. To avoid this, knock on the nozzle, using a piece of pipe to keep it towards the holder. Never knock directly on the nozzle tip. Be careful not to drop the nozzle.

5 **Check the nozzle needle movement which may vary as follows:**

- needle completely free
- needle free to move within the normal lifting range
- needle is sticking

The needle must not be removed by force because this often results in complete jamming. Unless it can be easily removed, immerse the nozzle in lubricating oil and heat oil to 150 - 200°C. Normally, the needle can be removed from a hot nozzle.

Maximum needle lift of nozzle, removing of nozzle from holder



A.*Nozzle needle lift*,B.*Accepted wear for the sealing face of nozzle holder*

Fig 16-6 201666 V1

6 **Clean the components.** If possible, use a chemical carbon dissolving solution. If there is no such available, immerse the details in clean fuel oil, white spirit or similar to soak carbon. Then clean the components carefully by tools included in the tool set. Do not use steel wire brushes or hard tools. Clean the nozzle orifices with needles provided for this purpose. After cleaning, rinse the details to remove carbon residues and dirt particles. Before inserting the needle in the nozzle body, immerse the components in clean fuel oil or special oil for injection systems. Seat surfaces, sliding surfaces (needle shaft) and sealing faces against the nozzle holder should be carefully checked.

7 **Clean the nozzle holder and the cap nut carefully.** If necessary, dismantle the nozzle holder to clean all details. Check the nozzle spring.

8 **Check the high pressure sealing faces of the nozzle holder.** That is, the contact face to nozzle and the bottom of the fuel inlet hole.

9 **Check maximum needle lift of nozzle, that is, sum of measures A and B.** If the wear B exceeds 0.10 mm, the nozzle holder can be sent to the engine manufacturer for reconditioning. If nozzle needle lift is out of the value stated in Chapter 06: Clearances and wear limits (at 20°C), the nozzle should be replaced by a new one

10 **Reassemble the injection valve.** Tighten the cap nut to the torque given in Chapter 07: Tightening torques for screws and nuts.

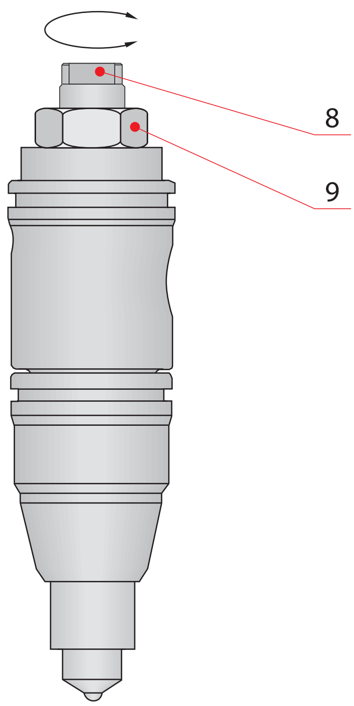
11 **Connect the injection valve to the test pump 864012 .** Use connection piece 167003 from the engine to connect injection valve to the test pump. Pump to expel air. Shut the manometer valve and pump rapidly to blow dirt out of the nozzle orifices. Place a dry paper under the nozzle and give the pump a quick blow. Note fuel spray uniformity.

Note!
Ensure hands are not in the path of the spray jets.

12 **Check the opening pressure:**

- open manometer valve,
- pump slowly and watch manometer to note the opening pressure.
- if the opening pressure is not rising to the stated pressure then adjust by turning the adjusting screw clockwise.

Adjusting of opening pressure



8.*Adjusting screw* 9.*Nut*

Fig 16-7 V1

13 **Place a dry paper under the nozzle and give the pump a quick blow.** Note fuel spray uniformity. If the spray is uniform, adjust the opening pressure to the stated value and check once more the spray uniformity.

14 **Check the needle seat tightness:**

- increase pressure to a value 20 bar below the stated opening pressure,
- keep pressure constant for 10 seconds and check that no fuel drops occur on the nozzle tip. A slight dampness may be acceptable.

15 **Check the needle spindle tightness:**

- pump until pressure is 20 bar below the stated opening pressure,
- measure time for a pressure drop of 50 bar. If the time is below 3 seconds, it indicates worn nozzle and it must be replaced by a new one. A time longer than 20 seconds indicates fouled needle, and the nozzle must be cleaned.

16 **If the tests according to step 10 to 14 give satisfactory results the injection valve can be re-installed in the engine.** Otherwise, replace the nozzle by a new one.

17 **If leakage occurs on the high pressure sealing surfaces, the damaged part should be replaced by a new one or reconditioned.**

18 **If nozzles or injection valves are to be stored, they should be treated with corrosion protecting oil.** The nozzle and fuel connection must be protected by plugs or tape.

16.4.3. Mounting of injection valve

V9

1 **Check that the bottom surface of the bore in the cylinder head is clean.** If necessary, clean or lap the surface by the tool 841020. If lapping is necessary, the cylinder head must be lifted off. For lapping, a steel washer and fine lapping compound is used. The injection valve seals directly to the bottom of the cylinder head bore.

2 **Put new O-rings on the injection valve.** Lubricate the injection valve with engine oil or vaseline.

3 **Fit the injection valve into the cylinder head bore but do not tighten the nuts.**

4 **If the protection piece has been removed, fit new O-rings onto both the protection piece and the connection piece .** Mount the protection piece onto the connection piece.

5 **Screw in the protecting sleeve on the connection piece if it has been removed.** Screw in the connection piece by hand. Tighten to correct torque. Tighten the protecting sleeve screws.

6 **Mount the injection pipe and tighten the cap nuts to torque.**

7 Before tightening the fastening nuts of the injection valve, let the valve to stay in the cylinder head bore for 30 minutes to allow the temperatures to equalize.

8 Finally tighten the nuts with using a torque wrench in the following steps:

a Both nuts to 20 Nm

b Both nuts to 30 Nm

c Both nuts to 40 Nm

d Both nuts to final torque 50±3 Nm

9 Mount the rocker arms.

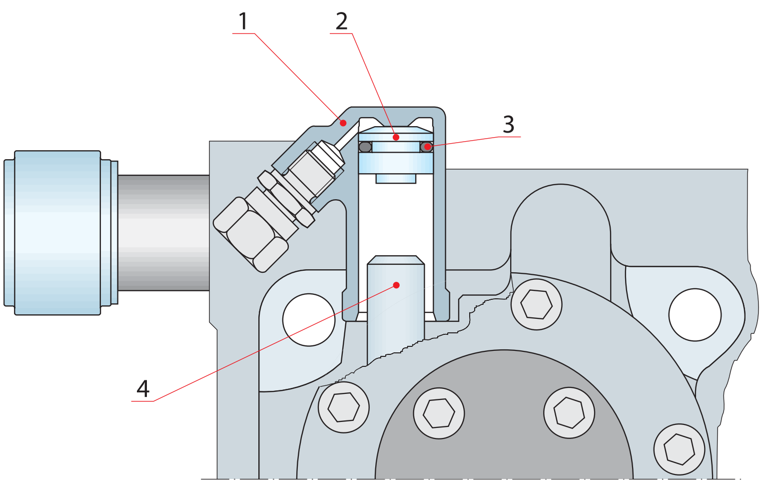
10 Mount the covers.

16.5. Pneumatic overspeed trip device

V9

The pneumatic overspeed trip device is mounted on the multihousing and acts directly on the fuel rack. If the overspeed trip device is activated, pressurised air acts on a piston in a cylinder mounted on 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 the pneumatic overspeed trip device, see section 22.4.

Pneumatic overspeed trip device



1. Cylinder, 2. Piston, 3. O-ring, 4. Fuel rack

Fig 16-8

201662 V1

17. Fuel System

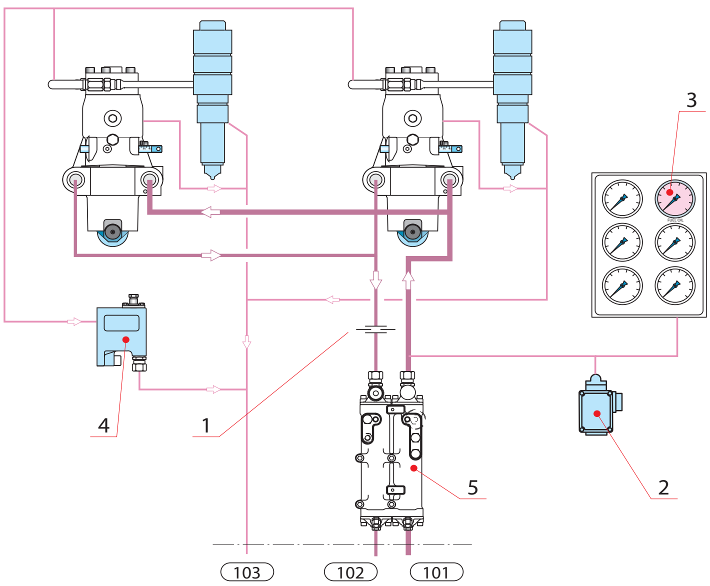
V6

The engine is designed for continuous heavy fuel duty. The main engine as well as the auxiliary engine can be started and stopped on heavy fuel provided that the fuel is heated to operating temperature and the jacket water preheated to described temperature.

As the fuel treatment system before the engine can vary widely from one installation to another, this system is not described in detail in this manual. See separate instructions. Normally a fuel feed pump delivers the correct flow to the engine through a filter. The correct pressure in the engine system is maintained with an adjustable throttle valve.

It is of great importance that the fuel treatment before the engine is done properly. The filtration of the fuel directly influences on the lifetime of the injection pumps and other components in the injection line and hence the performance of the engine.

Fuel system



1.*Adjustable orifice* 2.*Pressure switch* 3.*Pressure gauge* 4.*Alarm for broken injection pipe* 5.*Damper* 101.*Fuel inlet* 102.*Fuel return* 103.*Leak fuel drain, clean fuel.*

Fig 17-1 201752 V2

A pressure gauge (3) on the instrument panel indicates the fuel inlet pressure. A pressure switch (2) for low fuel pressure is connected to the automatic alarm system.

Fuel leaking from injection pumps and injection valves is collected in a separate enclosed system. Thus this fuel can be reused. A special module for automatic handling of this fuel back to the system can be delivered on request.

A separate pipe system leading from the top level of the engine block collects waste oil, fuel and water arising, for example, when overhauling cylinder heads.

The high pressure system, with injection pump and injection valve, is described in chapter 16.

17.1. Fuel oil safety filter

V2

During the first start up of the installation, a fuel oil safety filter (running-in filter) should be installed in the fuel system just before the engine. The purpose with this filter is to protect the fuel system during the first running hours. This filter should be used for max 50 h.

If the fuel system before the engine is opened later, it is recommended that this filter is used for a few hours again.

17.2. Fuel system maintenance

V6

When working with the fuel system, always observe utmost cleanliness. Pipes, tanks and the fuel treatment equipment, such as pumps, filters, heaters and viscosimeters, included in the engine delivery should be carefully cleaned before use.

The fuel should always be separated. It is recommended to fit an automatic filter in the fuel treatment system.

Always vent the system after reassembly, see section 17.3.

For maintenance of the fuel treatment equipment not mounted on the engine, see separate instructions.

17.3. Venting the system

V6

Open the air vent screws on the injection pumps. Start the fuel feed pump if the static pressure from the day tank is not sufficient.

Always vent the filters after changing cartridges in the filter.

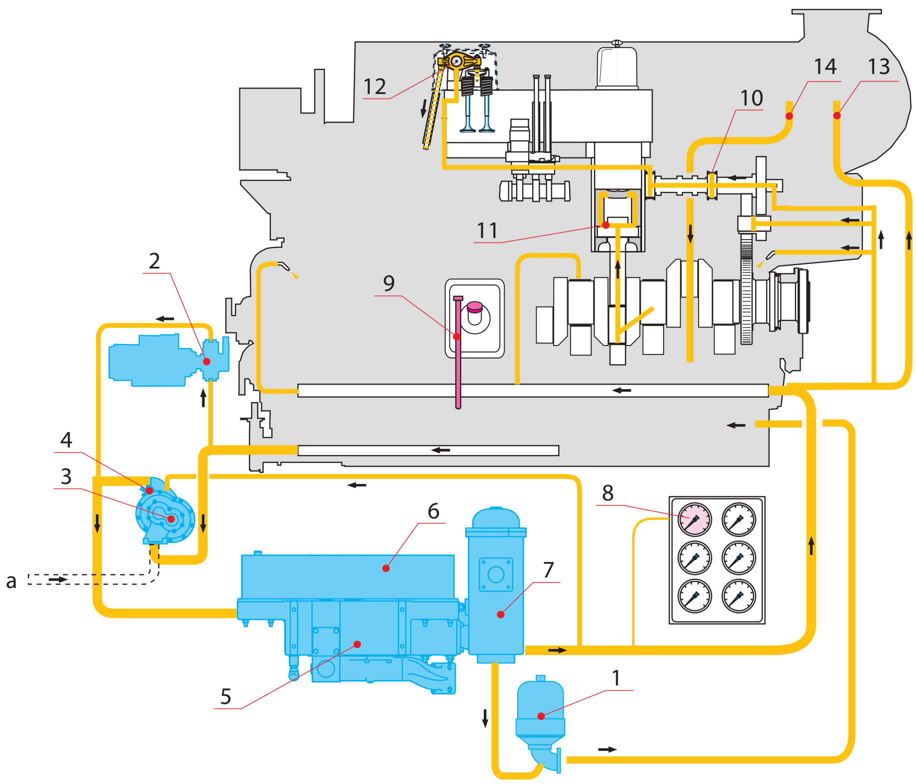
18. Lubricating Oil System

V9

Normally, a wet sump system is used, but also dry sump systems can be used.

The engine is provided with a lubricating oil pump (3) directly driven by the pump gear at the free end of the crankshaft. It is possible to connect an electrically driven stand-by pump in parallel if needed. The pump sucks oil from the engine oil sump and forces it through the lubricating oil cooler (6) equipped with a thermostat valve (5) regulating the oil temperature, through the lubricating oil main filter (7) to the main distributing channel in the engine block, and via side screw bores to the main bearings.

Lube oil system



1. Centrifugal filter, 2. Prelubricating oil pump, 3. Lube oil pump, 4. Pressure regulating valve, 5. Thermostatic valve, 6. Lube oil cooler, 7. Lube oil filter, 8. Pressure gauge, 9. Oil dipstick, 10. Camshaft bearings, 11. Gudgeon pins, 12. Rocker arm bearings, 13. Lube oil pipe to T/C, 14. Lube oil pipe from T/C, a. If dry sump.

Fig 18-1

201863 V1

Part of the oil flows through the bores in the crankshaft to the big end bearings and further through the connecting rod to the gudgeon pins (11), piston skirt lubricating and piston cooling spaces. Oil is led through separate pipes to other lubricating points, like camshaft bearings (10), fuel pump and valve tappets and valves, rocker arm bearings (12) and valve mechanism gear wheel bearings, and to oil nozzles for lubricating and cooling.

The electrically driven prelubricating pump is a gear type pump equipped with an overflow valve. The pump is connected in parallel to the engine driven lubricating oil pump.

The pump is used for:

- filling of the diesel engine lubricating oil system before starting, e.g. when the engine has been out of operation for a long time,
- continuous prelubrication of a stopped diesel engine through which fuel oil is circulating,
- continuous prelubrication of stopped diesel engine(s) in a multi-engine installation always when one of the engines is running.

The pressure in the distributing pipe is regulated by a pressure control valve (4) on the pump. The pressure can be adjusted by means of a set screw on the control valve. It is very important to keep the correct pressure in order to provide efficient lubrication of bearings and cooling of pistons. Normally, the pressure stays constant after having been adjusted to the correct value.

The pressure can rise above the nominal value when starting with cold oil but will return to the normal value when the oil is heated. A pressure gauge (8) on the instrument panel indicates the lubricating oil pressure before the engine (in the engine distributing pipe). The system includes three pressure switches for low lubricating oil pressure, two connected to the automatic alarm system and one for lower pressure to the automatic stop system (see chapter chapter 23, section 23.1).

The temperature can be checked from thermometers before and after the oil cooler (chapter 01., section 01.2). A temperature switch for high lubricating oil temperature is connected to the automatic alarm system (see chapter chapter 23, section 23.1).

The speed governor has its own oil systems, see separate instruction books.

The oil filling opening and oil dipstick (9) is located at the middle of the engine.

Connections for a separator are provided on the oil sump at the free end of the engine.

18.1. Maintenance of oil system

V4

Use only high quality oils approved by the engine manufacturer according to chapter 02, 02B.1.

Always maintain 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 maximum mark and never allow the level to go below the minimum mark. The limits apply to the oil level in a running engine. Add maximum 10% new oil at a time (see chapter 02, 02B.1). One side of the dipstick is graduated in centimeters. This scale can be used when checking the lubricating oil consumption.

Change oil regularly at intervals determined in maintenance schedule from the installation concerned, see chapter 04 and 02, section 02.2.2. While the oil is still warm, drain the oil system, as well as the oil cooler and filter. Clean the crankcase and the oil sump with proper rags (not cotton waste). Clean the main filter and the centrifugal filter.

Centrifuging of the oil is recommended, especially when using heavy fuels, see chapter 02, section 02.2.2.

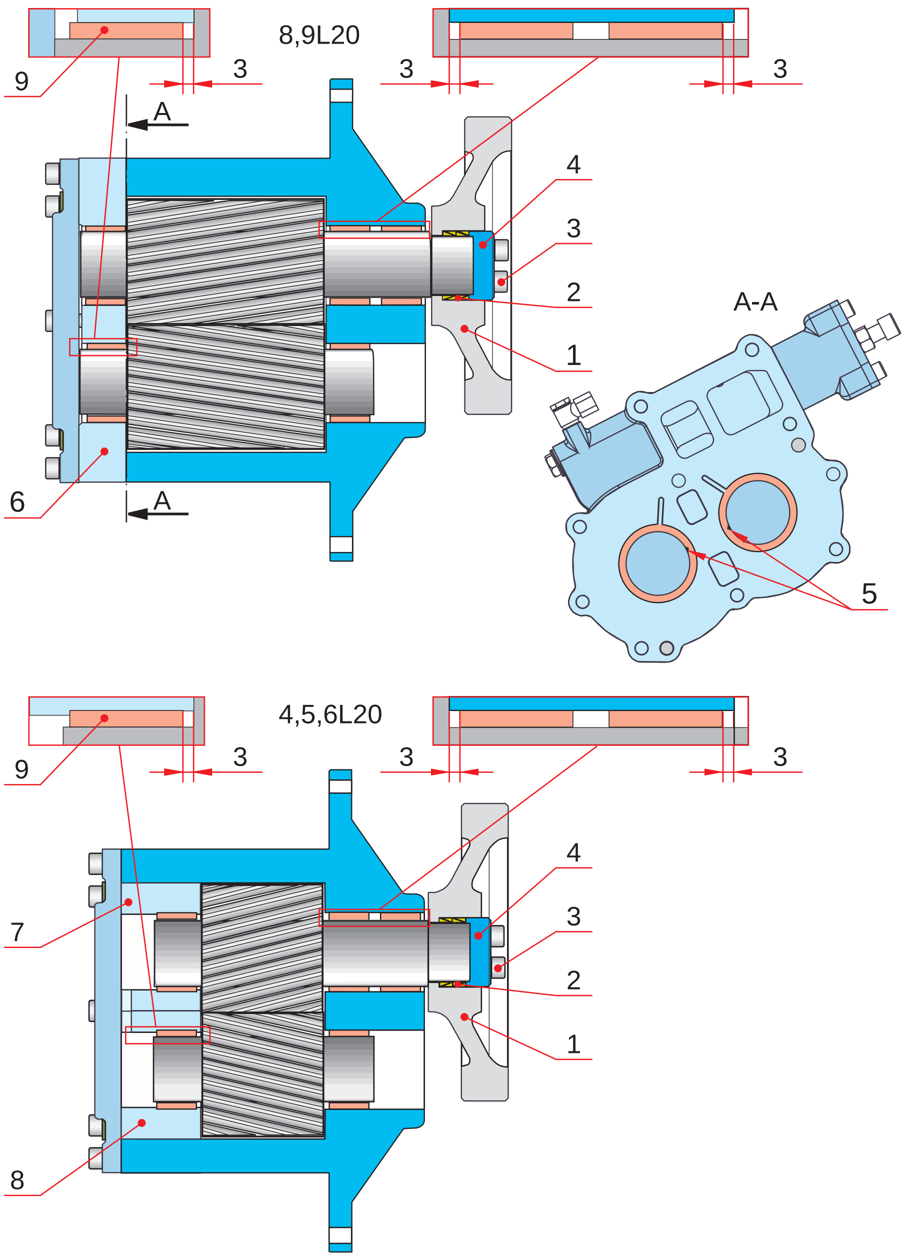
Caution!
Utmost cleanliness should be observed when treating the lubricating oil system. Dirt, metal particles and similar may cause serious bearing damage. When dismantling pipes or details from the system, cover all openings with blank gaskets, tape or clean rags. When storing and transporting oil, take care to prevent dirt and foreign matters from entering the oil. When refilling oil, use a screen.

18.2. Lubricating oil pump

V6

Lubricating oil pump is a gear type pump. The pump housing has an integrated pressure regulating/safety valve. Five identical sleeve bearings are used. External lubrication is not required. The cover is sealed with a glue compound.

Lube oil pump



1. *Drive gear* 2. *Frictional rings* 3. *Screw* 4. *Pressure plate* 5. *Bearings lubrication grooves* 6. *Spacer* 7. *Sleeve* 8. *Sleeve* 9. *Bearing bush.*

Fig 18-2 201864 V2

18.2.1. Removing of lubricating oil pump

V5

1 Drain the oil sump.

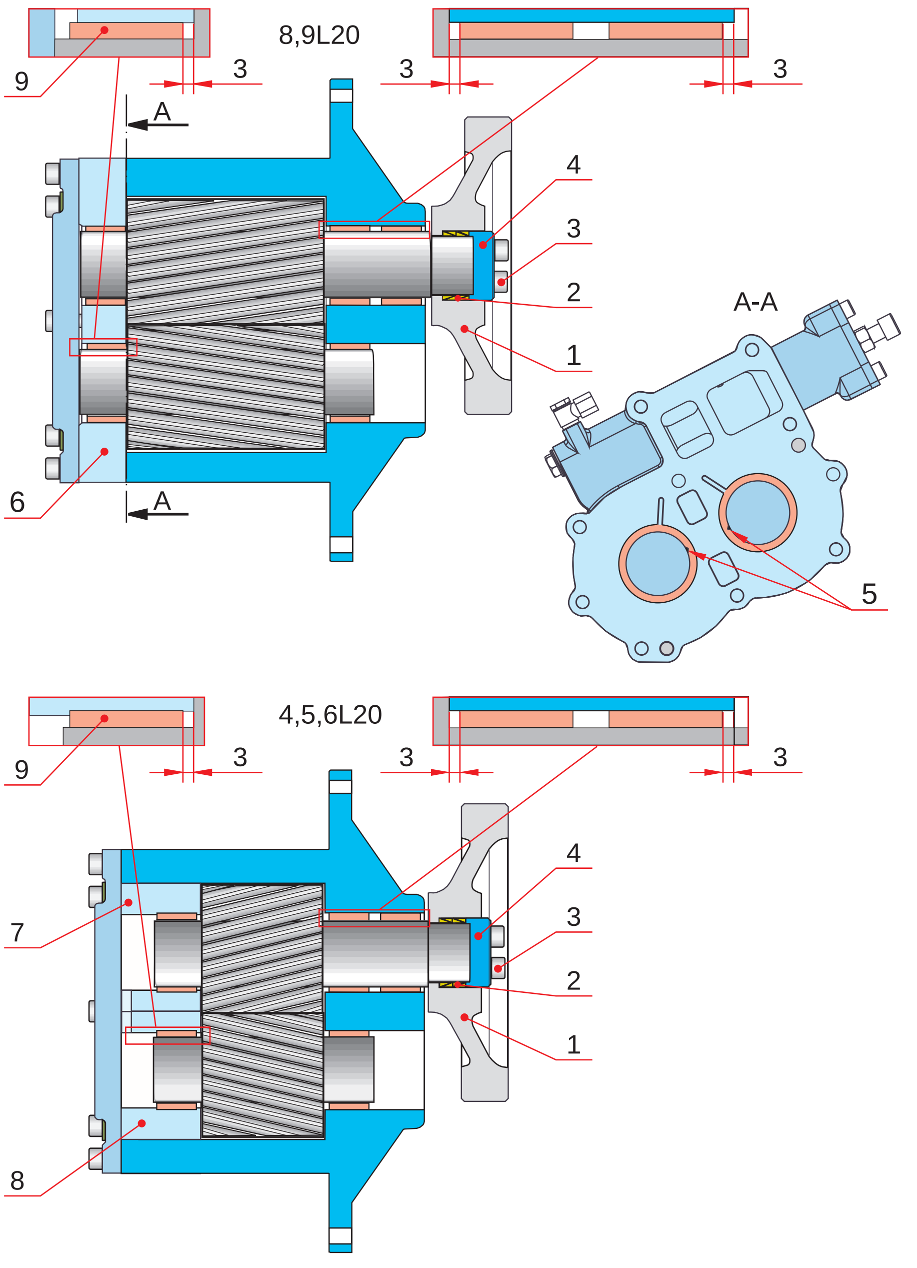
2 Remove the suction pipe connection between the oil sump and the lubricating oil pump.

3 Remove the oil pump connection and fastening screws of the lubricating pump.

4 Remove the lubricating oil pump using extraction screws.

5 Protect connections with suitable plugs, clean plastic or similar material.

Lube oil pump



1. *Drive gear* 2. *Frictional rings* 3. *Screw* 4. *Pressure plate* 5. *Bearings lubrication grooves* 6. *Spacer* 7. *Sleeve* 8. *Sleeve* 9. *Bearing bush.*

Fig 18-3

201864 V2

18.2.2. Dismantling of lubricating oil pump

V5

1. **Remove and inspect the regulating valve.** See, chapter 18: Lubricating oil pressure, regulating valve and safety valve.
2. **Remove the pressure plate (4) by loosening the fastening screws (3).**
3. **Pull out the gear wheel (1) without using any tool.** If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The friction ring elements come loose together with the gear wheel).

Warning!
Using an extractor may damage the shaft (axial scratches).

18.2.3. Inspecting the lubricating oil pump

V5

1. **Check all parts for wear and replace worn parts.** See, chapter 06: Clearances and wear limits at 20°C.
2. **Remove worn bearings with a suitable mandrel from the cover by machining.**
3. **Mount new bearings (freezing is recommended) so that the bearings are 3 mm below the sleeve and housing level.** Ensure that the bearing lubrication grooves (5) slide into the right position. See, Fig 18-3.
4. **Check the bearing diameter after mounting.** Check the gear wheel axial clearance, See chapter 06: Clearances and wear limits (at 20°C).

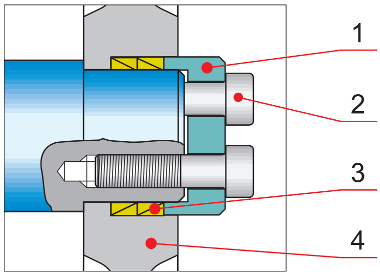
18.2.4. Assembling the lubricating oil pump

V6

1. **Clean all the details carefully before assembling.**
2. **Clean and oil all the contact surfaces before installing the gear wheel.**
3. **Reinstall the friction ring elements (3).**

Note!
Reinstall the friction ring elements exactly as shown in below figure. The friction ring elements should fall easily in place and must not jam.

Mounting the gear wheel



1. *Pressure plate* 2. *Screw* 3. *Frictional rings* 4. *Drive gear.*

Fig 18-4 201855 V3

4 Reinstall the pressure plate.

5 Tighten the screws a little and check that the gear wheel is in the right position.

6 Tighten the screws to torque. See,chapter 07.

7 If the gear wheel (4) has been changed, check the backlash after removing the cover.

8 Mount the pump covers.

Note!
After applying the sealant to the housing, the sleeves (7,8), see Fig 18-3 must be pressed along with the cover for the last 5 mm of assembly.

9 Mount the pipes.

18.2.5. Mounting of lubricating oil pump V3

1 Clean all sealing surfaces carefully and apply sealing compound to the sealing faces.

2 Mount the lubricating oil pump.

3 Mount the suction pipe connection between the oil sump and the lubricating oil pump.

4 Mount the oil pump connection.

5 Tighten all fastening screws to stated torque, see chapter 07.

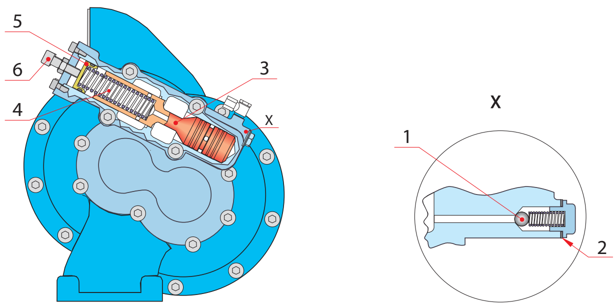
6 Connect all necessary pipe connections.

18.3. Lubricating oil pressure regulating valve and safety valve

V4

The pressure regulating valve, is integrated in the lubricating oil pump house and regulates the oil pressure before the engine by returning the surplus oil direct from the pressure side of the pump to the crank-case.

Pressure regulating valve



1.*Ball for safety valve,*2.*Sealing ring,*3.*Regulating piston,*4. *Spring,*5.*Spring holder,* 6. *Adjusting screw*

Fig 18-5 201876 V2

A pipe is connected to the engine distributing channel, where the pressure is kept constant if the engine is running at constant speed. This pressure actuates the regulating piston (3) and the spring (4) is tensioned to balance this force at the required pressure. Thus the pressure is kept constant in the distributing channel, irrespective of the pressure in the pressure side of the pump and of the pressure drop in the system. By tensioning the spring a higher oil pressure is obtained (if too low).

If, for some reason, the pressure should increase strongly in the pressure pipe, e.g. due to clogged system, the ball (1) will open and admit oil to pass to the regulating piston (3). This serves as a safety valve.

18.3.1. Maintenance of the valves

V5

1 **Dismantle all moving parts.** Check them for wear and replace worn or damaged parts by new ones.

2 **Clean the valve carefully.**

3 **Check that no details are jamming** while reassembling and with the oil pump cover mounted to the pump housing.

18.3.2. Adjusting of the lubricating oil pressure

V4

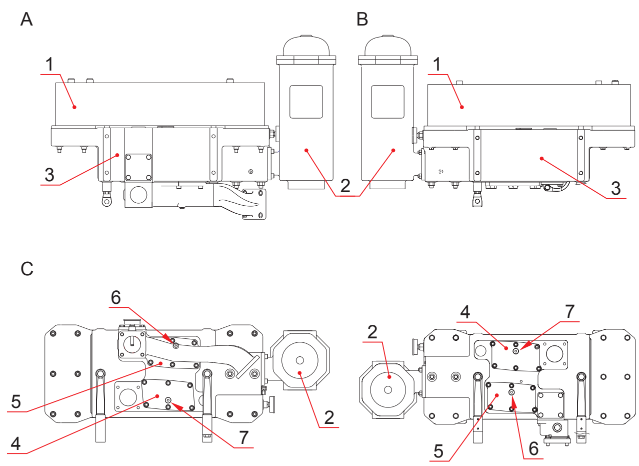
1. **Loosen the counter nut** on the adjusting screw.
2. **Slowly turn the adjustment screw (6)** until the pressure reaches the value mentioned in chapter 01, section 01.1., (can be seen from the engine's local pressure gauge).
3. **Tighten the counter nut.**
4. **Check the pressure.**

18.4. Lubricating oil cooler

V5

The cooler is of the brazed plate type. The plate cooler consists of a number of heat transfer plates brazed together into one unit with no seals.

Lube oil cooler



1.Plate heat exchanger, 2.Automatic filter, 3.Oil module, 4.Cover for LT-water therm. valve, 5.Cover for lube oil therm. valve, 6.Drain plug for oil, 7.Drain plug for LT-water.

A. TC at the driving end, B. TC at the free end, C. Viewed from underside.

Fig 18-6 201873 V2

18.4.1. Maintenance of lubricating oil cooler

V5

1. **Clean and test the cooler by hydraulic pressure.** Follow the intervals given in chapter 04. Cleaning is also needed if the lubricating oil temperature tends to rise abnormally.
2. **Clean the water side by removing the cooler from the engine.**
3. **Always when cleaning, check for corrosion and test by hydraulic pressure.**

Caution!
If water leakage to the lubricating oil is suspected, the heat exchanger must be pressure tested and/or changed.

18.4.2. Disassembling and assembling of cooler

18.4.2.1. Disassembling of cooler

V6

1. **Open the drain valve.**
2. **Drain the oil module.**

Caution!
Be careful when removing the plate heat exchanger! Despite the draining there will always be left a small amount of lube oil and water.

3. **Drain the water side as much as necessary.**
4. **Remove the heat shield and pipes, if necessary.**
5. **Loosen the plate heat exchanger fastening screws.**
6. **Remove the plate heat exchanger from the oil module.**

18.4.2.2. Assembling of cooler

V6

1. **Check cleanliness and scratches on all sealing surfaces.**
2. **Mount the O-rings on the oil module.** Always use new O-rings.
3. **Mount the plate heat exchanger on the oil module.**
4. **Tighten the plate heat exchanger fastening screws.**
5. **Reinstall the heat shield and pipes, if necessary.**

18.4.3. Cleaning of oil side

V4

Fouling of the oil side is normally insignificant. On the other hand, possible fouling will influence the cooler efficiency very strongly.

Due to the design, the heat exchanger cannot be cleaned mechanically from the inside. Slight fouling can be removed by blowing steam through the oil connection of the heat exchanger.

If the amount of dirt is considerable, use chemical cleaning solutions available on the market:

Alkaline degreasing agents:

Suitable for normal degreasing, however, not effective for heavy greases, sludge and oil coke. Requires high temperature. Always pour degreasing agent slowly into hot water, never the contrary. Rinse carefully with water after treatment.

Hydrocarbon solvents:

Include the whole range from light petroleum solutions to chlorinated hydrocarbons, e.g. thrichlorethylene. These products should be handled with care as they are often extremely volatile, toxic and/or narcotic.

Solvent emulsions:

Heavy fouling, e.g. oil coke, can often be dissolved only by using these solutions. Several brands are available on the market.

Note!
Follow the manufacturer's instructions to achieve the best results.

18.4.4. Cleaning of water side

V6

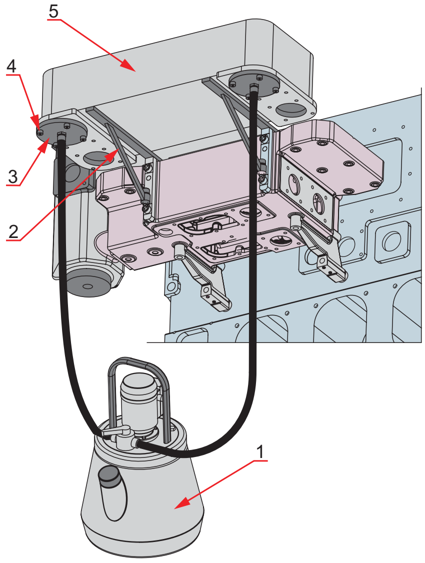
The cleaning should be carried out so that it does not damage the natural protective layer on the heat exchanger. A tool has been developed for this purpose, see Fig 18-7.

If the deposit in the plates is hard, e.g. calcium carbonate, it can be removed chemically by using commercial agents. After this treatment the heat exchanger should be rinsed and, if necessary, treated with a solution neutralising the residual washing agents. Otherwise, follow the manufacturer's instructions.

18.4.4.1. Cleaning the plate heat exchanger

V3

Cleaning method for plate heat exchanger, 845 005



1. *Circulating water pump (845 006)* 2. *Lifting bracket (845 007)* 3. *Joint flange (845 009)* 4. *Hexagon socket screw* 5. *Plate heat exchanger*

Fig 18-7

V1

1 Fit the lifting brackets.

2 Remove the screws that fasten the plate heat exchanger. Pull the plate heat exchanger onto the lifting brackets.

3 Connect the circulating water pump to the plate heat exchanger with the joint flanges.

4 Circulate cleaning fluid through the plate heat exchanger until it is clean.

5 After cleaning.

a) Circulate fresh oil through the plate heat exchanger.

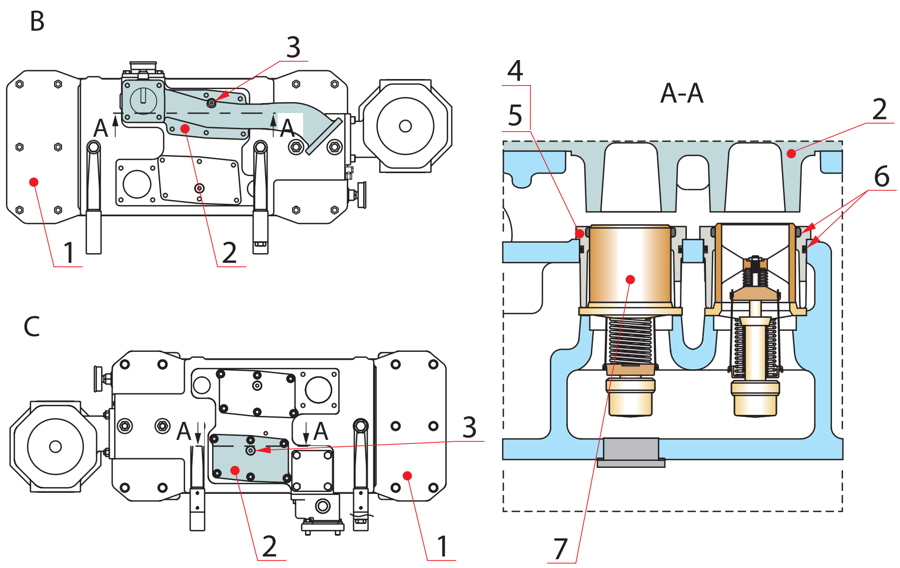
b) Test at a pressure of 8 bar and reassemble.

18.5. Thermostatic valve

V4

The oil system is provided with a fixed thermostatic valve fitted in the lube oil module.

Thermostatic valve for oil system



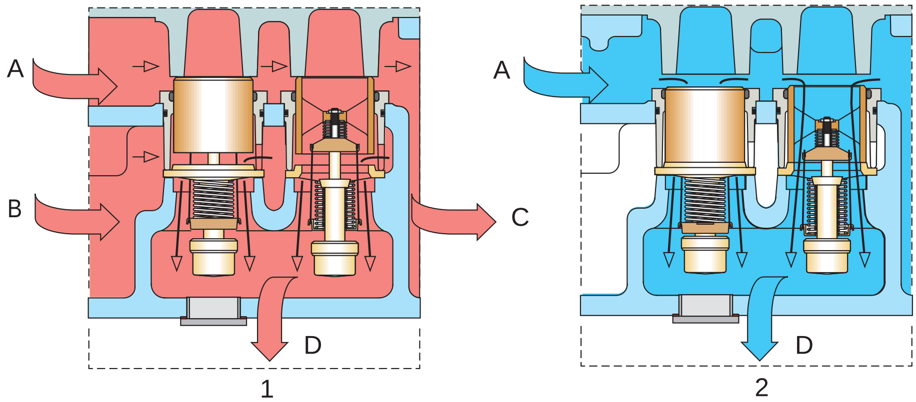
1.*Lubricating oil module*,2.*Cover*,3.*Drain plug*,4.*Screw (M6)*,5.*Holder*,6.*O-ring*, 7.*Element*

A-A.*Section*,B.*Viewed from underside TC at the driving end*,C.*Viewed from underside TC at the free end*

Fig 18-8 201874 V1

The Fig 18-9 shows the valve in a closed position (right). When the temperature exceeds the nominal value, the contents of the elements expands and forces the valve unit towards the seat, thus passing part of the oil through the cooler. This movement continues until the right temperature of the mixed oil is obtained. If the cooler becomes dirty, the temperature will rise a few degrees, which is quite normal, because the valve needs a certain temperature rise for a certain opening to increase the oil flow through the cooler.

Oil flow in temperature control valve



A. *From pump*, B. *From cooler*, C. *To cooler*, D. *To engine*

1. *Warm oil*, 2. *Cold oil*

Fig 18-9 201868 V1

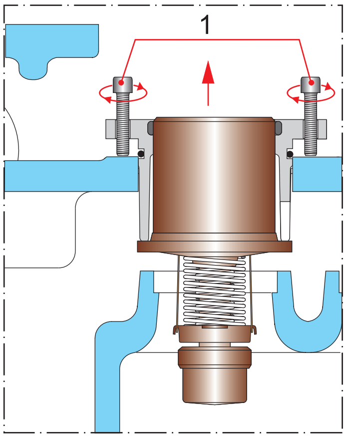
18.5.1. Maintaining the thermostatic valve V6

Normally, no service is required. A very low or very high oil temperature may depend on a defective thermostat. However, in the most of the cases, when the temperature is too high it depends on a dirty cooler.

1 **Drain the oil module.**

2 **Remove the cover (2), the holder of the element (5), and then the thermostatic element.** Use screws (M8) for extracting the holder of the element.

Extracting of the thermostatic element



1. *M8*>=25mm.*

Fig 18-10 201877 V4

3 **Check the element by heating it slowly in water.** Check at which temperatures the element starts opening and is fully open. The values can be found on the thermostatic element or in chapter 01, the lower value of the lube oil temperature is the opening temperature and the higher value is for the fully open valve.

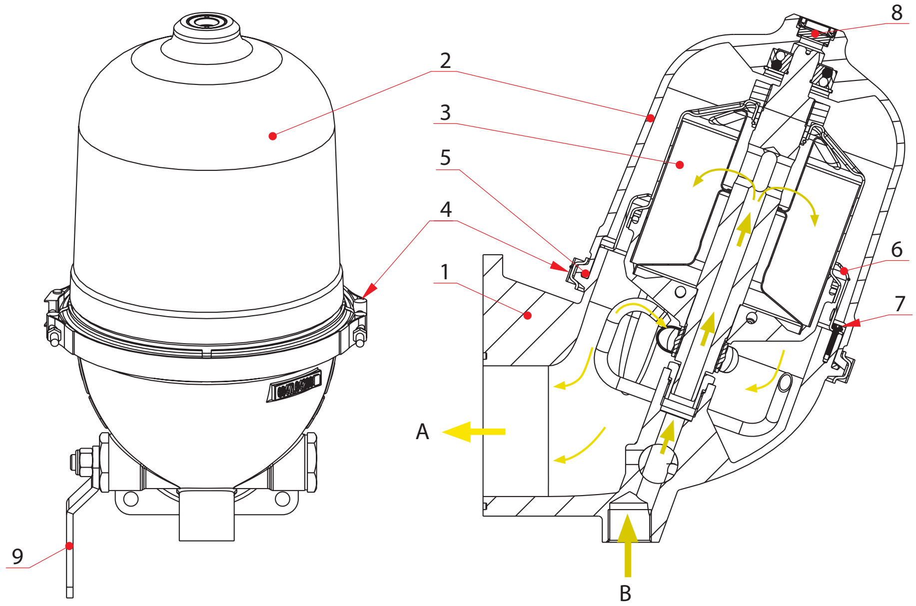
4 **Change the defective element.** Check O-rings and change, if necessary. Apply sealing compound to the sealing faces between the cover (2) and the oil module.

18.6. Centrifugal filter V5

A centrifugal filter is mounted in the flush oil line from the automatic filter. The purpose of the centrifugal filter is to remove the particles from the oil that has flushed the automatic filter.

The filter comprises a body (1) containing a cover (2) on which a dynamically balanced rotor assembly (3) is free to rotate. The rotor assembly rotates when oil from the jet pipe hits the rotor wheel.

Centrifugal filter



1.*Filter body assembly,*2.*Filter cover assembly,*3.*Rotor assembly,*4.*Band clamp,*5.*O-ring,*6.*Safety ring,*7.*Screw,*8.*Sight glass*9.*Isolating valve*

A. *Crankcase,* B.*Flushing oil inlet*

Fig 18-11 201883 V1

18.6.1. Cleaning the centrifugal filter V7

It is very important to clean the filter at regular intervals, see chapter 04, ensuring that the thickness of the dirt deposit inside the rotor does not exceed approximately 35 mm.

Note!
If it is found that the filter has collected the maximum quantity of dirt at the recommended cleaning intervals, it should be cleaned more frequently.

Clean the filter as follows, stop the flow of oil to the centrifuge by either stopping the engine or positioning the isolating valve on the side of the centrifuge to the "SERVICE" position. Ensure the centrifuge has come to a complete stop before proceeding, observe through sight glass window.

1 Slacken off filter cover band clamp (4), and remove it.

Warning!
Do not remove band clamp while centrifuge is running.

2 Lift off filter cover assembly (2).

a) Check top bearing for wear or damage.

b) Examine O-ring (5) for damage and renew, if necessary.

3 Slacken the screws retaining the safety ring and rotate anti-clockwise to remove.

4 Lift the rotor assembly and allow oil to drain from the rotor assembly, before removing it from the filter body.

a) Remove rotor assembly with care to ensure that the lower bearing, pelton wheel and drive tube assembly are not damaged.

5 Secure the rotor assembly and unscrew the rotor cover nut. This will separate the rotor cover from the rotor body.

6 Remove sludge from the inside of the rotor cover and body with a spatula or a suitable shaped piece of wood and wipe clean.

7 Clean the rotor components using a suitable cleaning fluid and discard the paper insert.

a) Ensure that all rotor components including the four nozzles located in the rotor body, are thoroughly cleaned with brass wire and free from debris.

8 Examine the rotor assembly O-ring for damage and renew if necessary.

9 Fit a new paper insert into the rotor body and locate the stand tube in the rotor body.

10 Reassemble the rotor by sliding the rotor cover over the paper insert in the rotor body. Tighten the rotor cover nut to a torque of 20 Nm.

11 Examine the lower journal bearing in the filter body for signs of damage or wear. Replace it, if necessary.

12 Re-assemble the rotor assembly into the filter body.

a) Ensure that the lower journal bearings, Pelton wheel and drive tube assembly are not damaged.

13 Replace the safety ring, (if necessary) and tighten the screws to secure the ring.

14 **Examine the centrifuge body O-ring and ball bearing in the filter cover for signs of wear or damage.** Renew, if necessary.

15 **Replace the filter cover assembly, (if necessary) ensuring the spigot on the top of the rotor engages smoothly in the ball bearing housed in the filter cover.** Slide the cover firmly down locating it on the flange of the filter body.

16 **Replace the band clamp, (if necessary) and tighten both bolts to a torque of 6-8 Nm.** Note the band clamp must be securely fitted during operation of the centrifuge.

17 **Reposition the isolating valve, on the side of the centrifuge, in the "ON" position.** Observe that the centrifuge rotor is turning through the sight glass in the filter cover. If the rotor is not turning ensure that the filter cover is seated on the filter body correctly, the ball bearing freely rotates and that the band clamp bolts are tightened to the correct torque.

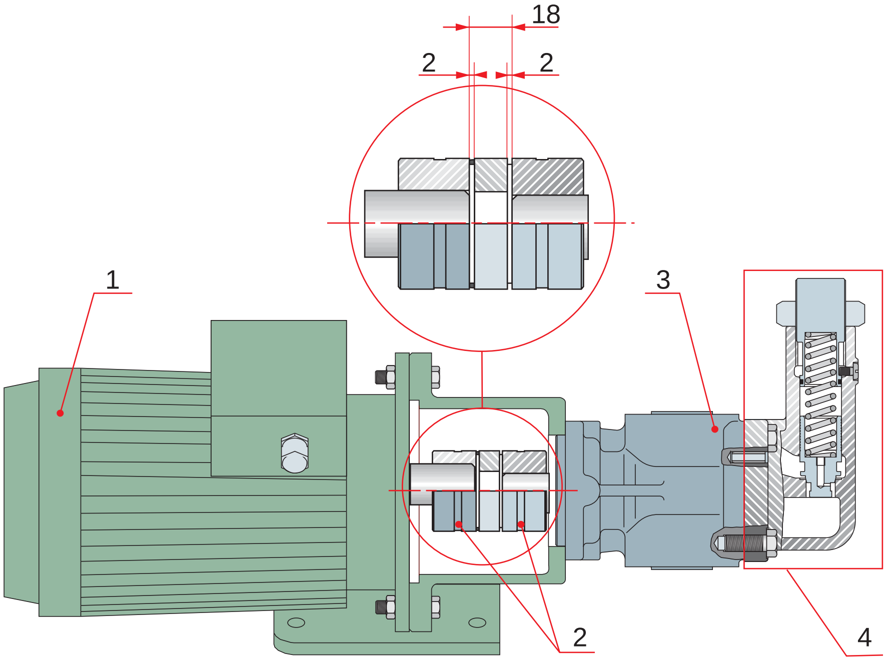
18 **Check all joints for leaks and for any excessive vibrations, with the centrifuge running.** Take remedial action if necessary.

18.7. Prelubricating pump

V6

The pump is of the gear type, driven by an electric motor. The pump is provided with an adjustable pressure control valve. The pressure should be limited to the max. value, about 2 bar, by unscrewing the adjusting screw to the end position in order to prevent the electric motor from being overloaded when running with very cold oil.

Prelubricating pump



1. *Electric motor,* 2. *Flexible coupling,* 3. *Prelubricating pump,* 4. *Pressure regulating valve*

Fig 18-12 V1

Note!
Be careful when adjusting the pressure by unscrewing the adjusting screw the spring or oil may come out.

Caution!
Do not run the prelubricating oil pump when the engine is running, otherwise the shaft seal will be damaged due to overheating.

Some installations are provided with a special electrical motor. With this special motor it is possible to use a pneumatic tool for prelubricating of the engine in the event of a "cold ship".

18.7.1. Maintenance of prelubricating pump V5

See the manual of the manufacturer. Normally, no regular maintenance is required. After three to six years the shaft seal may have to be replaced due to ageing. Low leakage rates are essential to the functioning of the slide ring sealing. The slide ring sealing should be renewed if the leakage rate increases.

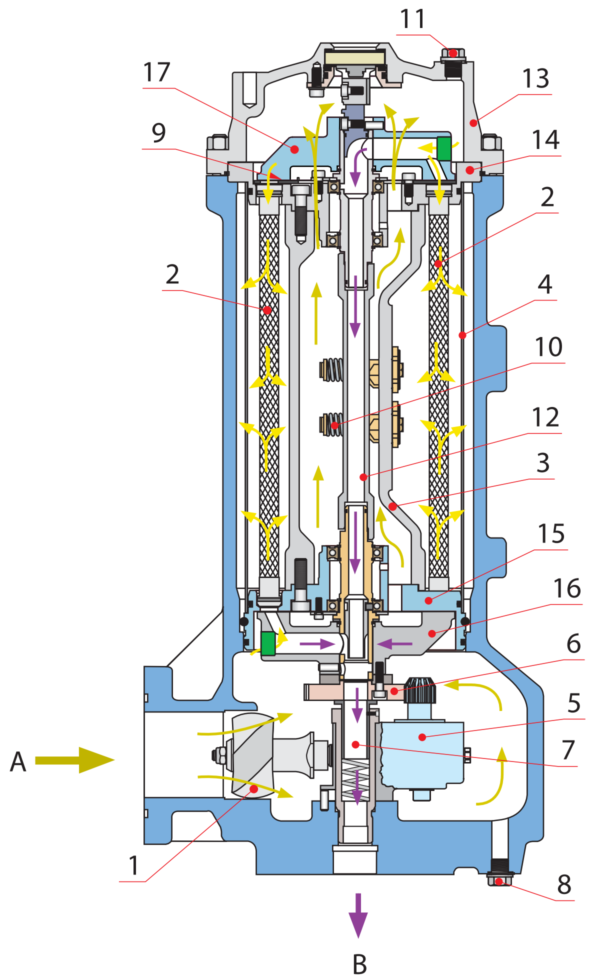
Take care not to damage the sealing ring faces. A slight scratch may disturb the sealing function. Avoid touching sealing faces with fingers.

18N. Lubricating oil automatic filter

V5

The filter is a full flow filter, that is, the whole oil flow passes through the filter.

Lube oil filter



1. *Turbine* 2. *Filter candle* 3. *Central Connection tube* 4. *Safety filter* 5. *Gear unit* 6. *Gear* 7. *Flushing bush* 8. *Screw plug* 9. *Cover plate* 10. *Overflow valve* 11. *Screw plug* 12. *Coupling pipe* 13. *Cover* 14. *End plate* 15. *Filter plate* 16. *Flushing arm, bottom* 17. *Flushing arm, top.*

A. Inlet, B. Flushing oil outlet.

Fig 18N-1 20AP1810 V1

The arrows in Fig 18N-1 show the flow through the filters.

At first, the oil flows through the inlet flange and turbine to the bottom end of the filter candles; a partial stream of about 50% is passed through the central connection tube to the top end of the filter candles. This means that the oil flows through the filter candles at both ends from the inside outwards and most of the dirt particles are retained in the inside of the candles. The oil filtered in this way now passes through the safety filter to the filter outlet.

The flow energy drives the turbine installed in the inlet flange. The high speed of the turbine is reduced by the worm gear unit and gear to the lower speed required for turning the flushing arms (16, 17).

The individual filter candles are now connected successively to the atmosphere by means of continuously rotating flushing arms (16, 17) and the flushing bush.

Flow during back-flushing, from outside of the candles to the inside through flushing arms in to the flushing line.The resultant turbulent stream in the longitudinal direction of the filter candles (cross-flow back flushing) and the counter flow back-flushing through the filter candles result in a particularly effective and lasting back-flushing action.

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.

Should for any reason the filter candles no longer be adequately cleaned, the overflow valves (10) are opened at a differential pressure of 2 bar upwards. The oil is filtered only through the safety filter.

However, before this situation arises, the installed LO differential pressure switch PDS243 emits an alarm, at 1.5 bar differential pressure, to the alarm system. At the same time the visual differential pressure indicator (located after the LO-filter) becomes red. The cause must now be localized and remedied.

The filter may only be operated in this emergency condition for a short time (opened overflow valves and differential pressure alarm). Prolonged operation in this mode can result in damage to downstream components.

The overflow valves are closed under normal operating conditions, even during start-up at lower fluid temperatures.

18N.1. Maintenance of automatic filter V3

Even automatic filters must be inspected and maintained regularly.

It is extremely important to remember that in spite of constant back-flushing the mesh may become clogged over the course of time, depending on the quality of the oil.

For trouble-free operation, carry out the following during maintenance:

1 **Check the filter and connections for leakages.**

2 **Conduct a visual inspection of all filter candles once a year.**

Note!
Should a higher differential pressure occur before an inspection is scheduled, all the filter candles and the safety filter must be checked and, if necessary, cleaned or replaced.

A highly contaminated safety filter is a sign of prolonged operation with defective or clogged filter candles and consequently (from a differential pressure of 2 bar upwards) opened overflow valves.

It is imperative to check these components.

3 **Check the ease of movement of the worm gear unit, the turbine, including gear during flushing arms (16, 17).** To do this, the cover and the complete filter element pack must be removed.

4 **Replace damaged or hard O-rings.** It is advisable to replace all static seals when inspecting and overhauling.

18N.1.1. Filter candles inspection and cleaning

V4

1 **Drain the filter, open the screw plug (11) and (8).**

Note!
Do not refill the system with the drained oil because it is very dirty.

2 **Remove the cover by opening the nuts.**

3 **Pull the entire filter element including flushing arm (16, 17) and gear out of the housing.**

Note!
Make sure that the exposed gear is not damaged.

4 **Remove the top flushing arm (17) and the upper cover plate.**

5 **Remove the end plate by unscrewing the screws.**

6 **The filter candles and safety filter can now be removed.**

7 **Place the filter candles and the safety filter in a suitable cleaner or diesel oil.** Maximum soaking time is 24 hours.

8 **After immersing clean them from the outside inwards using high pressure.**

- Ensure that the filter candles are cleaned at a pressure of maximum 60 bar and with the cleaning nozzle at a distance of not less than 20cm.
- To get a optimal cleaning effect it is recommended to use the special high-pressure cleaning unit (Part No. 471345) and cleaner (Part No.471346).
- When cleaning, hold the filter candles such that the dirt drains out slowly.

9 **Clean the parts and the overflow valves.** Replace worn parts if necessary.

10 **Mount the safety filter and the end plate.** Note the position of the guiding pin.

11 **Before the filter candles are installed, they must be visually inspected and damaged candles replaced with new ones.**

Note!
Defective filter candles must not be reused.

12 **Mount the filter candles in position with the chamfered end towards the bottom flushing arm.** Before installation of the entire filter element, check the ease of motion of the flushing facility. The bottom flushing arm (16) must not grind against the bottom filter plate

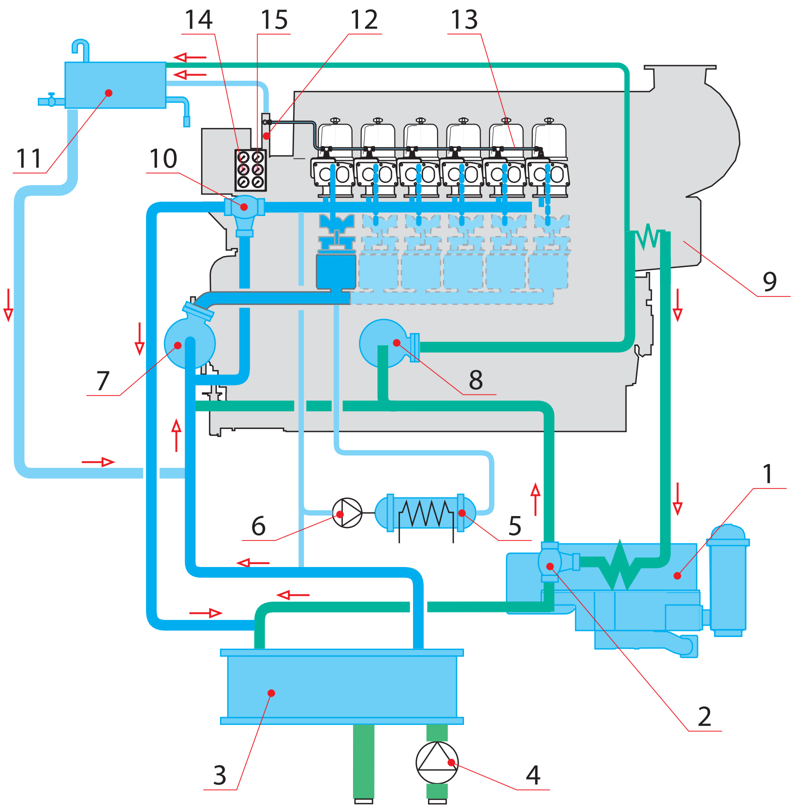
13 **Push the entire filter element into the housing.** By slightly turning, the coupling pipe, the gear is forced into the drive pinion of the gear unit . Re-assemble the filter in the reverse sequence to that described above.

19. Cooling Water System

V5

The engine is cooled by a closed circuit cooling water system, divided into a high temperature circuit (HT) and a low temperature circuit (LT). The cooling water is cooled in a separate central cooler.

Cooling water system



1.*Lube oil cooler* 2.*LT-thermostat valve* 3*Central cooler* 4.*Water pump* 5.*Pre-heater* 6,*Preheating water pump* 7.*HT-water pump* 8.*LT-water pump* 9.*Charge air cooler* 10.*HT-thermostat valve* 11.*Expansion tank* 12.*Water box* 13.*Vent piping from multiduct* 14.*HT-water pressure gauge* 15.*LT-water pressure gauge*

Fig 19-1 201968 V1

19.1. HT circuit

V5

The HT circuit cools the cylinders and cylinder heads.

A centrifugal pump (7)circulates the water through the HT circuit. From the pump the water flows to the distributing duct, cast in the engine block. From the distributing ducts the water flows to the cylinder water jackets, further through connection pieces to the cylinder heads where it is forced by the intermediate deck to flow along the flame plate, around the nozzle and the exhaust valve seats, efficiently cooling all these components. From the cylinder head the water flows through the multiduct to the collecting duct, further to the temperature control valve maintaining the temperature at the right level.

19.2. Venting and pressure control of HT circuit V6

For venting the system a venting pipe from the multiducts are connected to a box (12). From this box the vent pipe leads to the expansion tank (11) from which the expansion pipe is connected to the inlet pipe of the pumps (7 and 8), see Fig 19-1. A static pressure of 0.7 - 1.5 bar is required before the pumps. If the expansion tank cannot be located high enough to provide this pressure, the system is to be pressurized.

19.3. LT circuit V6

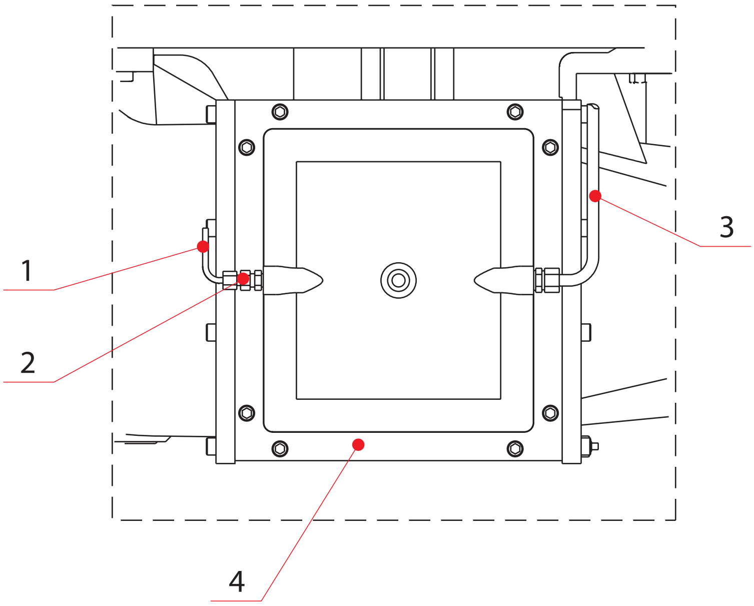
The LT circuit consists of a charge air cooler (9) and a lube oil cooler (1) through which a pump (8) of similar design as the HT pump, circulates the water. The circuit temperature is controlled by a temperature control valve (2) maintaining about the same LT circuit temperature on different load levels. The necessary cooling is gained from the central cooler (3), see Fig 19-1. The system outside the engine can vary from one installation to another.

19.4. Relief valve and venting of LT circuit V5

The LT circuit is provided with a relief valve (2), see Fig 19-2 , to prevent over pressure in the system. It is located on the top of air cooler (4) and equipped with the overflow pipe (1). A pressure of 5 bar is required to open the relief valve.

The LT-water circuit is continuously vented through a vent pipe (3), connected to the expansion tank.

Relief valve



1.*Overflow pipe*,2.*Non-return valve*, 3.*Venting pipe*,4.*Air cooler*.

Fig 19-2 201974 V1

19.5. Preheating of cooling water system V5

For preheating of the circuit, a heater circuit with the pump (6) and heater (5) are connected in the HT circuit before the engine. The non-return valves in the engine circuit force the water to flow in the right direction.

Before start, the HT circuit is heated up to 60 - 80°C by a separate heater. This is of utmost importance when starting and idling on heavy fuel.

19.6. Monitoring the cooling water system

V11

Local thermometers:

- HT before and after engine,
- LT before charge air cooler,
- LT before lube oil cooler,
- LT after lube oil cooler.

The temperatures mentioned in chapter 01: section 01.2, should not be exceeded.

Manometers (14) and (15) on the instrument panel indicate HT and LT pressures after the pumps. The pressures depend on the speed and the installation. Guidance values, see chapter 01:section 01.2.

The HT water outlet after the engine is provided with a temperature sensor for control, alarm and a stop switch. Main engines are provided with alarm switches for low HT and LT pressure.

For further information, see chapter 23.1.

19.7. Maintenance of cooling water system

V1

The installation - including expansion, venting, preheating, pressurizing - should be carried out strictly according to the instructions of the engine manufacturer to obtain correct and troublefree service.

The cooling water should be treated according to the recommendations in chapter 02., section 02.3, to prevent corrosion and deposits.

If risk of frost occurs, drain all cooling water spaces. Avoid changing the cooling water. Save the discharged water and use it again.

Remember to mount the plug and open the cooling water connections before the engine is started again.

19.7.1. Cleaning of cooling water system

V4

In completely closed systems the fouling will be minimal if the cooling water is treated according to the instructions in chapter 02, section 02.3. Depending on the cooling water quality and the efficiency of the treatment, the cooling water spaces will foul more or less over the course of time. Deposits on cylinder liners, cylinder heads and cooler stacks should be removed as they may disturb the heat transfer to the cooling water and thus cause serious damage.

The need of cleaning should be examined, especially during the first year of operation. This may be done by overhauling a cylinder liner and checking for fouling and deposits on the liner and block.

The deposits can be of the most various structures and consistences. In principle, they can be removed mechanically and/or chemically as described below. More detailed instructions for cleaning of coolers are stated in chapter 18, section 18.4.

a) Mechanical cleaning

A great deal of the deposits consists of loose sludge and solid particles which can be brushed and rinsed off with water.

On places where the accessability is good, e.g. cylinder liners, mechanical cleaning of considerably harder deposits is efficient.

In some cases it is advisable to combine chemical cleaning with a subsequent mechanical cleaning as the deposits may have dissolved during the chemical treatment without having come loose.

b) Chemical cleaning

Narrow water spaces (e.g. cylinder heads, coolers) can be cleaned chemically. At times, degreasing of the water spaces may be necessary if the deposits seem to be greasy (see chapter 18, section 18.4).

Deposits consisting of primarily limestone can be easily removed when treated with an acid solution. On the contrary, deposits consisting of calcium sulphate and silicates may be hard to remove chemically. The treatment may, however, have a certain dissolving effect which enables the deposits to be brushed off if there is only access.

On the market there are a lot of suitable agents on acid base (supplied e.g. by the companies mentioned in chapter 02, section 02.3).

The cleaning agents should contain additives (inhibitors) to prevent corrosion of the metal surfaces. Always follow the manufacturer's instructions to obtain the best result.

After treatment, rinse carefully to remove cleaning agent residuals. Brush surfaces, if possible. Rinse again with water and further with a sodium carbonate solution (washing soda) of 5 % to neutralize possible acid residuals.

19.8. Water pump

V5

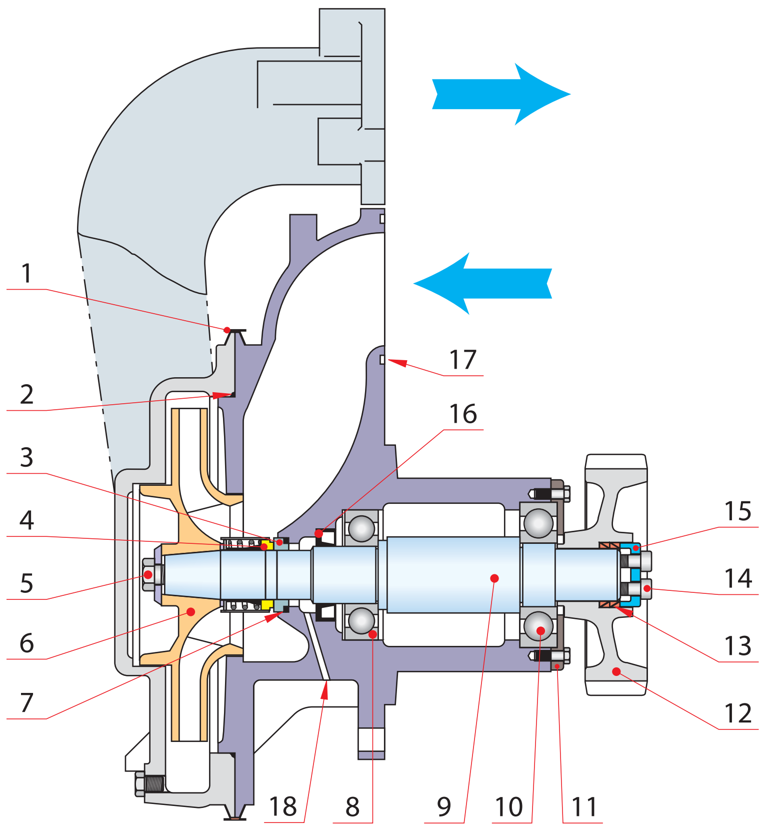
The water pump is a centrifugal pump and is driven by the gear mechanism at the free end of the engine. The shaft is made of acid resistant steel, the impeller (6) and the remaining details of cast iron.

The shaft is mounted in two ball bearings (8) and (10), which are lubricated by splash 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 conical ring elements (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 or lubricating oil from the sealing can flow out through an opening (18).

Cooling water pump



1.*Cover clamp,* 2.*O-ring,* 3.*Fixed ring,* 4.*Shaft sealing,* 5.*Screw,* 6.*Impeller,* 7.*O-ring,* 8.*Bearing,* 9.*Shaft,* 10.*Bearing,* 11.*Bearing retainer,* 12.*Drive gear,* 13.*Friction rings,* 14.*Screw,* 15.*Pressure plate,* 16.*Seal,* 17.*O-ring,* 18.*"Telltale" hole.*

Fig 19-3 201951 V1

19.8.1. Maintenance of water pump V4

Normal maintenance operations, like removal of 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 recommendations in chapter 04. or, if water and oil leakage occurs, immediately.

Check that the "telltale" hole (18) is open every now and then.

19.8.2. Dismantling and reassembling the impeller V2

1. **Remove the volute casing by loosening the clamp (1) and the fastening screws.**
2. **Loosen the impeller fastening screw (5).**
3. **Pull out the impeller using an extractor 837026.**
4. **Tighten the screw to torque, while reassembling the impeller.** See, chapter 07: Tightening torques for screws and nuts.
5. **When reinstalling the volute casing, check that the O-ring (2) and non-return valve O-rings on the engine block are intact and in position.** Check that the volute casing is in position.
6. **Mount the clamp and tighten the screws.**

19.8.3. Disassembling and assembling of mechanical shaft seal V5

1. **Remove the impeller according to section 19.8.2.**
2. **Carefully dismantle all seal details.** Sealing rings are very fragile.
3. **Take particular care not to damage sealing surfaces as a slight scratch may disturb the sealing function.**
4. **Replace the complete seal if it is leaky or if sealing faces are corroded, uneven or worn.** Avoid touching the sealing faces with fingers.

Warning!
Do not use mineral oil when fitting the seal. Use liquid soap or water.

Some of the Seal Components are manufactured from a rubber which is not suitable for use with Hydrocarbon oils.

Any discolouration or bloom on the rubber components of this seal will not in any way adversely affect its operation.

5 **Note that the seal is independent of the direction of rotation.**

6 **Reassemble the details in proper order.** Install the impeller according to section 19.8.2. Do not forget the thin washer between the spring and the O-ring.

19.8.4. Replacing of bearings and shaft seal

V5

1 **Remove the pump from the engine.**

2 **Disassemble the impeller and mechanical seal according to section 19.8.2 and 19.8.3.**

3 **Loosen the screws (14) and remove the pressure plate (15).**

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 ring elements (13) come loose together with the gear wheel).

Warning!
Using an extractor will only damage the shaft (axial scratches).

5 **Loosen the bearing retainer (11) 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.** Press the bearing by its inner ring with a suitable pipe.

8 **Inspect the shaft for wear and damage.**

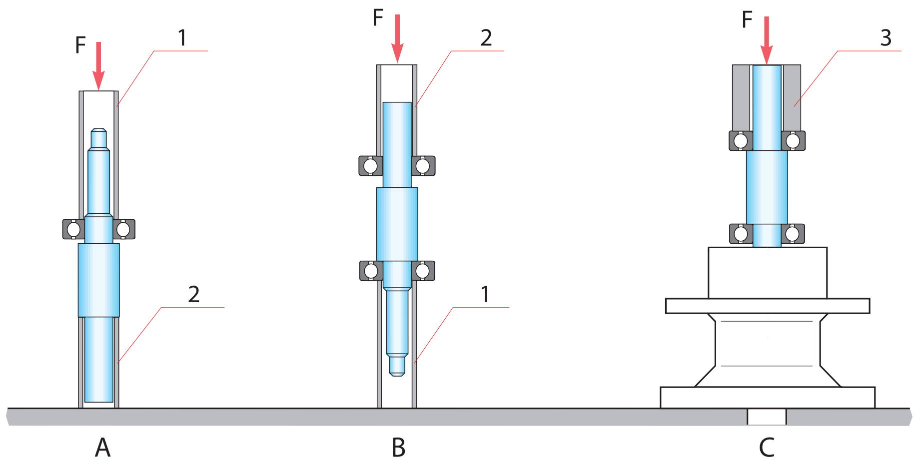
9 **Oil the new seal and insert it by pressing against the shoulder.**

10 **Oil the collar and press the bearing in by its inner ring with a suitable pipe.** See, Fig 19-4.

11 **Turn the shaft according to Fig 19-4.**

12 **Turn the housing and oil the outer surfaces of the bearings.** Press the shaft into the housing by both the inner and outer ring of the bearing with a suitable pipe.

Mounting of bearings



1, 2, 3 Pipes

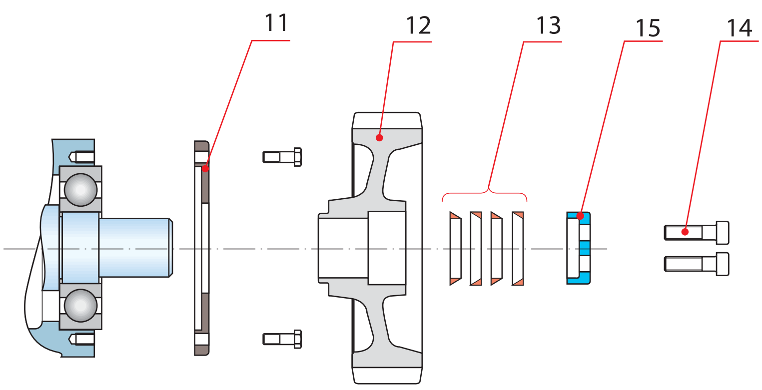
Fig 19-4

321956 V2

13 Fit the bearing retainer (11) and lock the screws with lock wire or locking compound.

14 Before reinstalling the gear wheel, all contact surfaces should be cleaned and oiled.

Mounting of gear wheel to water pump



11.*Bearing retainer,*12.*Drive gear,*13.*Friction rings,*14.*Screw,*15.*Pressure plate*

Fig 19-5

201976 V1

15 Reinstall the gear wheel and the friction ring elements (13). The friction ring elements should fall easily in place and must not jam.

16 Reinstall the pressure plate (15).

17 Tighten the screws a little and check that the gear wheel is in the right position.

18 Tighten the screws to torque according to Chapter 07: Tightening Torques and Instructions for Screw Connections.

19 Assemble the impeller and the mechanical seal according to instruction section 19.8.2 and 19.8.3.

19.9. Temperature control system

V5

The LT circuit is provided with a fixed thermostatic valve fitted in the lube oil cooler.

In some engines, the LT circuit can bee provided with a fixed blind flange fitted in the lube oil cooler. Then the water passes directly into the cooler even if the temperature is low.

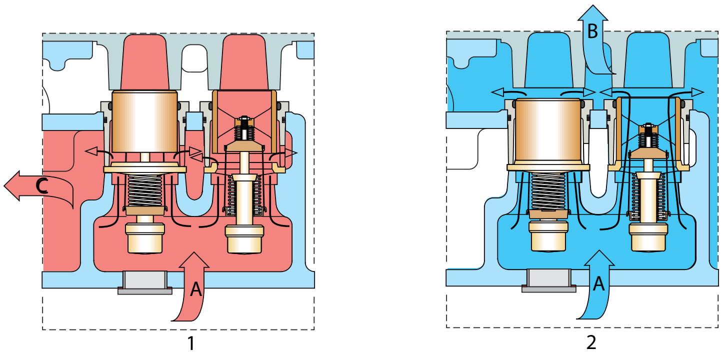
The HT circuit is provided with a fixed thermostatic valve that is either mounted inside the bracket of the connecting box or is integrated in the turbocharger. This helps to maintain the HT outlet water temperature. For operation temperatures, see Chapter 01: Recommended operating data.

19.9.1. LT and HT thermostatic valve

V5

The thermostatic valve is equipped with positive three-way valve action in which the water is positively made to flow in the direction required. When the engine is started up and is cold, the thermostatic valve causes all of the water to be positively bypassed back into the engine, thus providing the quickest warm-up period possible. After warm up, the correct amount of water is bypassed and automatically mixed with the cold water returning from the heat exchanger or other cooling device to produce the desired water outlet temperature. If ever required, the thermostatic valve will shut off positively on the bypass line for maximum cooling. The three-way action of the valve allows a constant water flow through the pump and engine at all times with no pump restriction when the engine is cold.

Water flow in temperature control valve



1.*Warm engine*,2.*Cold engine*

A.*From engine*,B.*By-pass*,C.*To cooler*

Fig 19-6 201971 V1

No adjustments are ever required on the thermostatic valve. The temperature is specified at the factory. The temperature can be changed only by changing temperature element assemblies which is easily accomplished by unscrewing the housing. The valve is entirely self-contained, and there are no external bulbs or lines to become damaged or broken. There are no packing glands to tighten and no parts to oil.

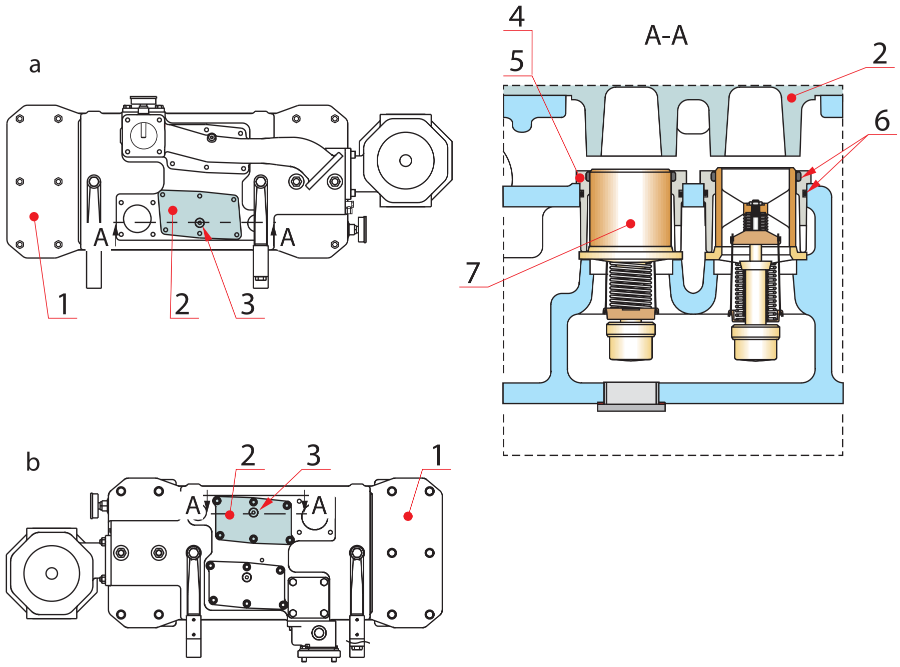
The power creating medium utilizes the expansion of the element contents,Fig 19-7, Fig 19-8 or Fig 19-9, which remains in a semi-solid form and is highly sensitive to temperature changes.

Most of the expansion takes place during the melting period of approximately two minutes over a temperature change of approximately 8.5°C.

The thermostatic valve is provided with two elements. Since flow is diverted either to bypass or heat exchanger, failure of an element would cause no change in pressure drop.

The contents of the elements has an almost infinite force when heated and is positively sealed. When the elements are heated, this force is transmitted to the piston thus moving the sliding valve towards the seat to the bypass closed position. This force is opposed by a high spring force, which moves the sliding valve to the heat exchanger closed position when the elements are cooled. The high force available on heating is the basis of the fail safe feature in which failure of the element would cause the engine to run cold.

LT thermostatic valve

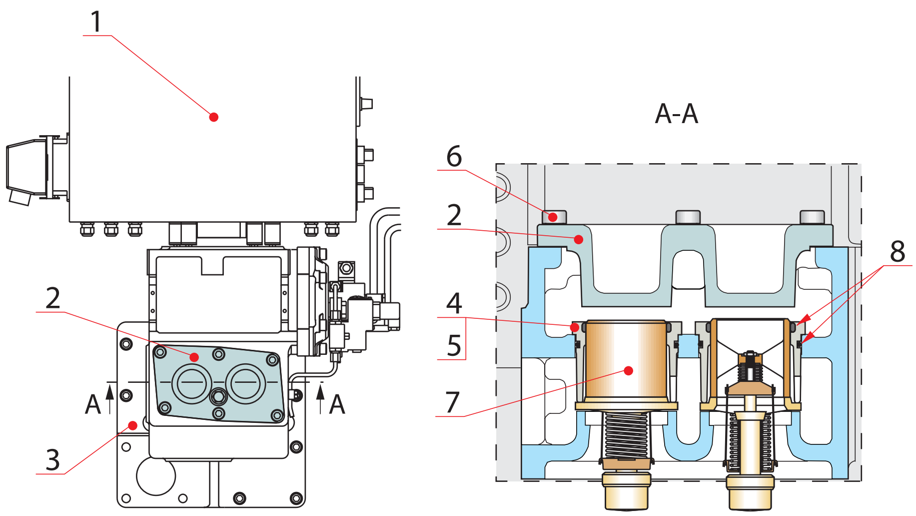


a. Viewed from underside TC at the driving end, b. Viewed from underside TC at the free end.

1. Lubricating oil module, 2. Cover, 3. Drain plug, 4. Screw, 5. Holder, 6. O-ring, 7. Thermostatic element.

Fig 19-7 201975 V1

HT thermostatic valve, TC at the driving end

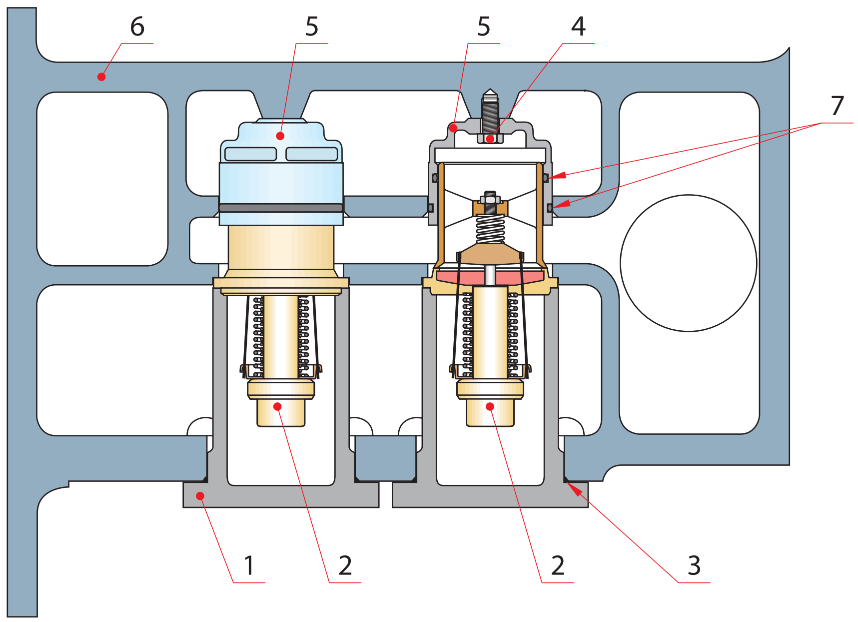


1. Connecting box, 2. Cover, 3. Bracket for connecting box, 4. Screw, 5. Holder, 6. Screw, 7. Element, 8. O-ring.

Fig 19-8

201972 V2

HT thermostatic valve, TC at the free end



1.*Flange for thermostat*,2.*Thermostat element*,3.*O-ring*,4.*Screw*,5.*Bush for thermostat*,6. *Bracket for turbocharger*,7.*O-ring*

Fig 19-9

201954 V2

19.9.2. Maintaining the temperature control system

V7

Normally, no service is required. Very low or high water temperature could indicate a malfunctioning thermostat or damaged O-rings.

1 **Drain the cooling water circuit.**

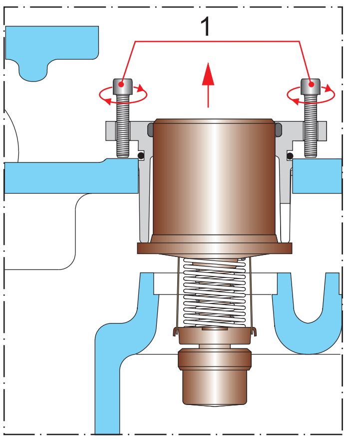
2 **Remove the elements by removing the cover (2) and the holder of the element (5).** See, Fig 19-7 and Fig 19-8 (TC at the driving end). Use screws (M8) for extracting the holder of element.

3 **Check the element by removing the flange of the thermostat (1).** See, Fig 19-8 (TC at the free end). Use the extractor tool (837 027) to remove the bush (5) of the thermostat.

4 **Change the defective element by heating it slowly in water.** Check the temperature at which the element starts opening and is fully open. Correct value is mentioned on the thermostatic element or see, chapter 01: Main Data, Operating Data and General Design. Lower value of water temperature indicates opening temperature and the higher for fully open valve.

5 **Change the defective element.** Check the O-rings and replace, if necessary. Apply sealing compound to the sealing faces between the cover (2) and the bracket, see Fig 19-7 and Fig 19-8.

Extracting of the thermostatic element



1. *M8* >=25mm.*

Fig 19-10

201877 V4

20. Exhaust System

20.1. Exhaust manifold

V6

Data and dimension
Multiduct
Material: Nodular cast iron
Weight: 8 kg
Test pressure: 10 bar (water side)

Exhaust pipes
Material: Special, heat resistant alloy nodular cast iron

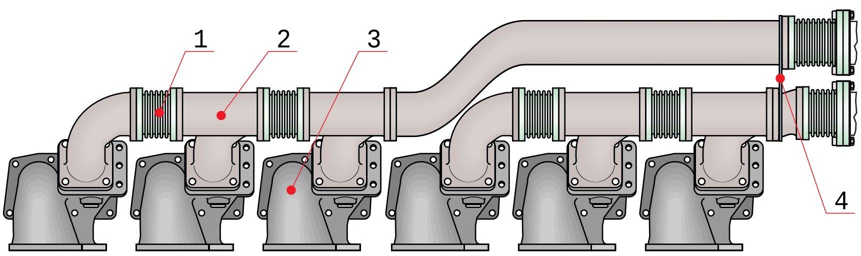
Bellows
Multiply design
Material: Heat resistant steel

The exhaust manifold is fitted between the cylinder head and the turbocharger. The manifold consists of the multiducts (3) and the exhaust pipes (2) with expansion bellows (1). The manifold is enclosed into an insulating box of sandwich design.

The turbocharging concept is a specific type of pulse charging, which is superior for sudden load application and frequent load variations. The exhaust gases are directed into exhaust pipes, which leads the exhaust gases to the turbocharger. The exhaust gases are discharged from each cylinder during the period when the other cylinders have the exhaust valve closed. This give an equal flow of gases to the turbocharger without any disturbing gas pulses to the other cylinders connected to the common pipe.

The multiduct, between the cylinder head and the exhaust pipes, acts as a bracket for the whole exhaust manifold, including the insulation box. The multiduct is cooled by the cooling water discharging from the cylinder head. The multiducts are vented through a venting pipe that runs along the engine. The cooling water flows through the multiduct down to the HT-water channel in the engine block. The multiduct also connects the air receiver in the engine block with the inlet air channel in the cylinder head. All the surfaces, engine block/multiduct, cylinder head/ multiduct and exhaust pipes/multiduct are sealed off.

Exhaust manifold (example)



1. Bellow, 2. Exhaust gas pipe, 3. Multiduct, 4. Support

Fig 20-1

202054 V1

The multiduct is rigidly attached to the cylinder head and engine block.

The exhaust manifold sections are made from alloy nodular cast iron. Each cylinder is joined to the manifold via an individual junction piece. The sections are interconnected with multi-ply metal bellows that absorb the heat expansion.

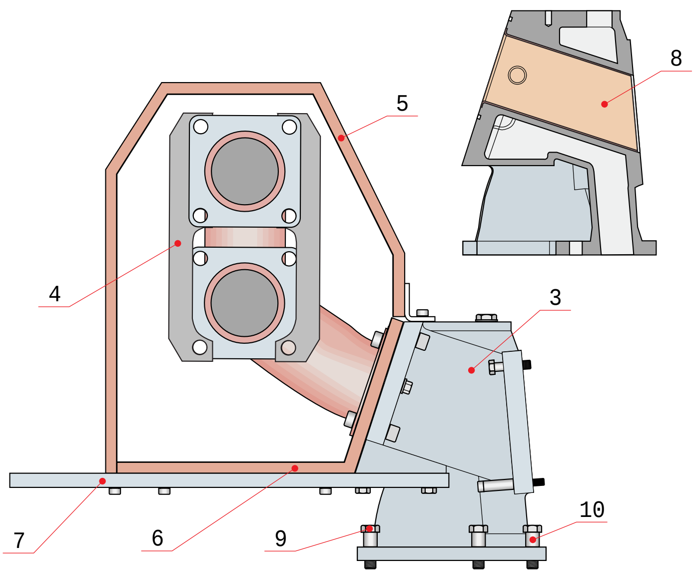
Note!
Check the condition of supports (4) at least once a year. Replace if necessary.

The complete exhaust system is enclosed by an insulation box, built up from sandwich steel sheet.

Caution!
The surface of the insulation box is hot.

Sensors for the remote measuring of exhaust gas temperatures are fitted at each cylinder and after the turbocharger. An optional sensor may also be fitted before the turbo.

Cross Section of Exhaust System



3. Multiduct, 4. Support, 5. Upper protecting panel, 6. Lower protecting panel, 7. Bracket, 8. Insert sleeve, 9. Screw, 10. Distance piece

Fig 20-2 202055 V1

20.1.1. Changing the expansion bellows V2

1 Remove necessary sheets on the insulation box.

2 **Remove the screws and remove the expansion bellows.**

3 **Check that the exhaust pipe flanges are parallel.** Position it on the same centre line to avoid lateral forces on the bellows.

4 **Mount the new expansion bellows and tighten the screws.**

Note!
The flow direction is marked with an arrow.

5 **Examine the supports (4) for damage.** Replace with new ones, if necessary.

6 **Mount necessary sheets and other parts.**

21. Starting Air System

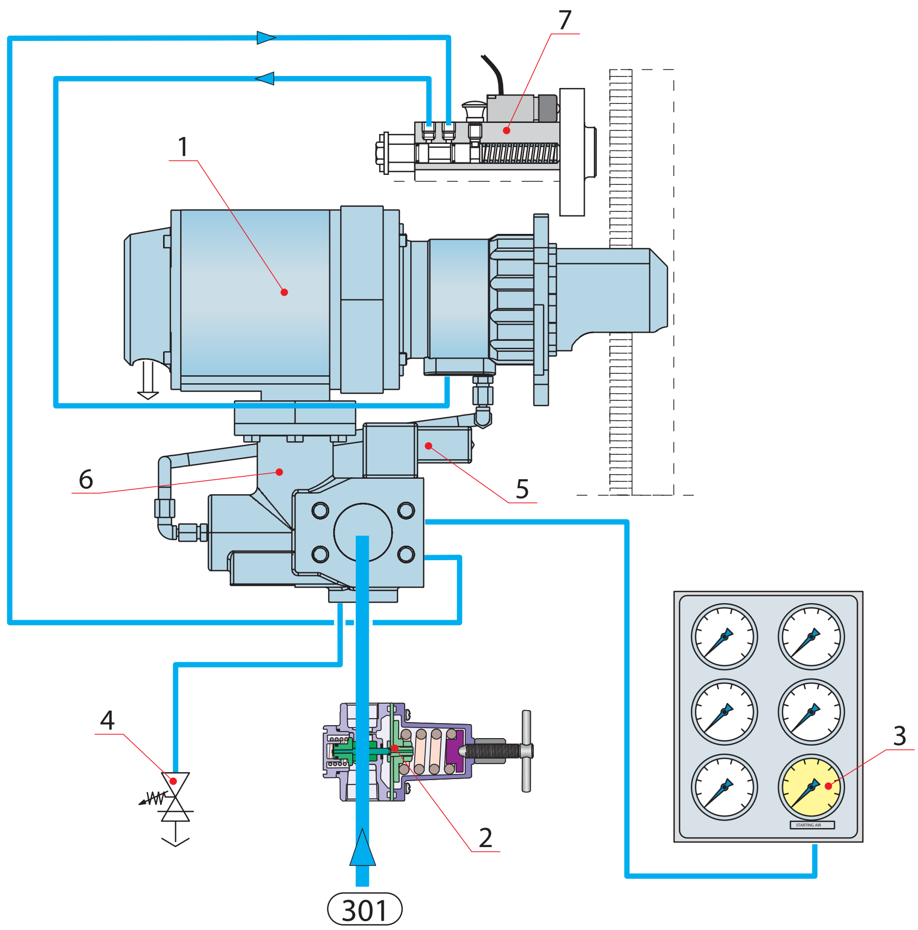
V15

The engine is started with compressed air of max. 10 bar. Minimum pressure required is 7.5 bar with the engine at operating temperature. A pressure gauge (3) mounted on the instrument panel indicates the pressure after the pressure reducing valve (2).

The air starter is controlled by solenoid valves (5,6) and start blocking valve (7).

As a precaution the engine cannot be started when the turning gear is engaged. Control air to the air starter is led through a blocking valve (7), mechanically blocked when the turning gear is engaged, thus preventing start.

Starting air system



1.*Air starter*,2.*Pressure reducing valve*,3.*Gauge for starting air*,4.*Safety valve*,
5.*Solenoid valve (5/2)*,6.*Starter control valve*,7.*Start blocking valve*

301.*Starting air inlet*

Fig 21-1 202160 V2

21.1. Starting device, turbine air starter

V16

Data and dimensions
Type: Turbine driven air starter
acting on the flywheel
Weight: 20 kg
Air pressure: 8 bar

The engine is provided with a turbine-type air starter. It is an air-operated, two-stage-turbine-driven, and pre-engaged starter drive, designed for operation with compressed air only. No lubrication is required in the supply air system.

The air starter can be grouped into:

- Integral relay valve
- Turbine Housing
- Gearbox Housing
- Bendix Drive

When the engine has reached a speed of 115 RPM, the current is cut off by a relay in the electronic speed measuring system, and the air starter is automatically disengaged.

In emergency situations (current failure or malfunctioning of control devices), the air starter can be started with a manually-operated valve. This causes the automatic disengage control of the air starter to be out of operation. Hence, to avoid any overspeed of the air starter, the valve must be closed when the engines starts.

Warning!
Do not operate the starter with compressed air unless it is properly attached to the engine and engages the flywheel.

A valve prevents starting when the turning device is engaged (as well as emergency starting by means of a valve).

21.1.1. Disassembly of starter

V15

Mark each section of the starter for reference during assembly. Do not disassemble the starter any further than necessary to replace a worn or damaged part. Mark the turbine rotor and note its direction of rotation.

Have a complete set of O-rings, seals, screws and other hardware available for assembly.

21.1.2. Cleaning and inspection of starter

V15

1 **Degrease all metal parts except bearings and the starter drive using commercially approved solvents.**

2 **Dry parts thoroughly.**

Caution!
Never wash bendix assembly or bearings in cleaning solvents. It is recommended bearings be replaced with new parts.

3 **Clean aluminium parts using a cleaning solution and soak for five minutes.** Remove the parts, rinse in hot water and dry thoroughly.

4 **Clean corroded steel parts with commercially approved stripper.**

5 **Clean corroded aluminium parts using a cleaning solution.** Immerse the parts in a chromic-nitric-phosphoric acid pickle solution. Rinse with hot water and dry thoroughly.

6 **Check for acceptable condition of parts.**

7 **Check all threaded parts for galled, crossed, stripped, or broken threads.**

8 **Check all parts for cracks, corrosion, distortion, scoring or general damage.**

9 **Check all bearing bores for wear and scoring.** Bearing bores must be free of scoring lines.

10 **Check the gear teeth and turbine housing ring gear for wear.** Check for spalling, fretting, surface flaking, chipping, splitting, and corrosion. If wear is apparent, check the gear teeth dimensions.

21.1.3. Assembly of starter

V16

Always press the inner race of ball bearings when installing onto a shaft. Always press the outer race of ball bearings when installing into a housing. The rotor retention screw must be replaced each time the turbine rotor is removed. All parts should be degreased and aluminum parts cleaned. For overhaul, all parts are included in the overhaul kit should be replaced.

All screw threads are treated at the factory with a fastener retention compound. Every screw, 1/4 inch diameter or larger, must have a drop of Loctite 290 applied to the threads before being re-used, screws smaller than 1/4 inch diameter must have a drop of Loctite 222 applied to the threads.

21.2. Starting air vessel and piping

V2

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 starting air system, a non-return valve and a blow-off valve are mounted.

Drain the starting air vessel from condensate through the drain valve before starting.

The piping between the air vessels and the engines should be carefully cleaned when installing. Also later on they should be kept free from dirt, oil and condensate.

The starting air vessels should be inspected and cleaned regularly. If possible, they should then be coated with a suitable anti-corrosive agent. Let them dry long enough.

At the same time, inspect the valves of the starting air vessels. Too strong tightening may result in damages on the seats, which in turn cause leakage. Leaky and worn valves, including safety valves, should be reground. Test the safety valves with pressure.

21.3. Pneumatic system

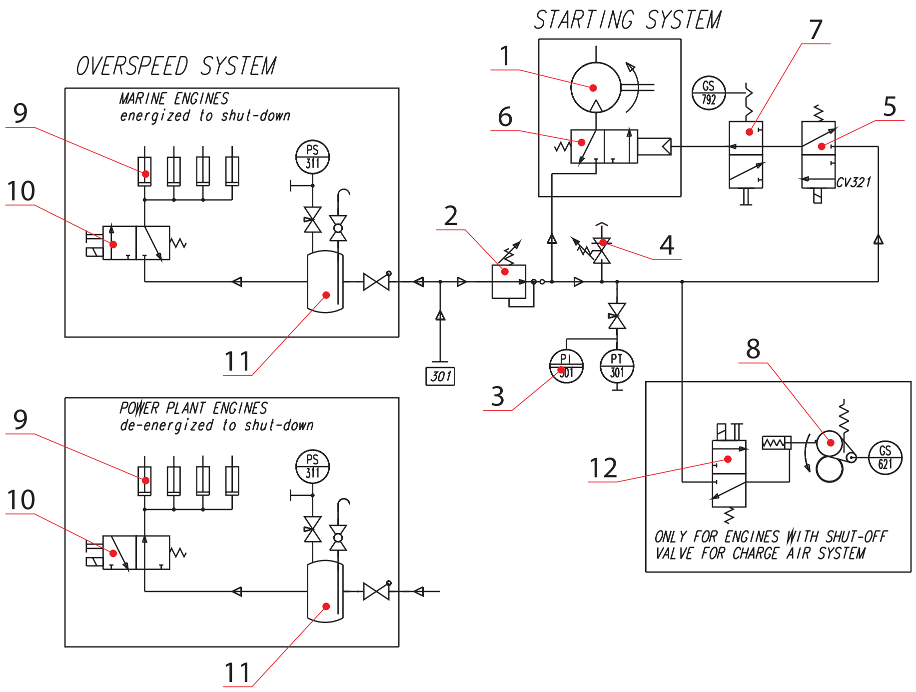
V15

The engine is equipped with a pneumatic system which controls the following functions by means of a solenoid valves:

- Start of engine
- Stopping of engine
- Overspeed Protection
- Control of Air Waste Gate

The staring system includes pressure reducing valve (2) and safety valve (4). Pressure reducing valve maintains the air pressure at correct level and safety valve ensures the pressure is at safe level for the air starter. The air starter is controlled by a solenoid valve (5) and blocking valve (7).

Pneumatic system



1. *Air starter* 2. *Pressure reducing valve* 3. *Gauge for starting air* 4. *Safety valve* 5. *Solenoid valve* 6. *Starter control valve* 7. *Start blocking valve* 8. *Shut-off valve* 9. *Pneumatic stop cylinders* 10. *Main stop valve* 11. *Air container* 12. *Solenoid valve*

Fig 21-2 202161 V1

The system includes an air container (11) and a non-return solenoid valve which ensures that the pressure in the system doesn't drop in case of low feed pressure. Fig 21-3 shows the solenoid valve. The solenoid valves can also be operated manually.

The pneumatic overspeed trip devices (9), described in detail in Chapter 22: Electro-pneumatic overspeed trip device, are controlled by a main stop valve (10). It is actuated by solenoid valve on an electric signal from the speed monitoring system, where by the engine stops.

The solenoid valve is able to function as a local stop.

Note!
When the engine is running, the air supply to the engine must always be open.

21.4. Maintaining the pneumatic system

V16

The system is built up from high quality components. It usually requires no other maintenance than the draining of condensed water from the vessel (11). The system function should however be checked regularly.

Note!
Regularly check the pressure after the pressure reducing valve (2).

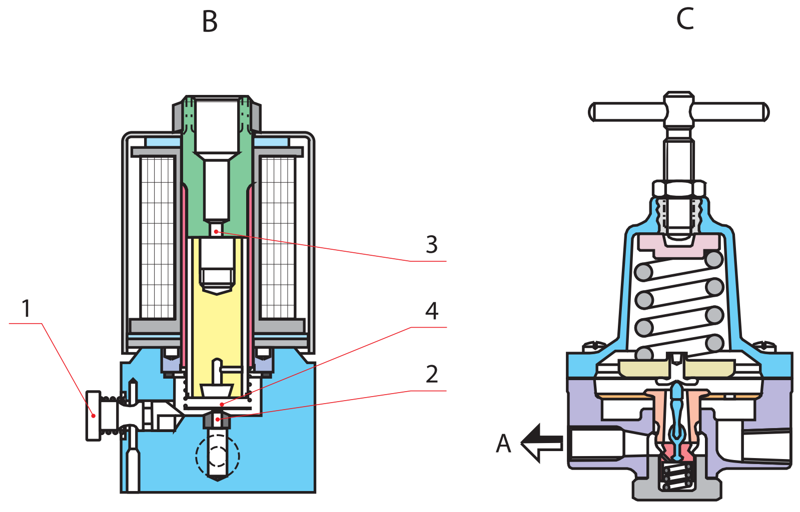
Solenoid valve: In case of a fault in the electric function of the valve, test the mechanical function of the valve by pushing the button (1) , see Fig 21-3. Should there be a mechanical malfunction, open the valve and inspect the following:

Check that the bores (2) and (3) and their seats are open and the gasket (4) is intact. Change the valve if it does not function after cleaning.

Water draining valve: Clean the valve if there is any disturbance. The valve can temporarily be disconnected by closing the main shut off valve for overspeed system.

Pressure reducing valve: The pressure reducing valve requires no maintenance. If there is problem, change the valve.

Pneumatic components



A:*Airflow direction*, B:*Solenoid valve*, C:*Pressure reducing valve.*

1. *Button* 2. *Bore* 3. *Bore* 4. *Gasket.*

Fig 21-3

V1

22. Control Mechanism

V3

During normal operation the engine speed is controlled by a governor (1) 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 a adjustable link rod (2).

The movement from the control shaft, to the injection pump fuel racks (16), is transferred through the regulating lever (6) and the 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 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 (17). When the stop lever is moved to stop position, the lever (18) 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 22.4.

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 by which the engine can be stopped remotely. The solenoid is also connected to the electro-pneumatic overspeed protection system and to the automatic stop system, which stops the engine at too low lubricating oil pressure, too high circulating water temperature, or at any other desired function.

22.1. Maintaining the control mechanism

V4

Warning!
Pay attention to the functioning of the system. Any defect in the system may result in over speeding of the engine and it may not be able to take the load.

1 **Clean and lubricate the racks, the bearings and the ball joints regularly with lubricating oil.** Ensure that the system works with minimal friction.

2 **Check the clearance of all connections.** The total clearance may correspond to 0.5 mm (maximum) of injection pump fuel rack positions.

3 **Check the adjustment of the system regularly.** For recommendations on adjustment of the system, see Chapter 4. For adjustment of stop position, overspeed trip devices and starting fuel limiter, see Chapter 22 : Checking and adjusting the fuel rack position.

4 **Check that all the accessories are installed in the right position when reassembling the system.** Ensure that all nuts are tightened to the right torque. Ensure locking elements like pins, retainer rings and locking plates are in the right position.

22.2. Check and adjustment

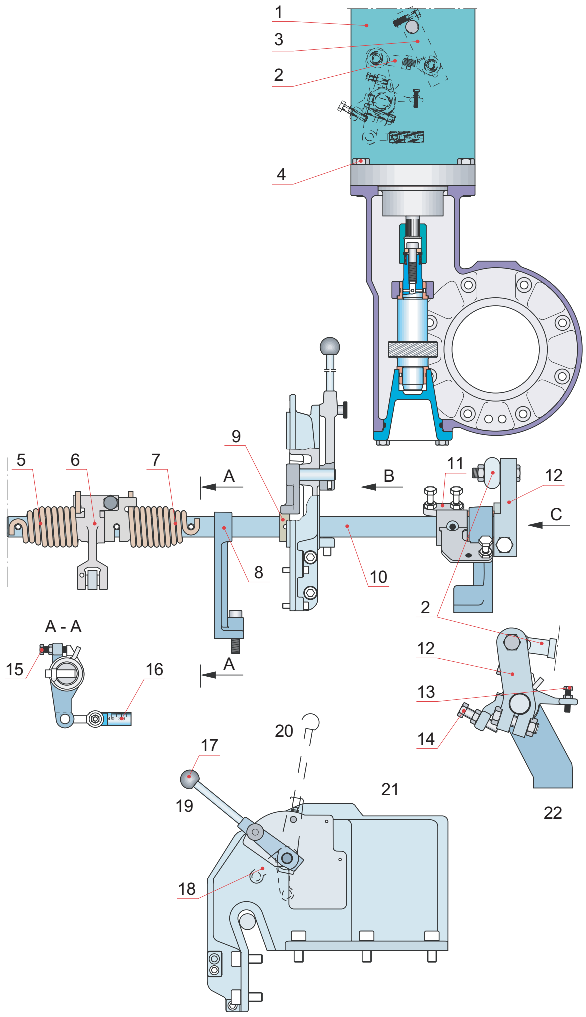
22.2.1. Checking and adjusting the fuel rack position V5

1 Checking the fuel rack position.

a) Set the governor lever in the maximum fuel position and the stop lever in the stop position.

b) Check that the fuel rack position of all injection pumps is maximum 3 mm.

Control mechanism



1. *Governor.* 2. *Adjustable link rod.* 3. *Governor lever.* 4. *Screw.* 5. *Spring.* 6. *Lever for injection pump.* 7. *Spring.* 8. *Bearing housing.* 9. *Lever.* 10. *Control shaft.* 11. *Load limiter.* 12. *Lever.* 13. *Adjusting screw.* 14. *Adjusting screw.* 15. *Adjusting screw.* 16. *Fuel rack.* 17. *Stop lever.* 18. *Lever for stop lever.* 19. *Stop position.* 20. *Working position.* 21. *View B.* 22. *View C.*

Fig 22-1 202257 V3

2 Adjusting the fuel rack position.

a) **Set the stop lever to the stop position. Check that the lever (18) is in proper contact with the lever (9).** A small torque can be set from the governor, too much torque will twist the shaft unnecessarily.

b) Adjust the fuel rack position according to the table below by adjusting the screws (15).

Engine configuration	Fuel rack position (mm)
Turbocharger at the free end (LF)	3
Turbocharger at the driving end (LD)	1

Note!
If changing the governor, see Chapter 22 : Speed governor.

22.2.2. Checking electro-pneumatic overspeed trip device

V3

1 Check of stop position

- Set the stop lever in the work position and the terminal shaft lever in the max. fuel position.
- Release the overspeed trip device manually.
- Check that the fuel rack positions is less than 3 mm.

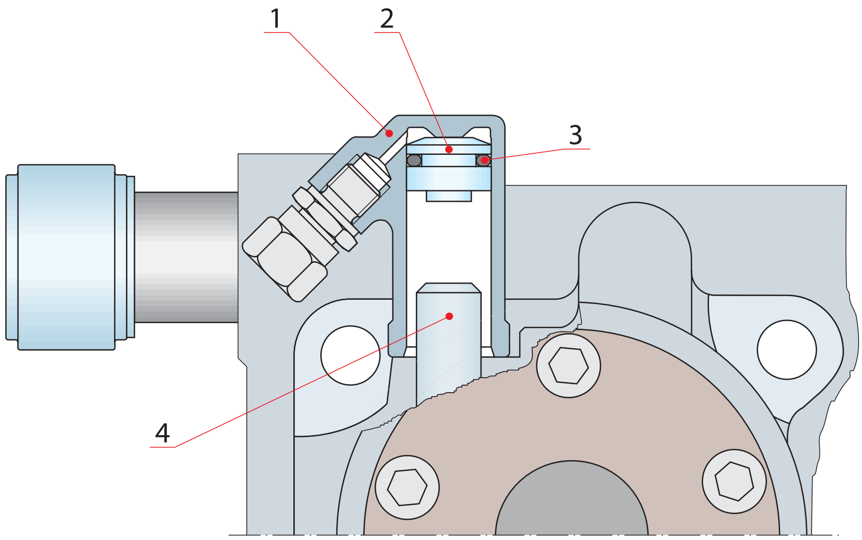
2 Adjustment of stop position

- The electro-pneumatic overspeed trip device requires no adjustment.
- If a fuel rack position of less than 3 mm cannot be obtained, check for wear.

3 Check and adjustment of tripping speed

- See section 22.4.2.

Electro-pneumatic overspeed trip device



1. *Cylinder,* 2.*Piston,* 3.*O-ring ,* 4.*Fuel rack*

Fig 22-2 202251 V2

22.3. Speed governor V1

Data and dimensions
Governor: Mechanical-hydraulic type
Weight: 19 kg

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.

22.3.1. Hydraulic governor drive V1

The governor is driven by a separate drive unit, which, in turn, is driven by the camshaft through helical gears. The governor is fastened to this drive unit and connected to the drive shaft through a serrated connection. The serrated coupling sleeve is secured with spring pins. The governor, with drive, can thus be removed and mounted as a unit or the governor can be changed without removing the drive unit.

Pressure oil is led, through drillings in the bracket, to the bearings and to a nozzle for lubricating the gears.

Check at recommended intervals:

- 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.

Change worn parts.

22.3.2. Removing the governor

V4

1 **Loosen the terminal shaft lever (3) and the governor electrical connection.**

2 **Open the governor fastening screws (4).** Pull the governor vertically upwards. Ensure that the governor does not fall or rest on its driving shaft, see Fig 22-1.

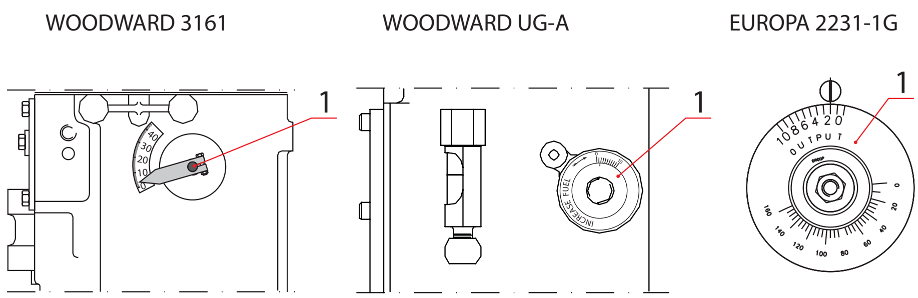
22.3.3. Mounting of governor

V5

When mounting the governor, proceed as follows:

1 **Put the fuel rack and governor in a position according to Fig 22-4.**

Governor terminal shaft position



1. *Position indicator of governor.*

Fig 22-3

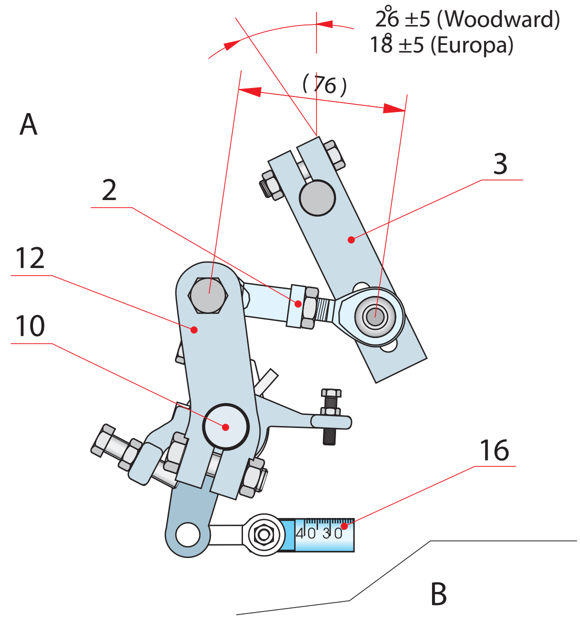
202258 V2

2 **The lever for governor must be assembled in a position according to Fig 22-4.**

3 **Fit the link rod (2) between the levers and lock the adjustment.**

4 **Check according to section 22.2.1.**

Governor shaft settings



2. *Adjustable link rod,* 3. *Lever for governor,* 10. *Control shaft,* 12. *Lever*

A: *Governor shaft,* B: *Engine block*

Fig 22-4 202259 V2

Table 22-2 Governor basic settings

Governor type	Fuel rack (mm)		Governor indicator
	FD	LD	
3161	6	3	7.2
UG-A	6	3	1.7
Europa 2231-IG	6	3	2

22.4. Electro-pneumatic overspeed trip device V16

See Fig 22-4 Electro-pneumatic overspeed trip device.

The overspeed trip device is controlled electronically . Air pressure of maximum 30 bar is used as an operating medium. The tripping speed is 15 % above the nominal speed.

The three-way solenoid valve (10, Fig 21-2,) receives the stop signal for overspeed from the electronic speed measuring system. See chapter 21. section 21.3. The solenoid valve is also connected to the stop system.

When the solenoid valve opens, air is fed into the three-way valve that conveys pressurized air to the cylinders (9, Fig 21-2.) Each injection pump has one cylinder. The piston of the air cylinder actuates the pin on the fuel rack moving it to the stop position.

The stop signal is normally energized for the time required to stop the engine completely. When de-energized, the air is evacuated through the three-way valve.

The solenoid valve (10)Fig 21-2 can also be operated manually.

22.4.1. Check and adjustment of stop position

V3

1 **Check of stop position**

- Set the stop lever in the work position and the terminal shaft lever in the max. fuel position.
- Release the overspeed trip device manually.
- Check that the fuel rack positions are less than 3 mm.

2 **Adjustment of stop position**

- The electro-pneumatic overspeed trip device requires no adjustment.
- If a fuel rack position is more than 3 mm, check for wear.

22.4.2. Check of tripping speed

V1

Check the tripping speed at idle by increasing the engine speed above the nominal speed by slowly bending the lever (12) with a suitable wrench in direction from the engine. When the nominal speed is reached and exceeded, the governor begins to decrease the fuel setting, i.e. the control shaft must be bended against the governor force.

Warning!
Do not increase the engine speed by more than 60 RPM above the tripping speed.

The tripping speed should be 15 % above the nominal speed, see chapter 06., section 06.1.

22.4.3. Adjustment of tripping speed

V8

Adjustments will be made in the box of the electronic speed measuring system, see instructions for speed measuring system, 23.

22.4.4. Maintenance

V1

1 **Three-way solenoid valve**

- If the solenoid is out of order, replace it by a new one.
- If the valve does not move, clean all channels. Check the valve piston.
- If air is leaking to the cylinders, change the sealings.

2 **Air cylinder, Fig 22-2 .**

- Check for wear.
- Check the tightness of the piston. Replace sealings by new ones, if necessary. Take care not to deform the teflon ring outside the O-ring.
- Lubricate the sealings and piston with lubricating oil.
- Check that the piston does not stick.

23. Instrumentation and Automation

23.1. UNIC automation system

V9

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.

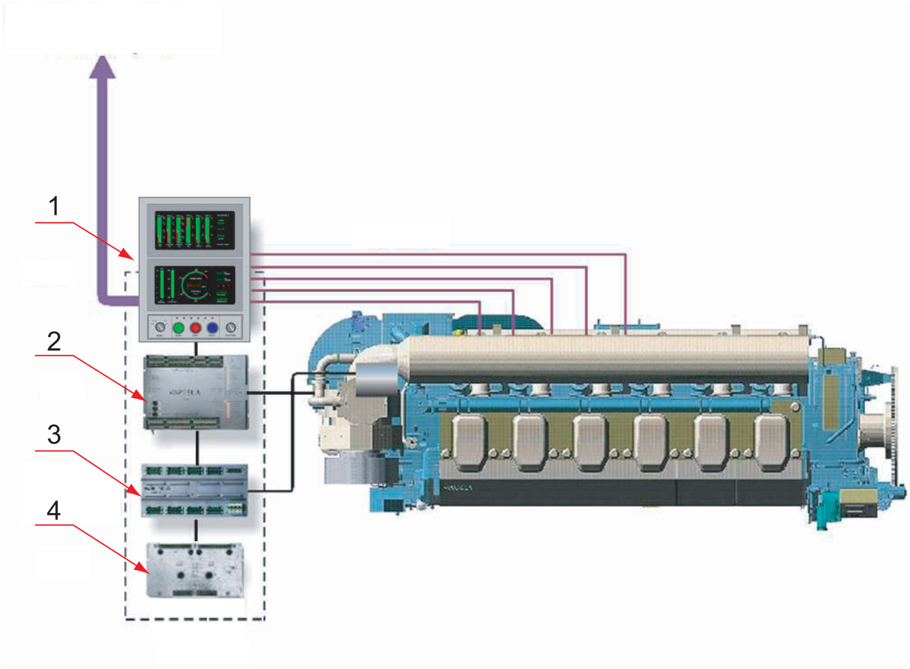
UNIC C1 Automation System

This engine is equipped with UNIC C1 automation system.

The system is a combination of the traditional approach of point-to-point wiring of sensor signals to an external alarm system, and a modern system handling fundamental engine safety and engine speed control.

Most sensors on UNIC C1 engines (see installation specific diagrams for details) are connected directly to the external system for remote alarm & safety handling. Sensor signals used for local indication are also wired to the LCP.

Overview of UNIC C1 system



1. *Local control panel* 2. *Engine safety module* 3. *Main control module*
4. *Power distribution module.*

Fig 23-1 V4

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.

The system is handles 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.
- Interfaces & converts all sensors and control signals to the external systems.
- 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).

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.

Sensor with flying lead design

Fig 23-2

V1

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.

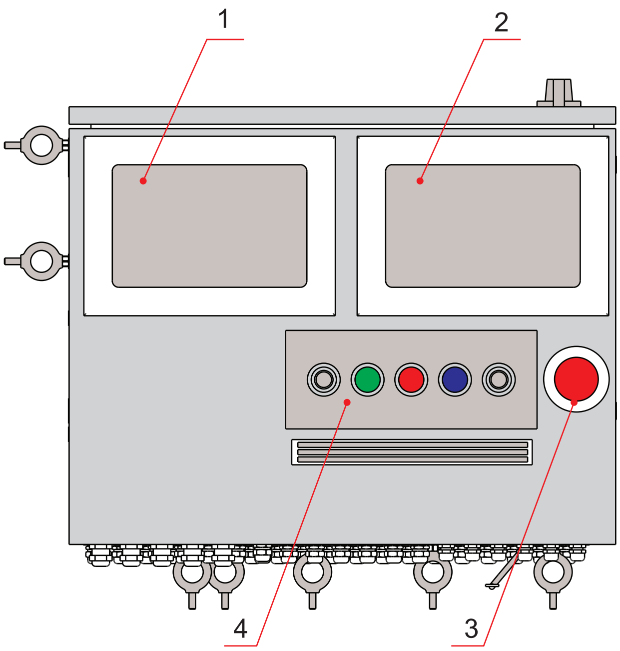
23.3. Parts of the UNIC System

23.3.1. Local control panel

V17

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 the following switches and buttons: a mode selector switch, a start button, an emergency stop button and a reset button, along with WIP-1*, a graphical display screen, and WIP-2*, a bar-graph display screen.

Connecting box of UNIC C1



1. *WIP-2* 2. *WIP-1* 3. *Emergency stop button* 4. *WCP-1*

Fig 23-3 V1

23.3.1.1. WIP-1* and WIP-2* displays

V4

WIP-1* & WIP-2* displays

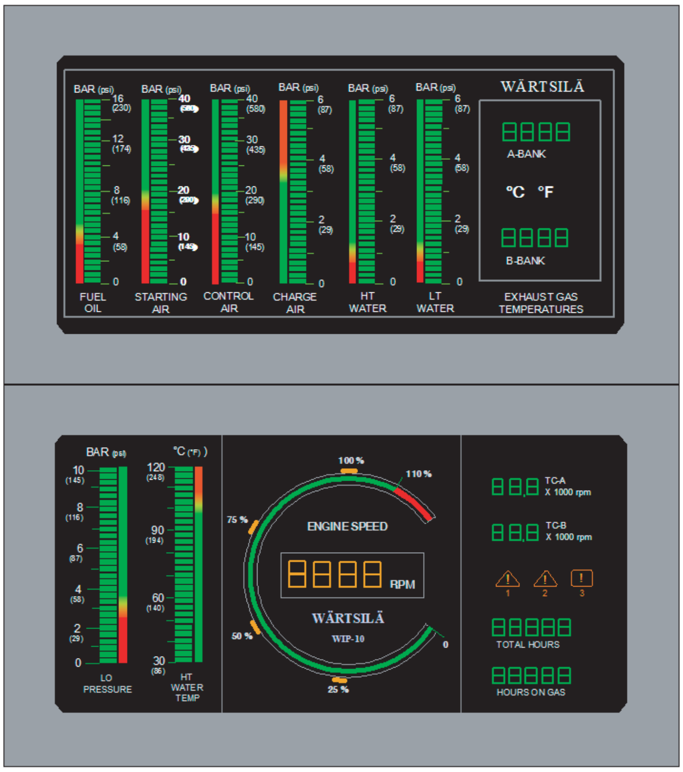


Fig 23-4

V1

- The WIP-1* display has indications of the following measurements:
  - Engine speed, a graphical relative indication of 0...120% and a numerical 4-digit indication.
  - Turbocharger speed A-bank, a numerical 3-digit indication.
  - Turbocharger speed B-bank, (if V-engine) a numerical 3-digit indication.
  - Hour counter, a 5-digit numerical indication.
- Bar graph indications for:
  - Lube oil pressure, 0...10 bar.
  - HT water temperature, 30...120 °C.

On WIP-1* there is a triangle symbol with a !-sign inside. The light for this symbol indicates a failure either in the PDM, MCM, ESM or WIP-2*. Also a binary output **Engine control system, minor alarm** will activate in this situation.

Note!
Some additional graphical symbols are appearing on WIP-1*, but these are not used in UNIC-C1 application.

- The WIP-2* display has bar graph indications of the following measurements.
  - Fuel oil pressure, 0...16 bar
  - Starting air pressure, 0...16 bar
  - Control air pressure, 0...40 bar
  - Charge air pressure, 0...6 bar
  - HT water pressure, 0...6 bar
  - LT water pressure, 0...6 bar

Additionally there is a 4-digit numerical indication of the exhaust gas temperature (range 0...750 °C) for each bank (cylinder selectable with selector switch). This is utilised only in marine applications.

On this display there is also pressure indications in PSI (in brackets) and the exhaust gas temperatures can either be displayed in °C or °F.

Normal values are represented with green colour in the bar graphs left of the measurement value, while abnormal values first turn yellow, then red. Abnormal values will create an alarm in the external alarm and monitoring system, as the same sensor signals as used in WIP-2*, in most cases are looped to the external alarm system.

Note!
In case of a sensor failure or sensor signal wire break, the lowest LED element in the bar-graph will flash. In case the sensor or the wiring provides an over-current, the highest LED element will flash.

23.3.1.2. Switches and buttons

V15

Below a description of the switches and buttons used in the LCP.

Control buttons and switches on the LCP

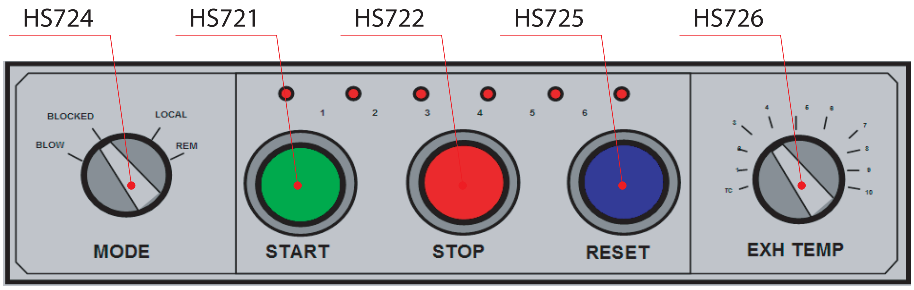


Fig 23-5 V3

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 23-5) 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.
- **HS726 Exhaust gas temperature selector switch** With this selector switch it can be selected, for which cylinder the exhaust gas temperature will be indicated on the display.

23.3.2. Main control module (MCM) V17

This module is an optional part of the system, in case of use of mechanical governors

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.

MCM module

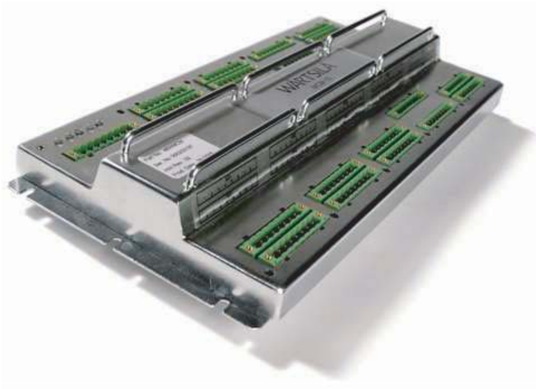


Fig 23-6 V1

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.

Red	Yellow	Execution in	Description
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.
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
- Timing track control*

Note!
* Only on engines with separate timing rack.

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. In/out signals

V3

The UNIC-C1 system has a number of binary input- and output signals used for control and information purposes. Safety-critical input signals must externally be furnished with 22 kΩ termination (end-) resistors for wire break detection. See the wiring diagram for wiring details. All binary output signals from the MCM are connected via internal opto-couplers, for galvanic isolation and protection of the engine-built electronic module. Binary outputs from switches/buttons and the ESM module are connected directly.

23.3.2.3. Binary Inputs

V3

The UNIC-C1 system is equipped with the following binary input signals:

- OS7302 Remote start

If no start blocking is active that is the generating set is in stand-by mode and output "IS872 Engine ready for start" is active, the activation of this input (closed contact) initiates a start of the generating set. The input is activated for minimum 0.5 seconds, after this the start process continues by itself. The input is disabled when the HS724 blow/blocked/local/remote switch is in blow, blocked and local position.

- OS7304 Remote stop

Activation of this input (closed contact) initiates an immediate stop of the generating set. When the generating set has reached zero speed (+ a short delay), the system automatically enters stand-by mode and "IS872 Engine ready for start" output is set high. The engine can now be restarted without performing a reset. The input is disabled when the HS724 blow/blocked/local/remote switch on the engine is in blow-, blocked- and local position. As shutdown mode has higher priority than start mode, simultaneous activation of start and stop (remotely or locally) results in a stop.

- OS7305 External shutdown 4 (emergency stop)

Activation of this input (closed contact) initiates an instant shutdown of the generating set. This shutdown is a latching function, and requires a reset. The input is in parallel with the local emergency stop button. The external contact must be equipped with a 22 kΩ resistor for wire break monitoring. An emergency stop is not overridden by any position of the HS724 blow/blocked/local/remote switch. As emergency stop mode has the highest priority, activation of any other command simultaneously is overruled, if this input is activated.

- OS7309 External shutdown 1 (from switchboard)

Activation of this input (closed contact) initiates an instant shutdown of the generating set. This shutdown is a latching function, and requires a reset.

- OS7312 External start blocking 1

A start is prevented, if this input is activated (open contact).

- OS163 Speed increase

Activation of this input (closed contact) ramps up the speed reference of the internal speed controller. During parallel running in droop mode, the activation of this input leads to a gradual increase of the generating set load. The same input is also used during synchronization.

- OS164 Speed decrease

Activation of this input (closed contact) ramps down the speed reference of the internal speed controller. During parallel running in droop mode, the activation of this input leads to a gradual decrease of the generating set load. The same input is also used during synchronization.

23.3.2.4. Binary Outputs

V7

The UNIC-C1 system is equipped with the following binary output signals:

- IS181 Speed switch 1 ("engine running")

This speed switch is a signal, from the ESM module and activates (contact closes) at 40% of rated speed. It represents the "engine running" level, and gives this information to systems and devices external to the generating set. Contact rating: 110 VDC / 0.5 A.

- IS1741/IS1742 Overspeed shutdown status
- IS2011 Lube oil pressure shutdown status

This alarm signal informs that the generating set has shut down due to low engine lube oil pressure. The signal derives input from a switch in the ESM module. The contact is open in case of Lube oil pressure shutdown. Contact rating: 60 VDC / 0.3 A.

- CV223 Pre-lubrication pump control

This control signal is a potential free,optically coupled, output signal which is active (closed contact) in the stop and stand-by mode. After a delay (same delay as alarm-blocking), it de-activates at start-up when the rotational speed reaches the run mode level (300 rpm). A LED on the opto-coupler indicates that the contact is closed. Contact rating: 30 VDC / 2 A or 250 VDC / 0.4 A.

- HS724 Local/remote indication

This status signal indicates whether the mode switch HS724 local/ remote/blocked/ blow on the local control panel is in remote position or local/blocked/blow position. The changeover contact is configured in such a way, that the local position contact is closed for local, and the remote position contact is closed for remote. It is not possible to remote start and stop the generating set, if the switch is in local, blocked or blow position. A shutdown is however always possible through the OS7305 External shutdown 4 (emergency stop) input.

- IS7602 Stop/shutdown 1 status

This status signal is a potential free opto-couple output signal used to inform that a stop, shutdown or emergency stop is active, and that the generating set has shut down. The contact opens if there is a stop/ shutdown. A LED on the opto-coupler indicates when the contact is closed. The signal is used to let external systems & devices know if the generating set is running or not. Contact rating: 30 VDC / 2A.

- IS4011 HT temperature shutdown status

This alarm signal indicates that the generating set has shut down due to high engine HT water temperature. The signal derives input from a switch in the ESM module. The contact is open in case of HT water temperature shutdown. Contact rating: 60 VDC / 0.3 A.

- OS441 Pre-heater control

This control signal is a potential free,optically coupled, output signal which is active (closed contact) in the stop and stand-by mode. After a delay (same delay as alarm-blocking), it de-activates at start-up when the rotational speed reaches the run mode level (300 rpm). A LED on the opto-coupler indicates that the contact is closed. Contact rating: 30 VDC / 2 A or 250 VDC / 0.4 A.

- IS780 Alarm blocking

This blocking signal is active (closed contact) in stop and stand-by mode. It de-activates at generating set start when the rotational speed reaches run mode level (300 rpm) after a delay. Contact rating: 24 VDC / 0.2 A.

- IS7305 External shutdown 4 status (emergency stop status)

This status signal informs that the generating set has been shut down by the safety system on activation of the remote or local emergency stop button. Contact open if there is an external shutdown. Contact rating: 60 VDC / 0.3 A.

- IB7324 Shutdown status

This status signal informs that the generating set has been automatically shut down by the safety system. Contact open if there is a shutdown. The signal is used by external systems in ships. Contact rating: 60 VDC / 0.3 A.

- IS872 Engine ready for start

This status signal is a potential free opto-couple output signal used to inform that the generating set is ready for start, that is, it is in stand-by mode. The contact is closed if the engine is ready, and no start blockings is active. A LED on the opto-coupler indicates when the contact is closed. Contact rating: 30 VDC / 2 A.

- IS875 Start failure
- NS881 Engine control system, minor alarm
- NS886 Engine control system, major failure

This alarm signal informs that there is a major problem (causing a generating set shutdown). The signal derives input from the MCM module. It activates only in case of a system related failure.

The reasons for a major failure are:

- MCM module failure.
- Dual power supply failure to the MCM or to the actuator driver.
- Actuator major failure.
- Dual speed sensor failure.

Contact open in case of major failure. Contact rating: 24 VDC / 0.2 A.

23.3.3. Engine instrumentation

V1

The following standard set of sensors and solenoids for monitoring, alarm and safety are mounted on the engine. The location of the sensors and the solenoids are shown below.

Table 23-3 Standard sensors

Standard sensors	Code
Fuel oil pressure, engine inlet	PT101
Lube oil pressure, engine inlet	PT201
Lube oil pressure, engine inlet	PTZ201
Starting air pressure, engine inlet	PT301
Control air pressure, engine inlet	PT311
HT Water pressure, jacket inlet	PT401
LT Water pressure, CAC inlet	PT471
Lube oil pressure, TC inlet (main engines only)	PT271
Charge air pressure, engine inlet	PT601
Charge air pressure, engine inlet	PT601-2
Fuel oil temperature, engine inlet	TE101
Lube oil temperature, engine inlet	TE201
Lube oil temperature, TC outlet (main engines only)	TE272
HT Water temperature, jacket inlet	TE401
HT Water temperature, engine outlet	TE402
HT Water temperature, engine outlet	TEZ402
LT Water temperature, CAC inlet	TE471
LT water temperature, LOC outlet	TE482
Exhaust gas temperature, after each cylinder	TE5011A..

Standard sensors	Code
Exhaust gas temperature, TC inlet	TE511
Exhaust gas temperature, TC outlet	TE517
Charge air temperature, engine inlet	TE601
Fuel rack position	GT165
Engine speed 1	ST173
Engine speed 2	ST174
Engine speed, primary	ST196P
Engine speed, secondary	ST196S
Tubocharger speed	SE518
Fuel oil injection pipe leakage	LS103-A
Lube oil low level in oil sump	LS204
Lube oil filter pressure difference	PDT243
Stop lever in stop position	GS171
Turning gear position	GS792

Table 23-4 Control solenoids

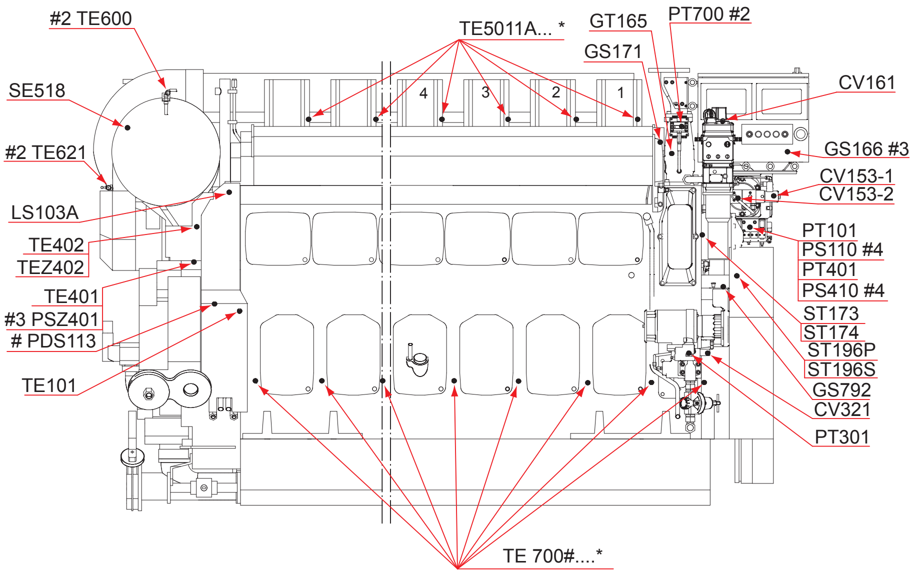
Control solenoids	Code
Start fuel limiter (If forward acting RE2231)	CV151
Governor stop solenoid (If RE2231)	CV152
Stop solenoid 1	CV153-1
Stop solenoid 2	CV153-2
VIC control solenoid	CV381
Starting solenoid	CV321
Charge air limiter, valve 1	CV657-1
Charge air limiter, valve 2	CV657-2

Table 23-5 Optional sensors

Optional sensors	Code
Lube oil temperature, engine outlet	TE202
Lube oil temperature, LOC outlet	TE232
LT water temperature, CAC outlet	TE472
Air temperature, TC inlet	TE600
Charge air temperature, CAC inlet	TE621
Crankcase pressure	PT700
Fuel oil filter pressure differential switch	PDS113
Fuel oil standby pump switch	PS110

Optional sensors	Code
Lube oil press switch, standby pump	PS210
HT water press switch, standby pump	PS410
LT water press switch, standby pump	PS460

Sensors location for UNIC C1 (TC at free end), operating side

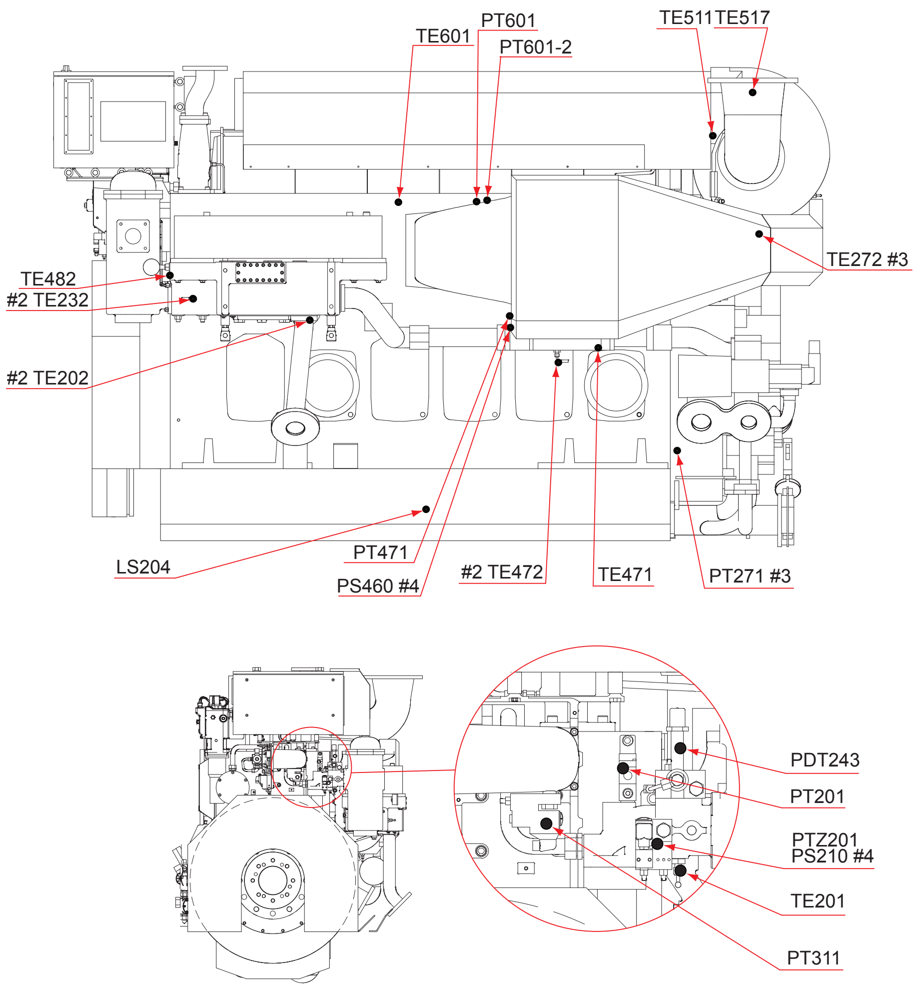


#) *Optional,* **#2)** *FAKS/CBM-option,* **#3)** *If main engine,* **#4)** *Stand by pump options,* ***)** *Depending on cylinder configuration.*

Fig 23-7

V1

Sensors location for UNIC C1 (TC at free end), rear side and driving end

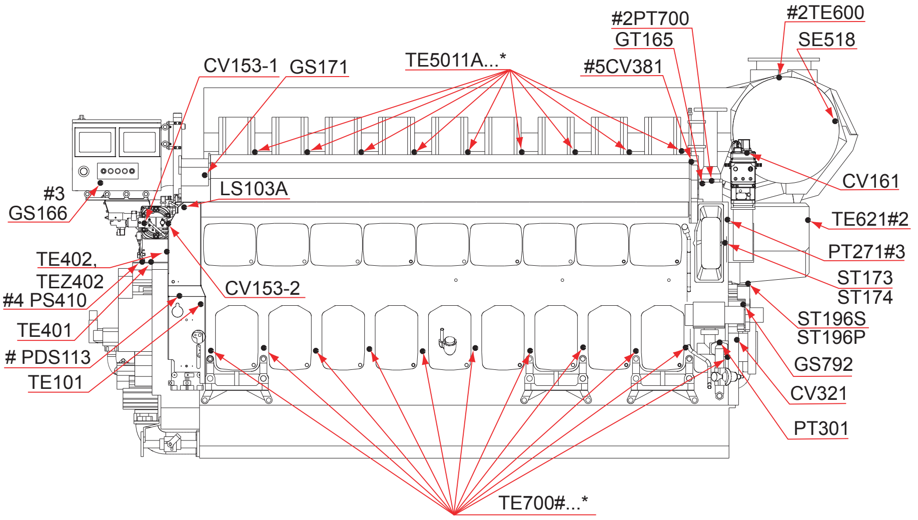


#2) *FAKS/CBM-option,* **#3)** *If main engine,* **#4)** *Stand by pump options,* ***)** *Depending on cylinder configuration.*

Fig 23-8

V1

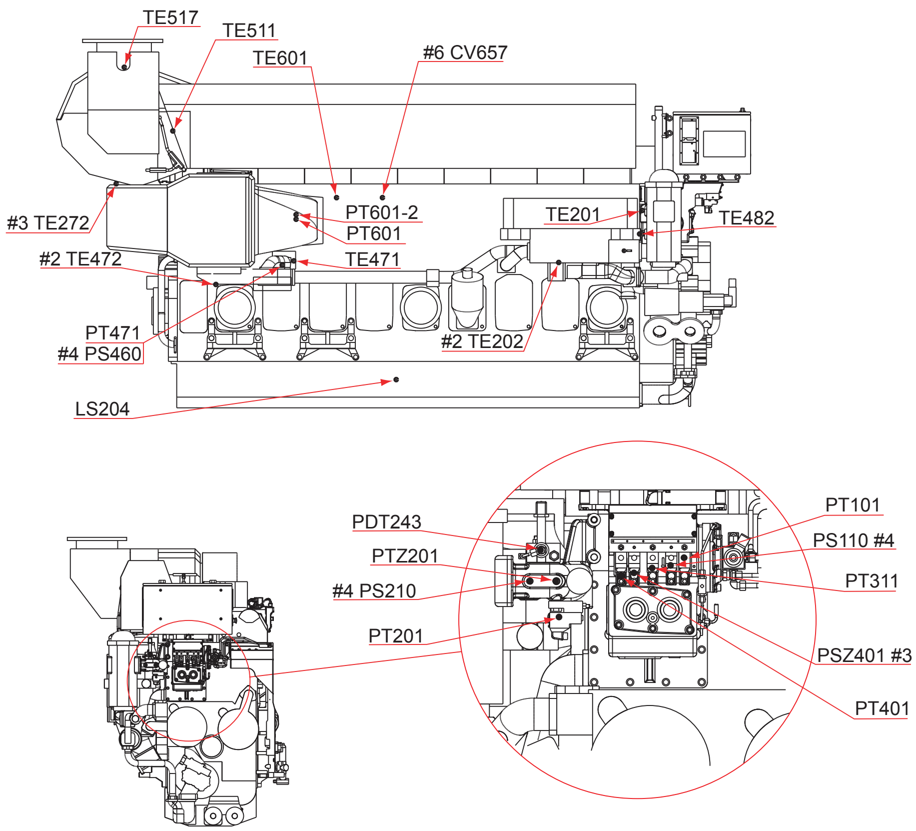
Sensors location for UNIC C1 (TC at driving end), operating side



#) *Optional,* **#2**) *FAKS/CBM-option,* **#3**) *If main engine,* **#4**) *Stand by pump options,* ***) *Depending on cylinder configuration,***#5**)*If VIC (Variable inlet valve).*

Fig 23-9 V1

Sensors location for UNIC C1 (TC at driving end), rear side and driving end



#2) *FAKS/CBM-option,* #3) *If main engine,* #4) *Stand by pump options,**) *Depending on cylinder configuration,*#6)*If AWG (Air waste gate).*

Fig 23-10 V1

Even if the above mentioned sensors are considered as standard the amount and type of sensors can in special cases vary, depending on the needs for various installations. The actual set of sensors and other electrical equipment mounted on the engine, as well as alarm, load reduction and shutdown set points, can be found in the installation specific documentation. See, Chapter 09: Specific Installation data.

23.3.4. Engine Safety Module ESM V3

The ESM (Engine Safety Module) module handles the fundamental engine safety, but also a number of speed measuring functions and it feeds these signals to dedicated instruments. The ESM is also the interface to the engine shutdown devices and local instruments and the module constitutes also the major signal interface to external systems of the engine.

The ESM module design is largely redundant, based on hardwired logic and design meeting the strongest safety regulation. All adjustments are performed with DIP-switches and trimmers i.e. the module needs no programming for application set-up.

The ESM module is located behind a window in the engine cabinet, which makes it possible to view all the status LED's of this module without opening the cabinet door.

ESM module

Fig 23-11 V1

Front panel of ESM

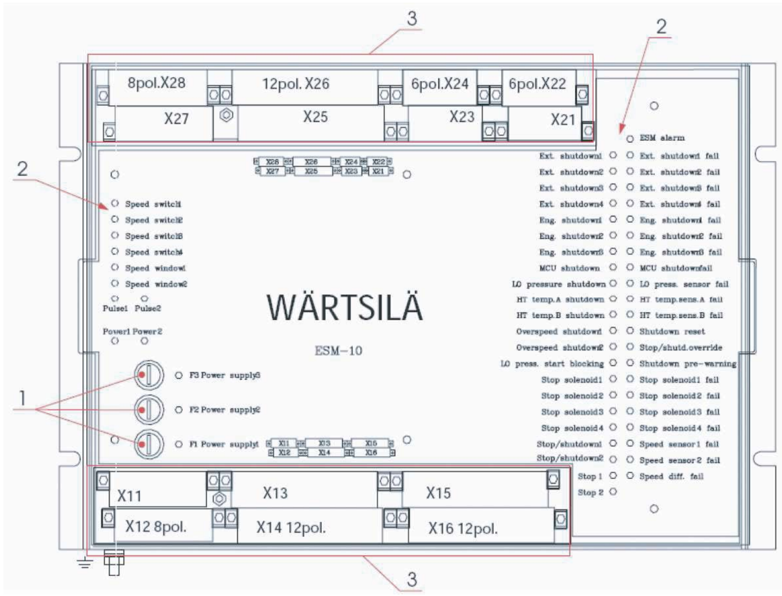


Fig 23-12

V1

1.*Fuses for power supply.*2.*LED indications for function of module.* 3.*Connectors (inputs/outputs).*

23.3.4.1. ESM power supply

V2

ESM internal power supply principle

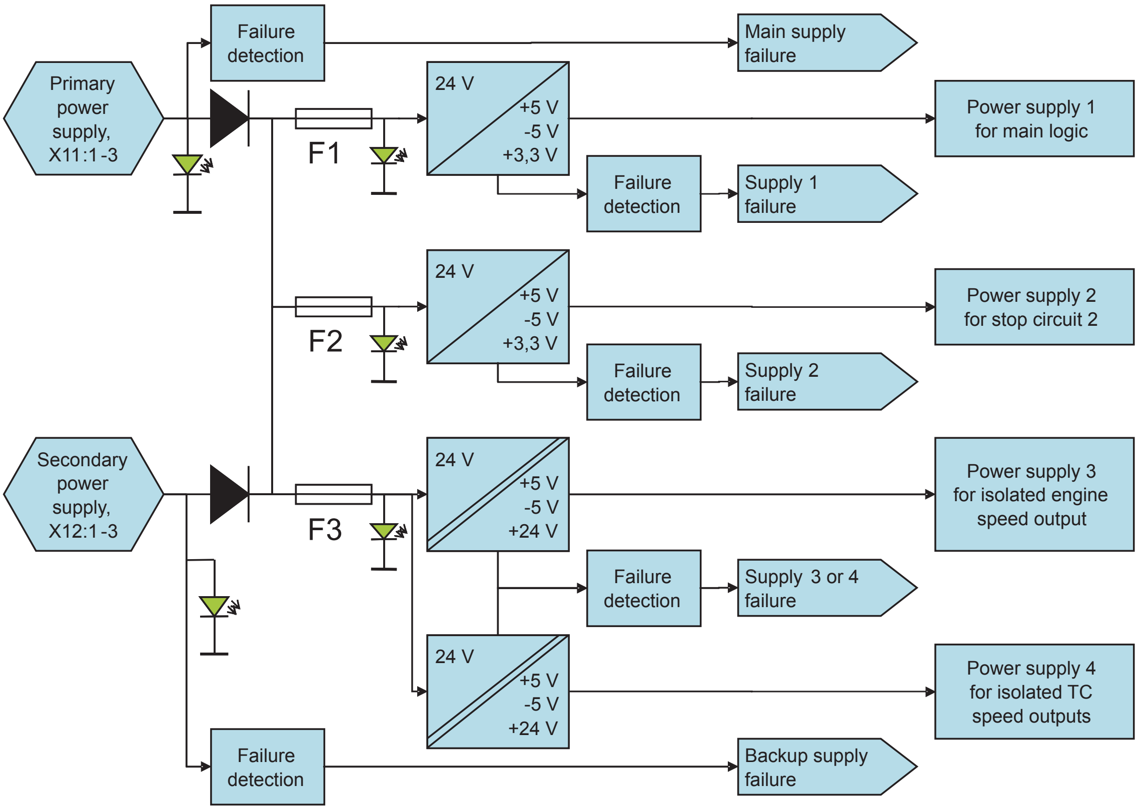


Fig 23-13

V3

To ensure that the module 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).
    - Power supply 1-4, (internal power supplies).
- LED indications (green) provided:
  - Power 1, (primary).
  - Power 2, (secondary).
  - Fuses 1-3, (internal supplies).
- Fuse values for ESM:
  - F1 = 3,15 AT
  - F2 = 3,15 AT
  - F3 = 0,25 AT

23.3.4.2. Speed measuring and speed switches

V18

Speed measuring and overspeed protection principle

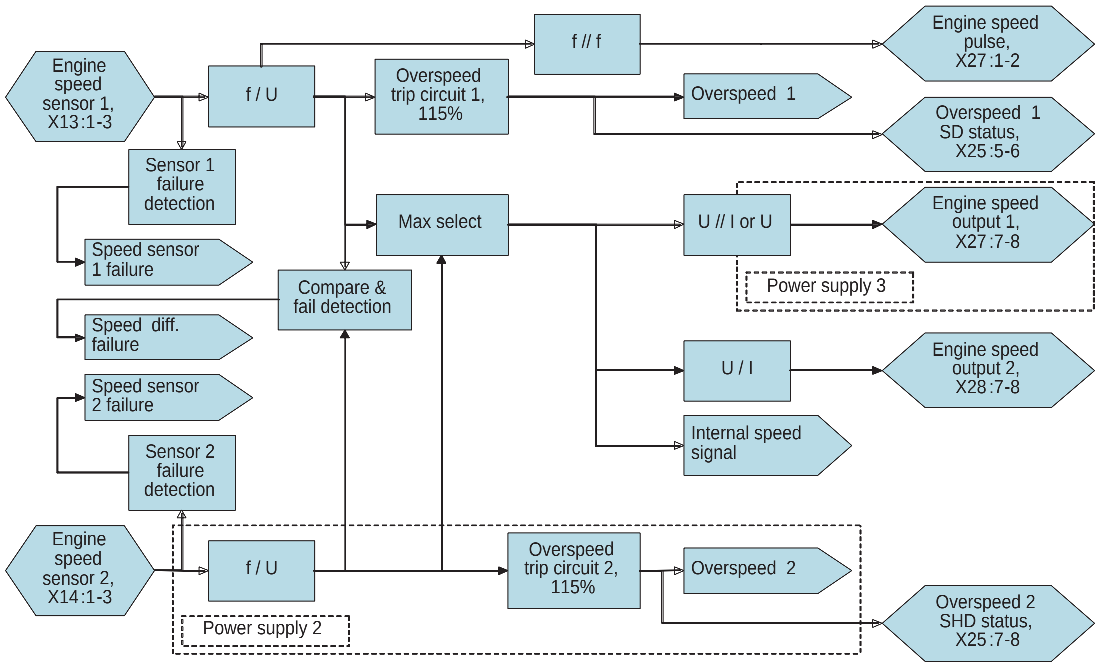


Fig 23-14

V1

The engine speed is measured with two independent speed sensors (see section 23.3.4.3) with separate supply circuits and with separate sensor failure detection circuits. The sensors are of inductive proximity PNP-type. The frequency from the speed sensors are converted into analogue voltages proportional to the rotational speed. The voltage signals are used to trig the internal overspeed trip circuits in ESM. Both overspeed limits are fixed to 115 % of rated engine speed.

Failure detection:

- 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 < 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 trigs ESM alarm output after 2 s delay, if failure remains.

Speed outputs:

- Engine speed output 1 (0-10 VDC or 4-20 mA depending of ESM type) is connected to external systems. The signal is galvanically isolated and short circuit proof.
- Engine speed output 2 (4-20 mA) is used internally for local indication (in WIP-1*).

Overspeed shutdown:

- Trigging point for overspeed shutdown 1 is 115 % of rated engine speed.
- Trigging point for overspeed shutdown 2 is also 115 % of rated engine speed.
- Driver outputs Stop solenoid 1 and Stop solenoid 2 activate the two stop solenoids CV153-1 and CV153-2. Stop solenoid 2 is only activated in case of emergency stop/overspeed.

LED indications provided:

- Speed sensor 1 failure, yellow.
- Speed sensor 2 failure, yellow.
- Speed differential failure, yellow.
- Speed pulse 1, green.
- Speed pulse 2, green.
- Speed switch 1 ("engine running"), green.
- Overspeed shutdown 1, red.
- Overspeed shutdown 2, red.

Status/control outputs provided:

- Speed switch 1 is used as "engine running" information, and is part of the external interface of the engine. The same internal switch also controls the hour counter.
- Speed switch 2 has configurable switching level and is also part of the external interface of the engine.
- The two overspeed status switches IS1741 and IS1742 are connected in series external to ESM, and are part of the binary output signals of the engine.

23.3.4.3. ESM speed sensor

V4

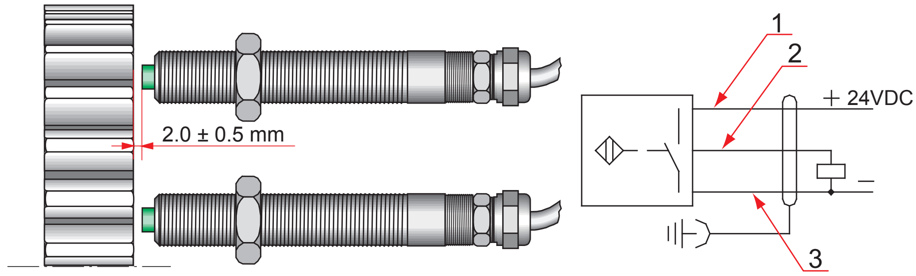
The rotational speed of the generating set is measured with a touch free inductive PNP-type proximity sensor. A 24 V DC current is supplied to the sensor from the ESM. The third pin of the sensor gives the speed proportional pulse train output. The pulse output voltage level varies between two fixed levels: 0 V DC and 24 V DC.

The electronics of the M12x1 flying lead sensor is resin-moulded into a tubular housing of nickel plated brass.

a) **Mounting the sensor:** Turn the engine until the top of a cog is visible in the sensor mounting hole. Carefully screw in the sensor by hand. Unscrew it approximately 1.5 revolutions for a sensing gap of 2.0±0.5 mm, and tighten the counter nut well with a spanner.

Note!
Do not run the engine while the sensor is being adjusted.

Engine speed sensor



1. *Black* 2. *Brown* 3. *Blue.*

Fig 23-15

V2

23.3.4.4. Stop and shutdown signals

V20

Lubricating oil pressure

A dedicated safety sensor (PTZ201 lubricating oil pressure) is connected to the ESM to activate the shutdown if the lubricating oil pressure is low. This analogue sensor (separate from the one connected to external systems) shuts down the engine at predefined pressure and delay set-points in the ESM.

Set-points for low lubricating oil pressure shutdown:

- 2.0 bar
- 2 seconds (delay)

If a sensor failure is detected, the shutdown is blocked and the sensor failure is indicated.

Provided sensor failure detection:

- Sensor failure indicated when the signal is out of range (<3.5 mA or >20.5 mA).
- ESM alarm output activates after 2 seconds, if the failure remains.

Provided LED indications:

- Lubricating oil pressure sensor failure, yellow.
- Lubricating oil pressure shutdown, red.
- Lubricating oil pressure start blocking, red

Provided status outputs:

- LO oil pressure shutdown status is part of the external signal interface of the engine.
- Oil pressure start-block is part of the external signal interface of the engine.

HT water temperature

Dedicated safety sensors (TEZ402 HT water temperature, jacket outlet) are connected to the ESM to activate the shutdown, if the HT water temperature is too high. The PT-100 signals of these analogue sensors are converted into internal voltage signals at the input stages in the ESM, and are used for further processing. A 4-20 mA output derived from the higher of these signals is used for local indication of the HT water temperature on the WIP-1*.

Set-point for high HT water temperature shutdown:

- 110 °C

Note!
In main engines in ship installations, this shutdown is disabled, and load reduction is initiated on the basis of another sensor signal in the external system of the engine.

Provided sensor failure detection:

- Sensor failure indicated when the signal is out of range.
- ESM alarm output activates after 2 seconds, if the failure remains.
- If a sensor failure is detected, the shutdown is blocked and the sensor failure is indicated.

Provided LED indications:

- HT water temperature sensor failure, yellow.
- HT water temperature shutdown, red.

Provided status output:

- HT temperature shutdown status is part of the external signal interface of the engine.

23.3.4.5. Shutdown reset

V7

There is a *Shutdown reset* input on ESM, and this is connected in parallel with the reset input of MCM (if used). Reset has to be pressed after all automatic shutdowns, as all shutdowns are latching in UNIC system. A reset will release this latch, and a start of the engine is possible to perform. Reset does however not override shutdown signals that are still active. The ESM reset input is disabled when rotational speed is more than 2 % of rated speed.

LED indication provided:

- Shutdown reset, yellow.

23.3.4.6. Other ESM inputs/outputs

V17

The following additional **inputs** are used in the ESM:

- **Stop 1** is activated by the MCM (if used) or by the local and remote stop signals. 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, activated until a predefined delay has elapsed, or until the reset is pressed. A red LED indicates that the Stop 1 input is activated. In this situation, an external status signal, the binary output Stop status is activated.
- **Stop 2** is activated by the LCP during an *engine blow* situation. Activation of this input keeps the primary electro-pneumatic stop solenoid and the governor stop solenoid energized during the blow procedure, to secure that the engine does not start. This input is non-latching , that is, reset is not necessary after the blow. A red LED indicates that the Stop 2 input is activated. In this situation, an external status signal, the binary output Shutdown status is not activated.
- **Main controller shutdown** is activated by the MCM (if used) in case of an automatically generated shutdown. 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, reset is required to release the shutdown. Signal interruption failure detection (using a 22 kΩ resistor) is provided between the two modules. LED indicators for *Main controller shutdown* (red) and *Main controller shutdown failure* (yellow) are provided.
- **External shutdown 2** is connected to the external safety system. Activation of this input keeps the primary electro-pneumatic stop solenoid energized, and the engine shuts down. This input is latching, that is, reset is required to release the shutdown. A signal interruption failure detection (using a 22 kΩ resistor in marine

configurations) is provided between the two modules. LED indicators for External shutdown 2 (red) and External shutdown 2 failure (yellow) are provided.

- **External shutdown 4** is connected to an external emergency stop signal, and the signal is in parallel with the local *HS723 Emergency stop* button. Activation of this input keeps both electro-pneumatic stop solenoid and the governor stop solenoid energized, and the engine will shut down. This input is latching, that is, reset is required to release the shutdown. Signal interruption failure detection (using a 22 kΩ resistor in marine configurations) is provided between the module and the external emergency stop button. LED indicators for *External shutdown 4* (red) and *External shutdown 4 failure* (yellow) are provided.

The following additional outputs are used in the ESM:

- **Stop status** activates when the manual stop is activated.
- **Shutdown status** activates in case any ESM initiated shutdown or the External shutdown 4 input is activated.
- **Stop/shutdown status 1** activates when the manual stop has been activated, or in case any ESM-initiated shutdown or an external shutdown input is activated.
- **External shutdown status 2** activates in case the External shutdown 2 input is activated.
- **External shutdown status 4** output in the ESM activates in case the External shutdown 4 (emergency stop) input is activated.

23.3.5. Power distribution module (PDM) V20

The power supply of the engine is set up according to overview scheme below.

Power supply and distribution principle

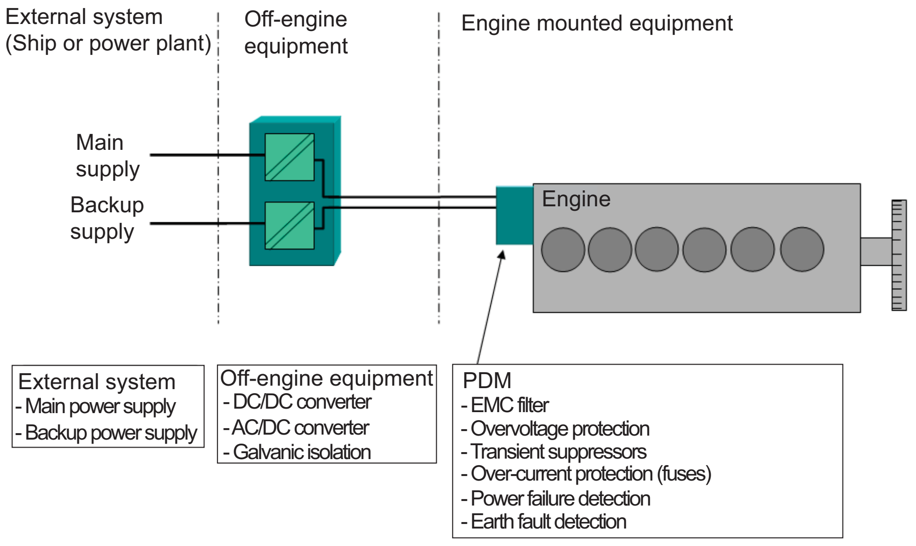


Fig 23-16 442381 V1

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

PDM module

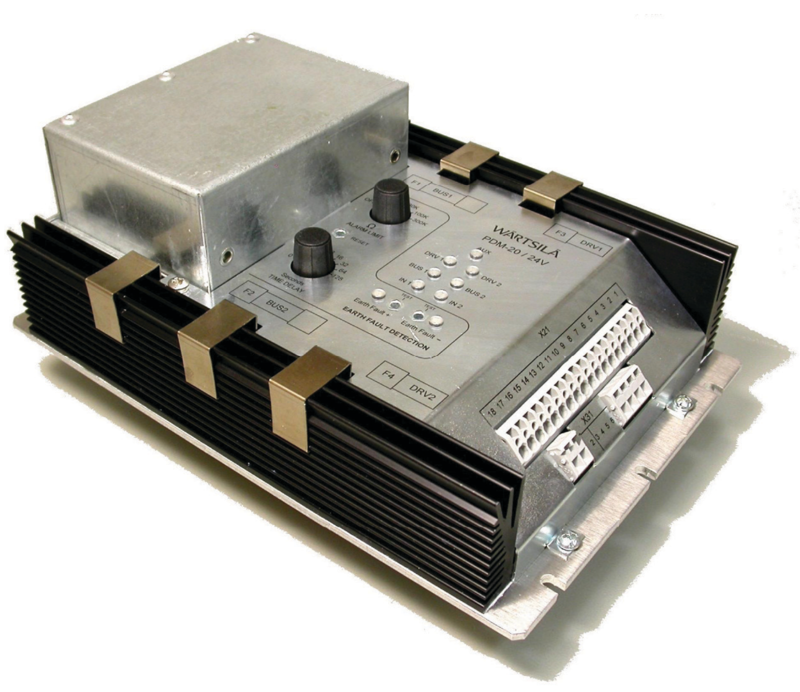
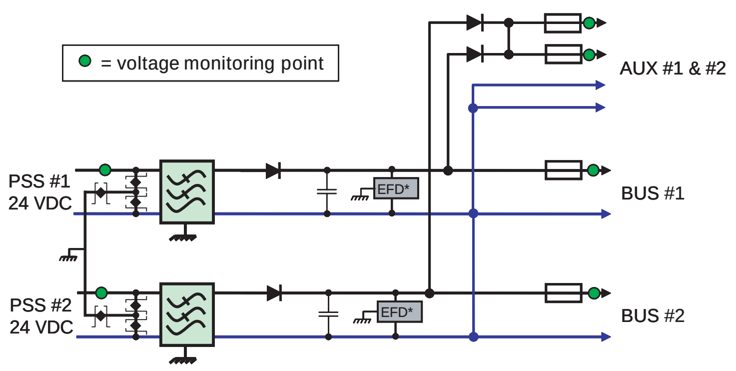


Fig 23-17 V1

Internally, the PDM is designed in the following principal way.

Principal internal design of PDM



*) when EFD not handled by external supply

Fig 23-18 V1

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.
- 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. A time delay for the activation of the earth fault is selectable between 0 - 128 seconds with a 9-step rotational switch.

Fuse sizes are:

- BUS 1: 10A
- BUS 2: 10A
- AUX 1: 10A
- AUX 2: 10A

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.

23.4. 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.

Step mode is active when INC/DEC pulse mode selector is set true

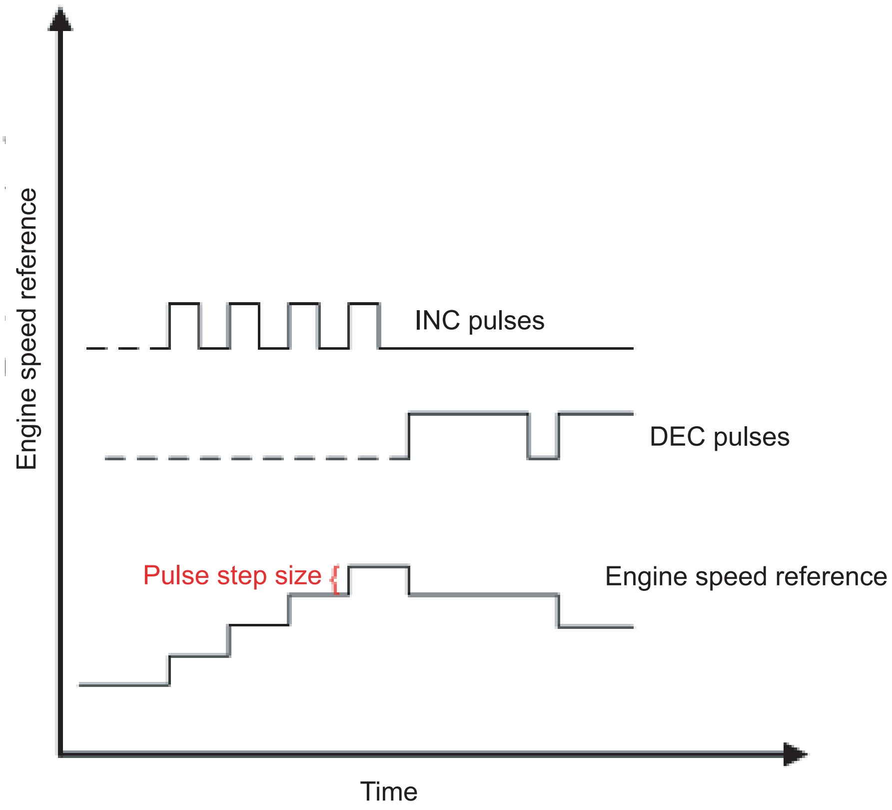


Fig 23-19 V1

Ramping mode is active when INC/DEC pulse mode selector is set false

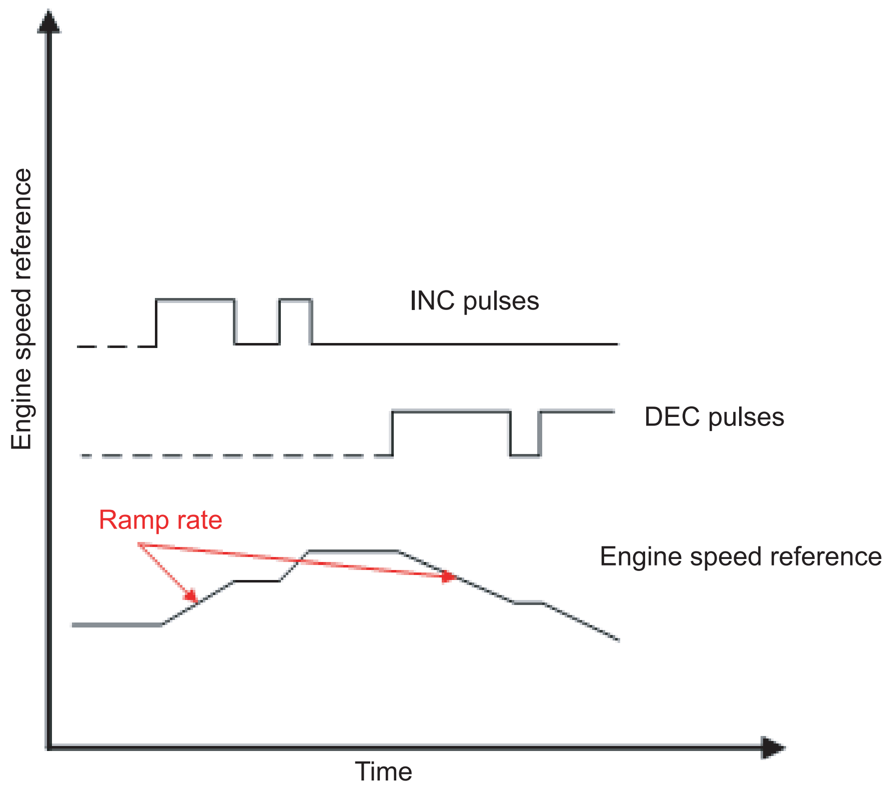


Fig 23-20 V1

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.

Clutching the first engine

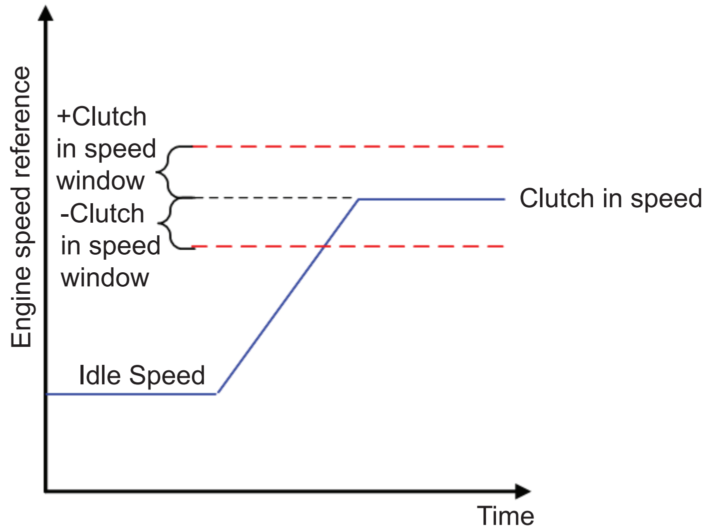


Fig 23-21 V1

Clutching the second engine

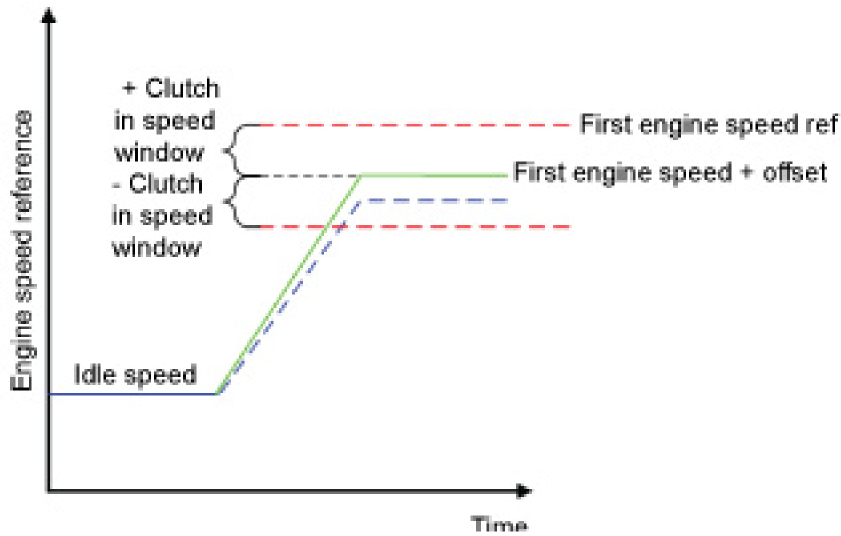


Fig 23-22 V2

Speed goal reference during start sequence, depending on pre-set of binary inputs.

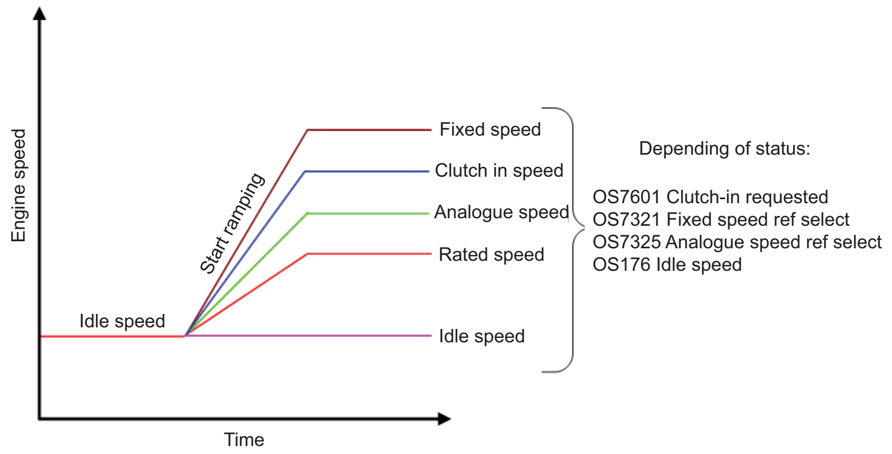


Fig 23-23 V1

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.

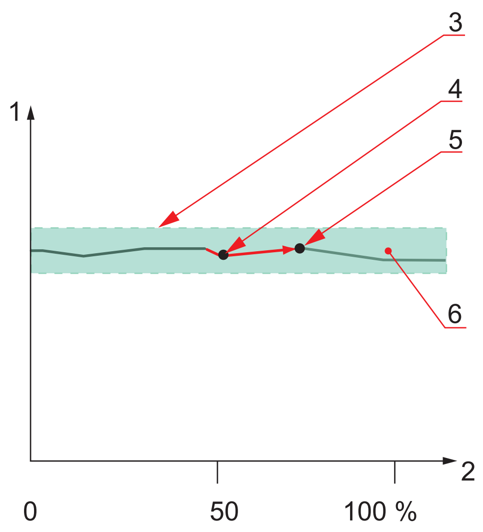
23.4.4. kW control mode V20

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.

kW control mode



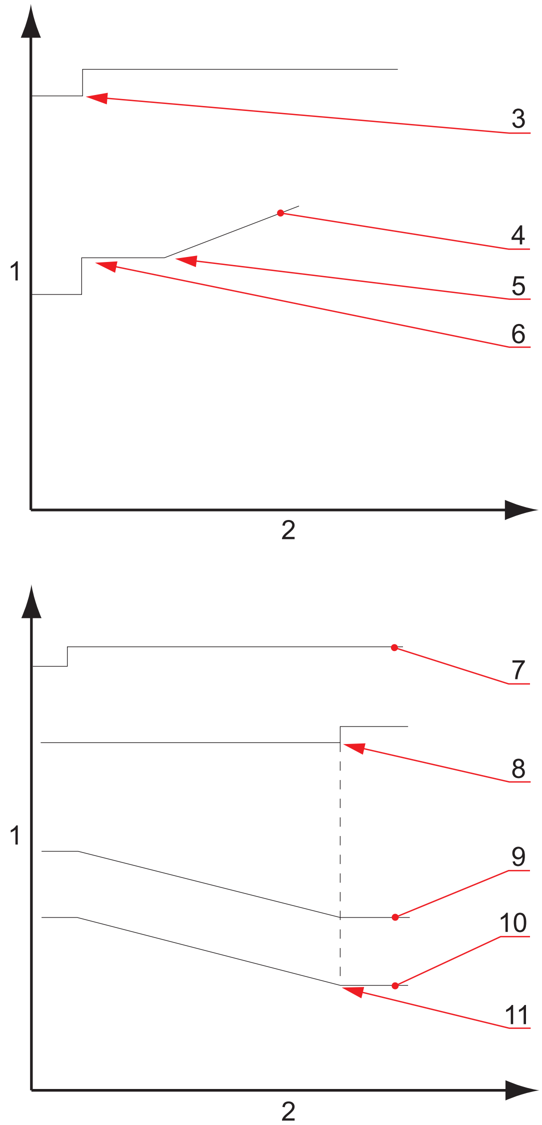
1. *Engine speed (rpm)* 2. *Engine load (%)* 3. *Operating area for true kW control* 4. *Operating point with old load reference* 5. *Operating point after ramping to new load reference* 6. *Grid frequency*

Fig 23-24 V2

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.

Relative base load reference



1. *Engine load reference* 2. *Time* 3. *Gen CB is closed* 4. *Engine load reference* 5. *Engine load reference is started to ramp to goal reference* 6. *Relative base load is set to engine load reference* 7. *OS7321, Engine unload* 8. *Gen CB open command is set active* 9. *Engine load reference* 10. *Engine load* 11. *Relative trip load*

Fig 23-25 V4

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.

Droop mode

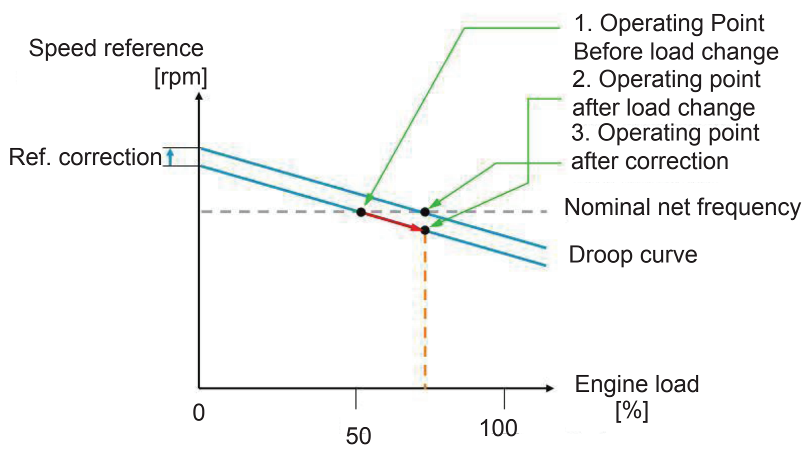


Fig 23-26

V1

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 %.

External system compensates the negative effect derived from Droop slope

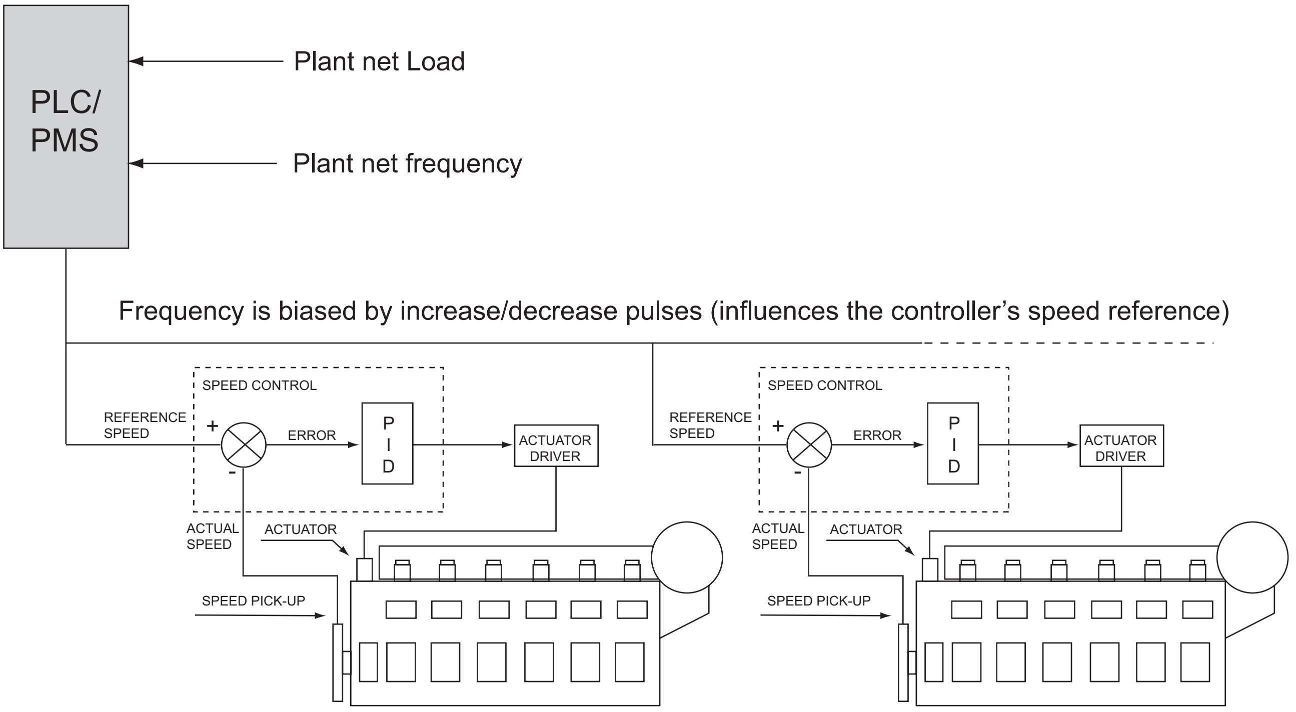


Fig 23-27 V1

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.

Ramp control in droop mode

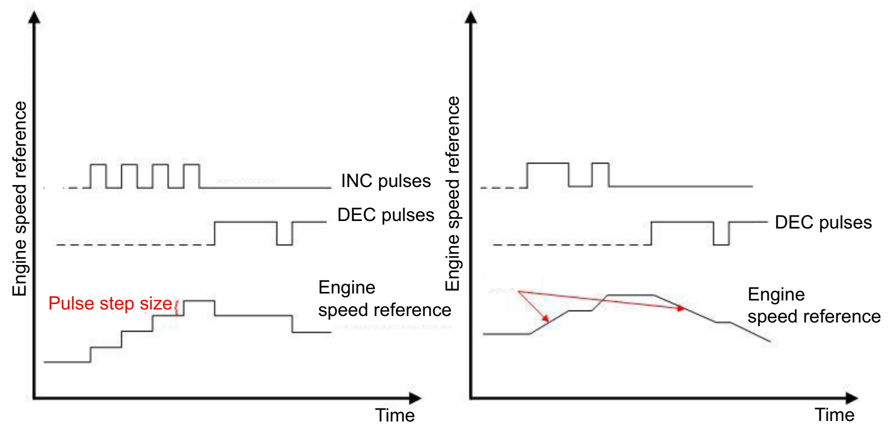


Fig 23-28 V1

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.

Operating point diagram

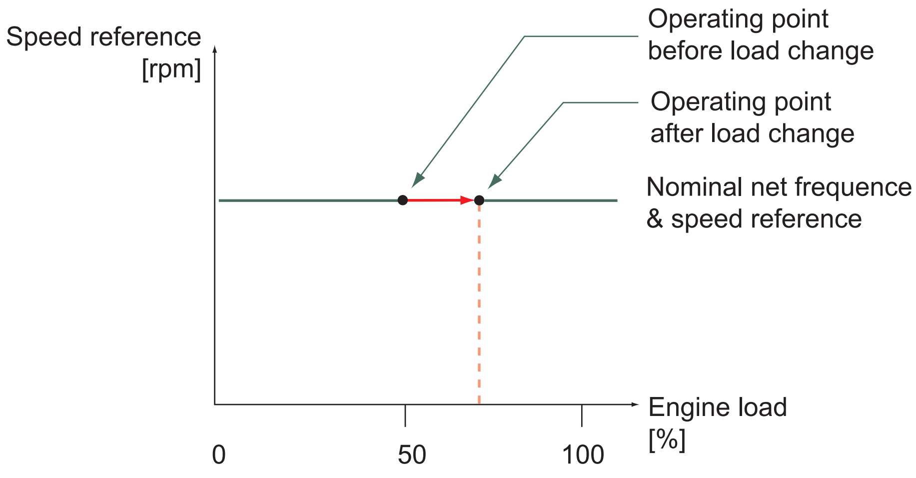


Fig 23-29 V1

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.

Ramping of LS ramp during uploading

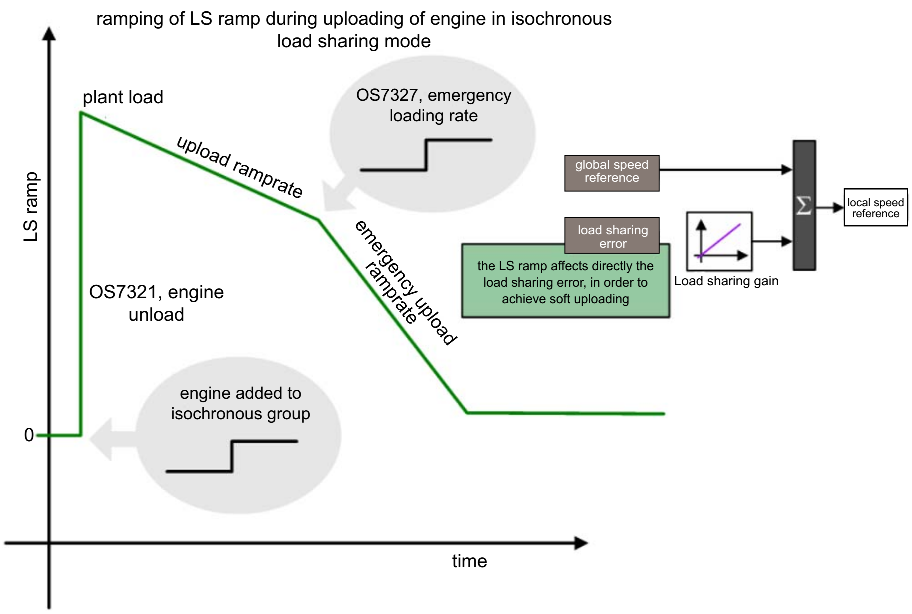


Fig 23-30 V1

Ramping of LS ramp during unloading

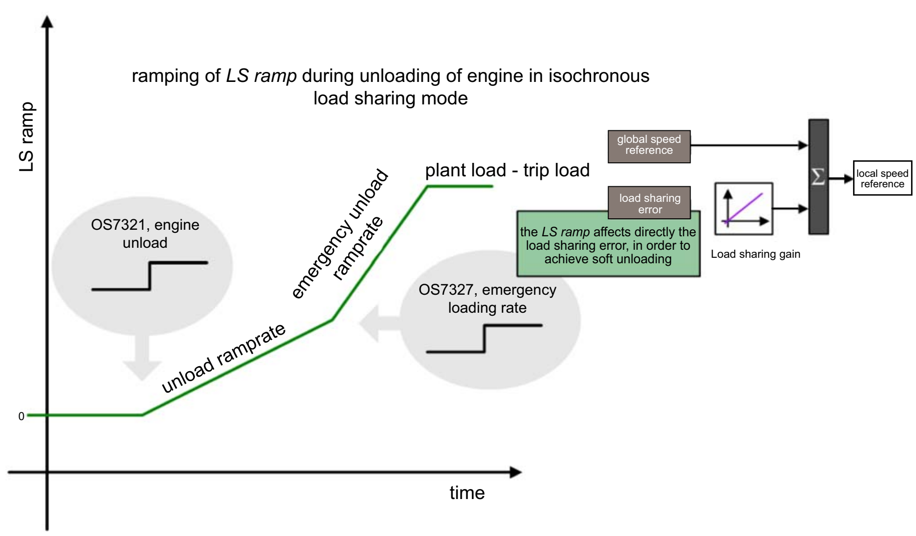


Fig 23-31 V1

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.

23.4.7. Backup governor (optional) V2

In some mechanical main propulsion engine applications a mechanical backup governor is provided. Should the MCM speed controller have a dual power supply loss or otherwise fail, the mechanical backup governor will automatically take over. This mechanical governor will however only provide fundamental speed governing in droop, while special dynamic features and control modes will not be provided.