INSTRUCTION MANUAL

Number	**41508- 41514**
Installation	**SURMA ENERGY**
Engine type	**WÄRTSILÄ 18V34SG**
Engine number	**22606, 22607, 22608, 22609**
Specification	**174415**

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

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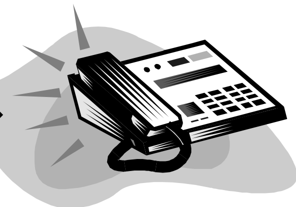

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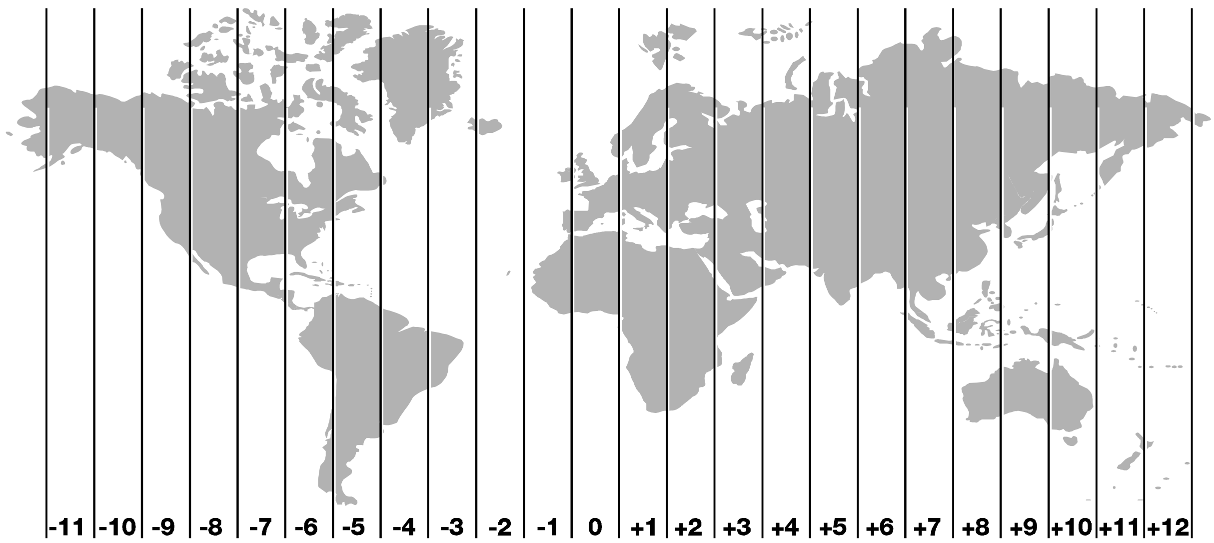

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00. Contents, Instructions, Terminology

00.1 Contents of the Manual

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

00.2 General rules

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

2 **Keep an engine log book for every engine.**

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

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

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

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

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

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

00.3 Terminology

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

Terminology

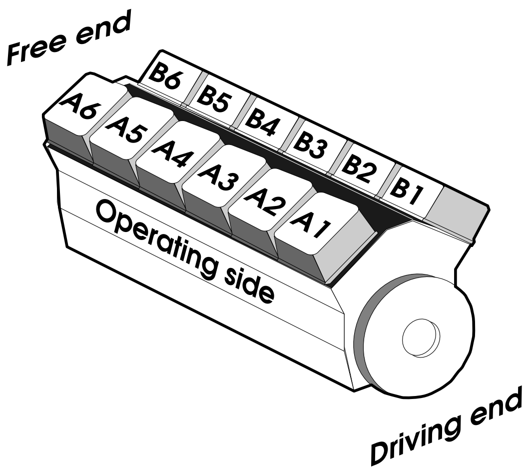

Fig 00-1 3200549501

Designation of bearings.

- Main bearings. The flywheel bearing is No. 0, the first standard main bearing is No. 1, the second No. 2 etc.

- The thrust bearing rails are located at the flywheel bearing. The outer rails close to the flywheel are marked with 00 and the inner rails with 0.
- The camshaft bearings are designated as the main bearings, the thrust bearing bushes being designated 00 (outer) and 0.
- Camshaft gear bearings. The bearings located on the flywheel side are designated 00 and the inner bearings 0.
- Upper and lower bearings shells. In bearings where both the shells are identical, the upper one is marked with “UP”.

Designation of bearings

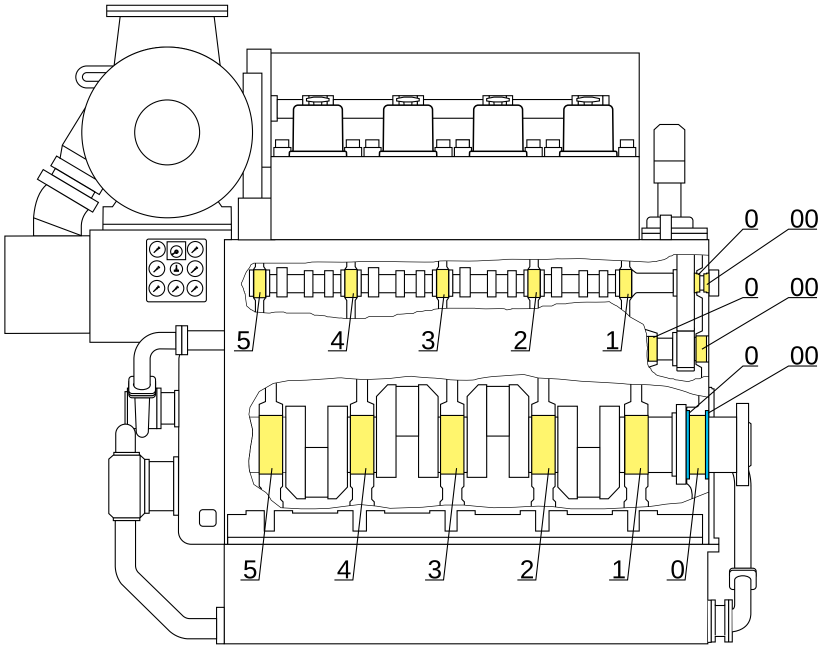

Fig 00-2 3200528935

Operating side and rear side. Details located at the operating side may be marked with “M” (Manoeuvring) and correspondingly “B” for the back of the engine (B-bank on a V-engine).
Clockwise rotating engine. When looking at the engine from the driving end the shaft rotates clockwise.
Counter-clockwise rotating engine. When looking at the engine from the driving end the shaft rotates counter-clockwise.
Bottom dead centre, abbreviated **BDC**, is the bottom turning point of the piston in the cylinder.
Top dead centre, abbreviated **TDC**, is the top turning point of the piston in the cylinder. TDC for every cylinder is marked on the graduation of the flywheel. During a complete working cycle, comprising in a four-stroke engine two crankshaft rotations, the piston reaches TDC twice:
a) For the first time when the exhaust stroke of the previous working cycle ends and the suction stroke of the following one begins. Exhaust

valves as well as inlet valves are then somewhat open and scavenging takes place. If the crankshaft is turned to and fro near this TDC, both exhaust and inlet valves will move, a fact that indicates that the crankshaft is near the position which can be named **TDC at scavenging.**

b) The second time is after the compression stroke and before the working stroke. Slightly before this TDC the fuel injection takes place (on an engine in operation) and this TDC can therefore be defined **TDC at firing.** Characteristic is that all valves are closed and do not move if the crankshaft is turned. When watching the camshaft and the injection pump it is possible to note that the pump tappet roller is on the lifting side of the fuel cam.

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

Example of reading the flywheel

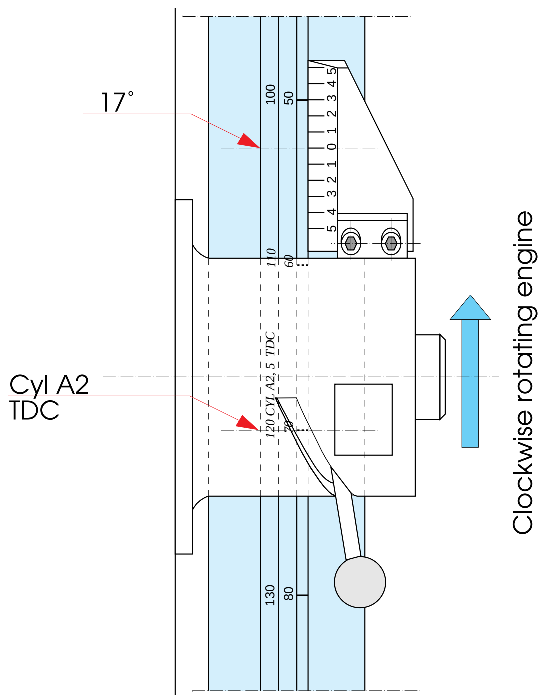

Fig 00-3 3200538935

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

00A. Risk Reduction

00A.1 General

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

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

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

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

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

Identified hazard,hazardous situation or event	Chapter of engine manual																
	3	4	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Inhalation of exhaust gas dust		x	x	x	x	x			x					x			
Explosion or fire if flammable gas/vapour is leaking into the insulation box. 4)	x													x			
Touching of moving parts	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x
High pressure hoses, risk of oil spray.	x	x	x	x	x	x	x	x	x	x		x	x		x	x	

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

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

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

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

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

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

- Crankcase safety explosion valves will open if there is a crankcase explosion.

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

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

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

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

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

- Ejection of:

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

- Oil spray if running without covers,
- Ejection of fuel injector if not fastened and

— turning device engaged and turned.
— engine turning due to closed generator breaker/coupling

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

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

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

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

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

00B. Welding Precautions

00B.1 Precautions General

Main principles:

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

00B.1.1 Preventing uncontrolled current loops

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

00B.1.2 Preventing Radiation

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

00B.1.3 Preventing damage due to sparkles

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

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

00B.2 Precaution checklists

00B.2.1 Checklists General

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

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

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

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

00B.2.3 WECS 2000 checklist

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

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

00B.2.4 WECS 3000 checklist

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

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

00B.2.5 WECS 7000/8000 checklist

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

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

01. Main Data, Operating Data and General Design

01.1 Main data for Wärtsilä 34 SG

Cylinder bore . . . . 340 mm
Stroke . . . . 350 mm
Piston displacement per cylinder . . . . 31.78 l

Firing order		
Engine type	Clockwise rotation	Counter-clockwise rotation
12V34	A1-B1-A5-B5-A3-B3-A6-B6-A2-B2-A4-B4	A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5-B1
16V34	A1-B1-A3-B3-A7-B7-A4-B4-A8-B8-A6-B6-A2-B2-A5-B5	A1-B5-A5-B2-A2-B6-A6-B8-A8-B4-A4-B7-A7-B3-A3-B1
18V34	A1-B1-A7-B7-A4-B4-A2-B2-A8-B8-A6-B6-A3-B3-A9-B9-A5-B5	A1-B5-A5-B9-A9-B3-A3-B6-A6-B8-A8-B2-A2-B4-A4-B7-A7-B1

Normally the engine rotates clockwise.

Lubricating oil volume in the engine			
Engine type	12V34	16V34	18V34
App. oil volume in litres Normal sump Deep sump	 1875 2825	 2405 3620	 2670 4020
Oil volume between max. and min. marks c. litres/mm	4.6	6.1	6.9

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

01.2 Recommended operating data

Apply to normal operation at nominal speed.

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

(x) Depending on speed and installation.

01.3 Reference conditions

Reference conditions according to:

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

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

Reduction factor = (a + b + c) %

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

01.4 General engine design

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

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

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

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

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

The pistons are of composite type fitted with a Wärtsilä Diesel 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 ring.

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

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

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

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

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

The turbochargers are located at the free end of the engine.

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

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

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

The starting system. The engine is provided with two air driven starting motors.

Cross-section of Wärtsilä 34SG, V-engine

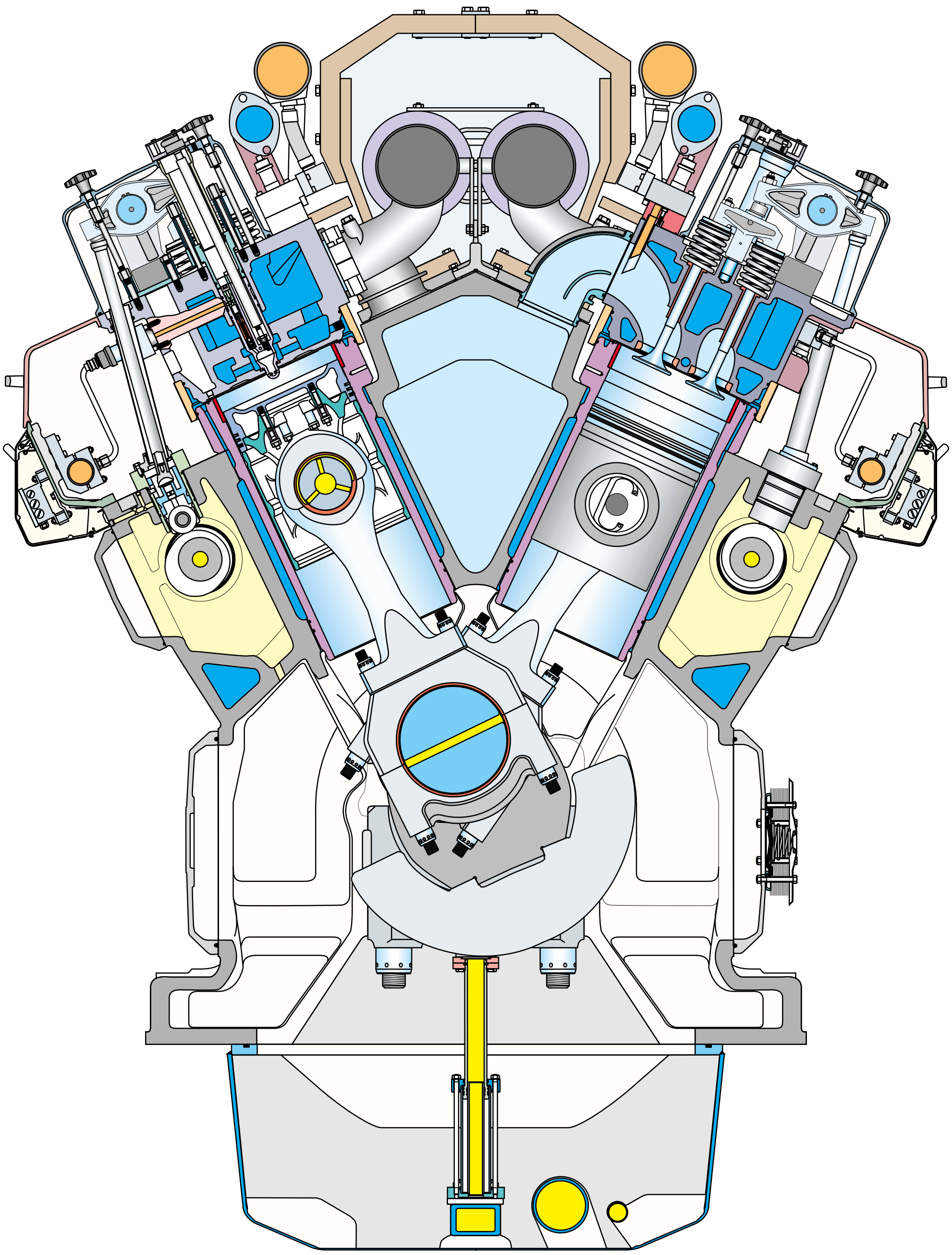

Fig 01-1 3201549539

02. Fuel, Lubricating Oil, Cooling Water

02.1 Fuel

02.1.1 General

The engine is designed to operate on natural gas. The maximum limits of gas characteristics for a certain engine are stated in the documentation delivered with the engine.

02.1.2 Gas quality

The Wärtsilä®34SG engine is designed for running on natural gas qualities according to the following specification:

Gas quality, maximum limits	
Lower Heating Value LHV 1), min.	24 MJ/m^3_N
Methane number (MN)	See installation specific instructions
Methane content, CH_4, min.	70 vol-%
Hydrogen sulphide, H_2S	0.05 vol-%
Hydrogen, H_2 2)	3 vol. %
Water and hydrocarbon condensates before the engine	Not allowed
Ammonia	25 mg/m^3_N
Chlorines + Fluorines	50 mg/m^3_N
Particles or solids content *)	50 mg/m^3_N
Particles or solids size *)	5 µm
Gas inlet temperature	0 - 50°C

*) Content of gas in engine inlet

1) Lower Heating Value corresponds to the energy content of the gas. If the LHV is lower than specified above, the engine output has to be adjusted or a higher gas pressure to the engine is needed.

Methane Number is a scale for evaluation of the knock resistance of the fuel. A higher number means better knock resistance. If the components of the fuel gas are known, the methane number can be calculated. Heavier hydrocarbons as ethane, propane and butane will lower the methane number.

If the methane number does not match the requirements, the engine should be derated according to special instructions.

Carbon dioxide and **nitrogen** will increase the methane number.

2) Hydrogen contents above 3 vol-% must be agreed on case by case basis.
Hydrogen sulphide H_2S may cause corrosion on the gas handling equipment.

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

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

02.2 Lubricating oil

02.2.1 System oil characteristics

Viscosity. Viscosity class SAE 40.
Viscosity index (VI). Min. 95
Alkalinity (BN). Lubricants with a BN of 4 - 7 mg KOH/g have to be used.
Sulphated ash level. The content of sulphated ash in gas engine lubricants is a very important property. Too high ash content can cause preignition, knocking and spark plug fouling, while too low ash content can lead to increased valve wear. Low ash lubricants with sulphated ash level of max. 0.6 w-% have to be used.
Additives. The oils should contain additives that give good oxidation stability, corrosion protection, load carrying capacity, neutralization of acid combustion and oxidation residues, and should prevent deposit formation on internal engine parts (piston cooling gallery, piston ring zone and bearing surfaces in particular).
Foaming characteristics. Fresh lubricating oil should meet the following limits for foaming tendency and stability (according to the ASTM D 892-92 test method):

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

In this test a certain amount of air is blown through the lubricating oil sample. The first number in the results is the foam volume after a blowing period of 5 minutes and should be less than or equal to 100 ml. The second number is the foam volume after a settling period of 10 minutes and should always be 0 ml.
Sequences I and III are performed at a temperature of 24°C and sequence II at a temperature of 93.5°C.

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

02.2.2 Lubricating oil qualities

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® 34SG engine type, have gone through an approval test according to the engine manufacturer's procedure.

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

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

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

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

02.2.3 Maintenance and control of the lubricating oil

a) **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.

To be representative of the oil in circulation, the sample should be taken with the engine in operation at the sampling cock located immediately after the oil filter on the engine, in a clean container holding 0.75 - 1 litre. Take samples before, not after adding new oil to compensate for consumption. Before filling the container, rinse it with the oil from which the sample is to be taken.

In order to make a complete assessment of the condition of the oil in service, the following details should be furnished with the sample: Installation, engine number, oil brand, engine operating hours, number of hours the oil has been in use, where in the system sample was drawn, type of fuel, any special remarks. Oil samples with no information except installation and engine number are close to valueless.

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

Viscosity. Should not 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 50 % above the guidance value at 40°C.

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). The minimum allowable BN value of a used oil is 50 % of the nominal value of a new oil.

TAN (Total Acid Number). Should not increase by more than 2.5 mg KOH/g compared to nominal value of a new oil.

Insolubles. The quantity allowed depends on various factors. The oil supplier's recommendations should be followed. However, an n-Pentane insoluble value above 0.5 w-% calls for attention. A value higher than 1.0 w-% cannot be accepted for longer periods.

Nitration and oxidation. If nitration level exceeds 20 Abs/cm and/or oxidation level exceeds 25 Abs/cm, oil must be changed.

In general it can be said that the changes in the analysis give a better basis of estimation than the absolute value. Fast and great changes may indicate abnormal operation of the engine or of a system.

b) **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.

c) **Guidance values for oil change intervals** are to be found in chapter 04. Intervals between changes are influenced by system size (oil volume), operating conditions, fuel quality and total oil consumption.

When changing oil the following procedure is recommended:

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

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

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

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

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

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

02.2.4 Lubricating oils for turbochargers

Please note that different types of turbochargers can be used for the engine. The chargers has a common lubricating oil system with the engine, see chapter 15. See also attached manufacturers instruction for the turbocharger.

02.2.5 Lubricating oils for engine turning device

It is recommended to use EP-gear oils, viscosity 400-500 cSt at 40 °C=ISO VG 460 as lubricating oils for the turning device. The list of lubricating oils for the engine turning device approved by the turning device manufacturer can be found in the end of this chapter.

02.3 Cooling water

02.3.1 General

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

Before treatment, the water must be limpid and 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 frost occurs, please contact the engine manufacturer for use of anti-freeze chemicals.

Fresh water generated by a reverse osmosis plant 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!

02.3.2 Additives

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

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

Attention! **Sodium nitrite is toxic.**

Corrosion rate as a function of nitrite concentration

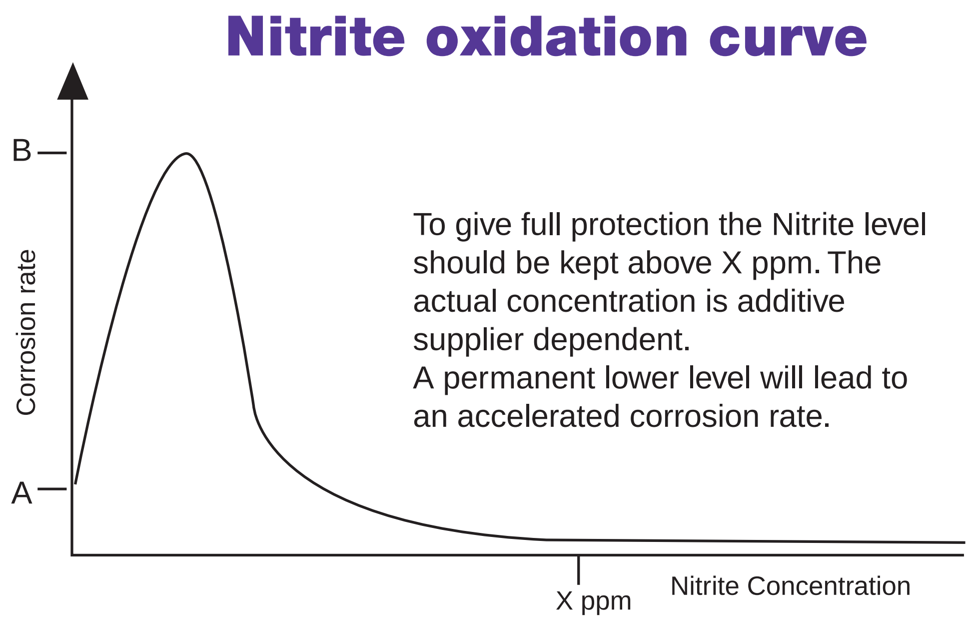

Fig 02-1 3202602002

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 02-1. 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 & 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 ex-changers with large soft solder surfaces - **toxic** - risk of spot corrosion when too low concentration
Nitrite + borate	- no increased risk of corrosion at over doses - innocuous for the skin	- tendency to attack zinc coverings and soft solde-rings - **toxic:** lethal dosage 3 - 4 g solid nitrite - risk of spot corrosion when too low concentration
Sodium silicate	- not toxic - harmless to handle	- not active when water velocity exceeds 2 m/s - commercial products very expensive - increased risk of corrosion when too low concen-tration; spot corrosion - limited suitability
Sodium molybdate	- not toxic - harmless to handle	- more expensive than toxic additives - increased risk of corrosion, if unsufficently dosed - can cause deposit formation (molybdates can collect to ferrous sulphates)
Organic and inor-canic syn-ergistic based	- not toxic	- more expensive than sodium nitrite and molybdate based additives - big active quantitives by mass

02.3.3 Treatment

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

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

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

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

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

Most suppliers will provide a test kit for the concentration control. Additionally a frequent laboratory analysis of cooling water at 3 months interval is recommended to ensure safe engine operation.

02A. Environmental Hazards

02A.1 General

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

02A.2 Fuel oils

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

02A.2.1 Handling

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

02A.2.2 Personal protection equipment

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

02A.2.3 First aid measures

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

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

02A.3 Natural gas

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

In a gas engine installation, gas may cause danger situations in some cases. The most serious situations are caused by gas leaks into the engine room, gas fires and gas explosions caused by unburned gas in the exhaust system.

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

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

02A.4 Lubricating oils

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

02A.4.1 Handling

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

02A.4.2 Personal protection equipment

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

02A.4.3 First aid measures

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

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

02A.5 Cooling water additives, nitrite based

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

02A.5.1 Handling

- Avoid contact with skin and eyes.
- Keep away from food and drinks. Do not eat, drink or smoke while handling.
- Keep in well ventilated place with access to safety shower and eye shower.

- Soak liquid spills in absorbent material and collect solids in a container. Wash floor with water as spillage may be slippery. Contact appropriate authorities in case of bigger spills.
- Bulk material can be land dumped at an appropriate site in accordance with local regulations.

02A.5.2 Personal protection equipment

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

02A.5.3 First aid measures

- **Inhalation:** In the event of over exposure to spray mists move victim to fresh air, keep warm and lying still. If effects persists, seek medical advice.
- **Skin contact:** Wash immediately with plenty of water and soap. Remove contaminated clothing. If irritation persists, seek medical advice.
- **Eye contact:** Rinse immediately with plenty of clean water and seek medical advice. If possible, keep rinsing until eye specialist has been reached.
- **Ingestion:** Rinse mouth with water. Drink milk, fruit juice or water. Do not induce vomiting without medical advice. Immediately seek medical advice. Do not give anything to drink to an unconscious person.

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

02A.6 Fly ashes and exhaust gas dust contaminated components

When handling the fly ashes, exhaust gas dusts and when working inside the exhaust gas system or when handling any component contaminated with exhaust gas dust, at least the following minimum precautions and safety procedures must be applied:

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

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

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

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

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

02A.6.1 Personal protection equipment

- Respiratory organs protection: Toxi particles: Use P3 filter respirator or 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.
- Hands protection: Gloves.
- Eye protection: Wear goggles.
- Skin and body protection: Wear covering clothing.

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

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

02A.6.2 First aid measures

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

02A.7 Lead in bearings

Lead has valuable lubricating properties and therefore it is incorporated into many bearing alloys.
The bearings in Wärtsilä engines consists of lead and are therefore a toxic hazardous waste. Lead containing parts that are not used anymore must be wasted according to local waste disposal plant instructions.

02A.8 Fluoride rubber products

02A.8.1 Handling instructions - normal sealing applications

In normal sealing applications the use of fluoride rubber products does not cause any health hazards. The handling of products, e.g. installation and service, can be made without any risk – provided that normal industrial hygiene is applied.

02A.8.2 Handling instructions in case of overheated seats and valve blow-by

When changing O-rings, for instance after a valve blow-by, operators handling the remains of burnt fluoride rubber must wear impenetrable acidproof gloves to protect the skin from the high corrosive remains. Appropriate glove materials are neoprene or PVC. All liquid state remains must be considered to be extremely corrosive.
Neutralisation of the remains can be done by using large amounts of calcium hydroxide solution (lime water). Used gloves must be disposed off.

02A.8.2.1 Use of fluoride rubber products at temperature 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 of or test of fluoride rubber at temperatures above 275 °C must be avoided. If the material, in spite of above recommendations, is exposed to higher temperatures, or in case of an accident, there is a risk that the temperature will rise out of control.

02A.8.3 Special conditions

02A.8.3.1 Grinding dust

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

02A.8.3.2 Fire

In case of a fire, burning fluoride rubber can cause the formation of toxic and corrosive degradation products (e.g. hydrofluoric acid, carbonyl fluoride, carbon monoxide and carbon fluoride fragments of low molecular weight).
Burning (incineration) of fluoride rubber is allowed only when using approved incinerators equipped with gas emission reduction systems.

02A.8.3.3 Decontamination

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

02A.8.4 Personal protection equipment

- Hand protection: impenetrable acidproof gloves (neoprene or PVC).
- Inhalation protection: breathing mask.

02A.8.5 First aid measures

- Inhaling: Move the patient from the danger zone. Make sure that he blows his nose. Consult medical personnel.
- Eye contact: Rinse immediately with water. Contact medical personnel.
- 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. Contact medical personnel.

RAW WATER QUALITY, APPROVED COOLING WATER ADDITIVES AND TREATMENT SYSTEMS

FOR WÄRTSILÄ VASA 32, WÄRTSILÄ 20, WÄRTSILÄ 32, WÄRTSILÄ 46, WÄRTSILÄ 64, WÄRTSILÄ 32DF, WÄRTSILÄ 50DF AND WÄRTSILÄ 34SG ENGINE TYPES

RAW WATER QUALITY

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

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

APPROVED COOLING WATER ADDITIVES

Manufacturer	Additive name
S.A. Arteco N.V. Technologiepark-Zwijnaarde 2 B-9052 Ghent/Zwijnaarde, Belgium	Havoline XLi
GE Betz Europe Interleuvenlaan 25 B-3001 Heverlee, Belgium GE Betz 4636 Somerton Road Trevose PA 19053, United States	CorrShield NT 4293 CorrShield NT 4200
Drew Ameroid Marine Division Ashland Chemical Company One Drew Plaza Boonton, NJ 07005, USA	DEWT-NC powder Drewgard 4109 Liquidewt Maxigard Vecom CWT Diesel QC-2
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

Manufacturer	Additive name
Maritech AB Box 143 S-29122 Kristianstad, Sweden	Marisol CW
Nalco Chemical Company One Nalco Centre Naperville, Illinois 60566-1024 USA	Nalco 39 (L) Nalcool 2000
Nalfleet Marine Chemicals PO Box 11 Winnington Avenue, Northwich Cheshire, CW8 4DX, UK	Nalcool 2000 Nalfleet EWT 9-108 Nalfleet CWT 9-131C
Rohm & Haas La Tour de Lyon 185, Rue de Bercy 75579 Paris, Cedex 12, France	RD11 RD11M RD25
RRS-Yhtiöt Pieksämäentie 398A 77570 Jäppilä, Finland	Korrostop KV
Tampereen Prosessi-Insinöörit Oy Keisarinviitta 22 33960 Pirkkala, Finland	Ruostop XM
Texaco Global Products, LLC 1111 Bagby Houston, TX 77002	Havoline XLi
TotalFinaElf 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
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

Product designation	Dosage per 1 m³ of system capacity	Concentration of active corrosion inhibitor
Q8 Corrosion Inhibitor Long-Life	50 – 100 litres	1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
Maricol CW	8 – 16 litres	1000 – 2000 ppm as NO_2
Nalco 39 (L) Nalcool 2000 Nalfleet EWT 9 - 108 Nalfleet CWT 9 - 131C	16 - 36 litres 32 - 48 litres 2.2 - 3.4 litres 8 - 12 litres	550 - 1200 ppm as NO_2 1000 - 1500 ppm as NO_2 1000 - 1500 ppm as NO_2 1000 - 1500 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
Ruostop XM	20 litres	120 ppm as Mo
Havoline XLi	50 - 100 litres	1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
WT Supra	50 - 100 litres	1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
Dieselguard NB Rocor NB Liquid Cooltreat AL	2 - 4.8 kg 10 - 24 litres 50 – 100 litres	1500 ppm as NO_2 1500 ppm as NO_2 1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
Vecom CWT Diesel QC-2	6 - 10 litres	1500 - 2500 ppm as NO_2

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

Note 2: The nitrite content of nitrite-based cooling water additives tends to decrease in use. The risk of local corrosion increases substantially when nitrite content goes below the recommended limit.

APPROVED COOLING WATER TREATMENT SYSTEMS

ELYSATOR

As an alternative to the approved cooling water additives, the Elysator cooling water treatment system can also be used. The Elysator protects the engine from corrosion without any chemicals. It provides a cathodic/anodic protection to engine's cooling water system by letting magnesium anodes corrode instead of the engine itself. Raw water quality specification is the same as in connection with cooling water additives. More information in document 4V92A1322.

The Elysator can be a sensible alternative in installations where the environmental factors are considered important.

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

Supplier	**Treatment system**
International Watertreatment Maritime AS N-3470 Slemmestad Norway	Elysator

REQUIREMENTS AND OIL QUALITY

SYSTEM OIL REQUIREMENTS AND QUALITY FOR WÄRTSILÄ® 34SG ENGINES

Viscosity
Viscosity class SAE 40

Viscosity Index (VI)
Min. 95

Alkalinity (BN)
Lubricating oils with BN of 4-7 mg KOH/g have to be used.

Sulphated ash level
The content of sulphated ash in gas engine lubricating oils is a very important property. Too high ash content can cause preignition, knocking and spark plug fouling, while too low ash content can lead to increased valve wear. Low ash lubricating oils with sulphated ash level of max. 0.6 % w/w have to be used.

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

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

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

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

CONDEMNING LIMITS FOR USED LUBRICATING OIL

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

PROPERTY	UNIT	LIMIT	TEST METHOD
Viscosity	cSt at 40 °C	max. 50% increase	ASTM D 445
Viscosity	cSt at 100 °C	max. 25% increase	ASTM D 445
Water	% V/V	max. 0.30	ASTM D 95 or D 1744
Base Number	mg KOH/g	max. 50% depletion	ASTM D 2896
Total Acid Number	mg KOH/g	max. 2.5 mg KOH/g increase	ASTM D 664
Insolubles	% w/w in n-Pentane	max. 1.0	ASTM D 893b
Oxidation	Abs/cm	max. 25	IR
Nitration	Abs/cm	max. 20	IR

APPROVED LUBRICATING OIL QUALITIES FOR WÄRTSILÄ® 34SG

NATURAL GAS OPERATION

SUPPLIER	BRAND NAME	VISCOSITY	BN	SULPHATED ASH (w-%)
BP	**Energas NGL**	**SAE 40**	**4.5**	**0.45**
Castrol	**Duratec L**	**SAE 40**	**4.5**	**0.45**
ChevronTexaco	**Geotex LA**	**SAE 40**	**5.2**	**0.45**
ExxonMobil	**Pegasus 705**	**SAE 40**	**5.3**	**0.49**
	Pegasus 805	**SAE 40**	**6.2**	**0.50**
	Pegasus 905	**SAE 40**	**6.2**	**0.49**
	Pegasus 1	**SAE 40**	**6.5**	**0.49**
Petro-Canada	**Sentinel 445**	**SAE 40**	**4.7**	**0.40**
Shell	**Mysella LA 40**	**SAE 40**	**5.2**	**0.45**
Total	**Nateria X 405**	**SAE 40**	**5.2**	**0.45**

USE OF NON-APPROVED LUBRICATING OILS:

Before using a lubricating oil not listed in the tables above, the engine manufacturer must be contacted. Lubricating oils that are not approved have to be tested according to engine manufacturer’s procedure.

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

APPROVED LUBRICATING OILS FOR ENGINE TURNING DEVICE

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

LUBRICATING OILS FOR ENGINE TURNING DEVICE				
SUPPLIER	**BRAND NAME**	**VISCOSITY cSt at 40 °C**	**VISCOSITY cSt at 100 °C**	**VISCOSITY INDEX (VI)**
Agip	**Blasia 320**	**300**	**23.0**	**95**
BP	**Energol GR-XP 460**	**425**	**27.0**	**88**
Castrol	**Alpha SP 460**	**460**	**30.5**	**95**
ChevronTexaco	**Meropa 460**	**460**	**31.6**	**100**
ExxonMobil	**Spartan EP 460** **Mobilgear 634**	**460** **437**	**30.8** **27.8**	**96** **96**
Shell	**Omala Oil 460**	**460**	**30.8**	**97**
Total / Lubmarine	**Elf Epona Z 460**	**470**	**30.3**	**93**

03. Start, Stop and Operation

03.1 Turning of crankshaft

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

03.1.1 Electrically driven turning device

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

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

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

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

Electrically driven turning device

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

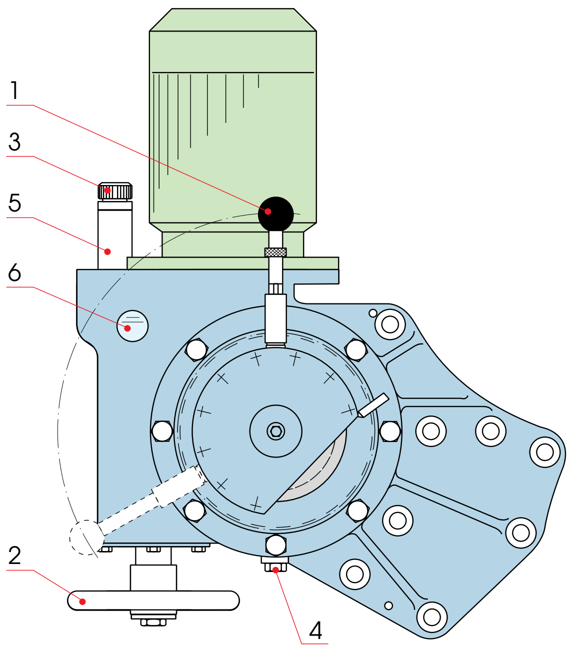

Fig 03-1

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03.2 Start

Before starting the engine, check that:

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

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

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

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

Note! Avoid running the engine on low loads. Misfiring may cause unburned gas entering the exhaust system and can result in a gas explosion in the exhaust system.

03.2.1 Manual start

Before the WECS engine control system activates a start request, the engine must be ready for start. The engine modes and the conditions that must be fulfilled to get the engine ready for start are explained in chapter 23.

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

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

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

4 **Push the start button** to initiate the start sequence.

5 **The WECS engine control system performs** engine and exhaust pipe ventilation as well as gas system tightness checks before the start command is executed

Note! **Re-start of the engine is possible after the ventilation sequence of the exhaust system is finished. The exhaust system is equipped with automatic ventilation and it will stay open for a while (see installation documentation) after the stop. During this time the start will be blocked.**

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

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

03.2.2 Automatic start

See installation specific documentation.

03.3 Stop

03.3.1 Manual stop

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

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

03.3.2 General

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

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

03.4 Normal operation supervision

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

03.4.1 Every second day or after every 50 running hours

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

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

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

3 **Check the indicator for pressure drop** over the lubricating oil filter. Too large of a pressure drop indicates clogged filter candles, which results in reduced oil filtration when the by-pass valve is open. Reduced oil filtration results in increased wear. Inspect and clean/change the filter candles.

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

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

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

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

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

Condensation in charge air coolers

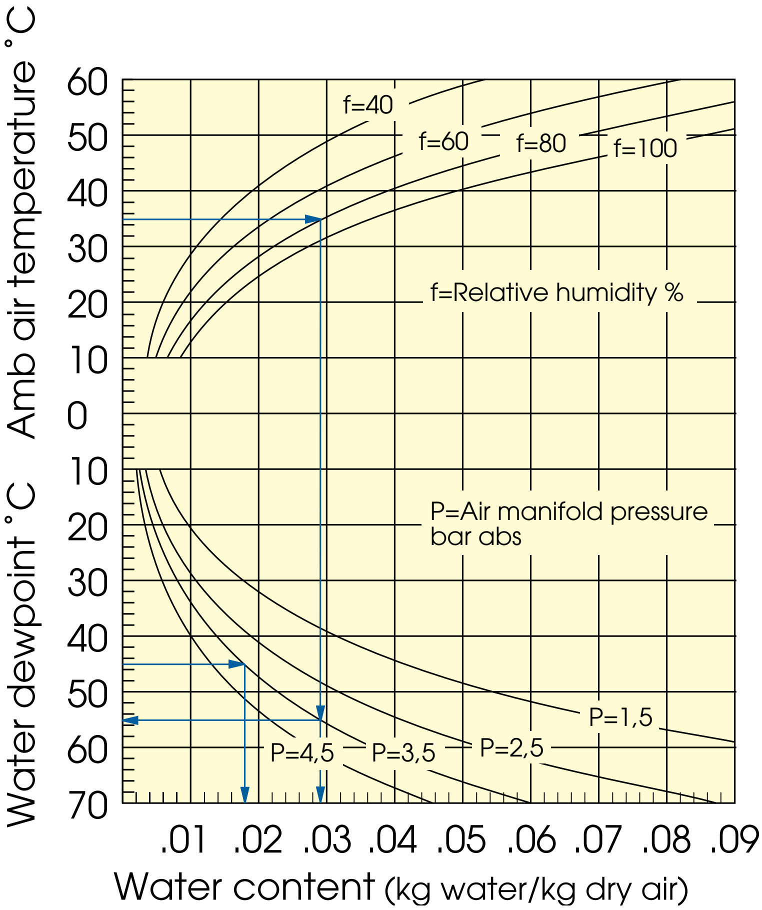


Fig 03-2 3203528930

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

03.4.2 Once a month or after every 500 running hours

1. **Clean the centrifugal lubricating oil filters.**
2. **Check content of additives** in the circulating water.

03.4.3 In connection with maintenance work

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

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

2 Disconnect the electronic equipment according to the instructions in appendix 00B, if any welding is performed on the engine. Keep the return connection near the welding point.

Note! **Welding may, if incorrectly performed, cause serious injury on the electronic engine control system.**

03.4.4 General

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

2 Strong gas blow-by past the pistons is one of the most dangerous things that can occur in an engine. If gas blow-by is suspected, check the crankcase pressure. If the pressure exceeds 300Pa (30 mm H_2O), check the crankcase venting system, if in order, pull the pistons!

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

03.5.1 Manual start

1 Check

- the lubricating oil level
- the cooling water level in the expansion tank
- the raw water supply to heat exchangers
- the starting air pressure is min. 18 bar

2 Observe all points in section 03.2.1.

03.6 Start after overhaul

1 Check gas system for leakage.

2 Check the cooling water system for leakage, especially:

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

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

4 Start the priming pump. 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.**

5 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.

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

03.7 Operation supervision after overhaul

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

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

3 After overhauling, the following instructions are especially important:

- Check pressures and temperatures
- Check the automatic alarm and stop devices
- Check the pressure drop over the gas filter and lubricating oil filter
- Check the oil level in the oil sump/oil tank. Estimate the condition of the oil
- Check the ventilation (de-aerating) of the engine cooling water system
- Check the telltale holes of the coolers
- Check the content of additives in the cooling water
- Listen for jarring sounds
- Check the crankcase pressure
- Check the starting air pipes

03.8 Running-in

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

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

Avoid “running-in” at continuous and constant low load!

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

Running-in programme

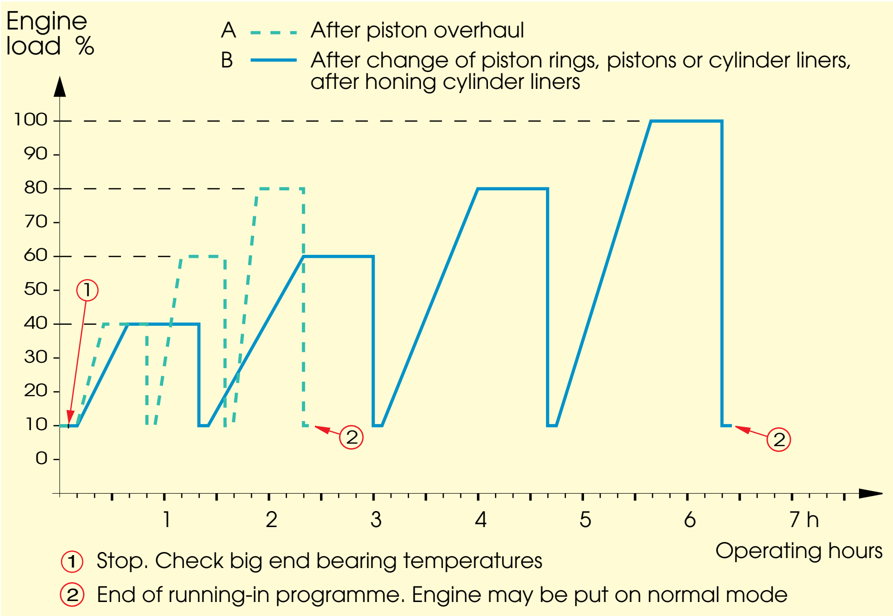


Fig 03-3 3203569701

03.9 Maintenance of turning device

The turning device needs no other maintenance than change of the gear box lubricating oil once during the first year of operation. Approved lubricating oils, see chapter 2. After that, the oil should be changed according to chapter 04. Check also that the vent hole (3), Fig 03-1 is open.

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

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

3 **Fill the gear box with oil** (according to the table in chapter 2) through the filling hole (5) until the oil level reaches the level gauge glass (6). Utmost cleanliness should be observed.

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

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

Project: WFI-P Power Plant Technology, IN023

Name: Power plant

Subject: **Wärtsilä safety manual for lean burn gas engine**

1 General

This section of manual describes mainly the safety features of auxiliary components i.e. outside engine in the power plant.

2 Hazardous area classification

2.1 Classification for engine

In the case of an adequately ventilated enclosure containing gas-fuelled engines it need not be classified solely by reason of the engine fuel. This is the case with a normal power plant installation.

In the case of a gas compressor driven by a gas engine, the engine is seen as an ignition source and the gas compressor is a source of possible gas leak. The possibility of a gas leak is considered to be much higher in a gas compressor, thus, a gas engine driven compressor is classified as hazardous area, normally zone 2 or class I division 2.

The above mentioned statement is based on the following standards:

2.1.1 American Codes

American Petroleum Institute

API 500: Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2

- Section 8.2.5 Hydrocarbon-fuelled Prime Movers

National Fire Protection Association

NFPA 37: Standard for Stationary Combustion Engines and Gas Turbines

NFPA 850: Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

2.1.2 European Codes

EN-60079-10 Electrical apparatus for explosive gas atmospheres; part 10 Classification of hazardous areas

EN-1834-1 Reciprocating internal combustion engines – Safety requirements for design and construction of engines for use in potentially explosive atmospheres – Part II engines for use in flammable gas and vapour atmospheres.

There are no current EU guidelines for gas engine power generation installations; in such a case Internationally recognised codes are accepted.

2.1.3 UK Codes

The Institute of Petroleum

IP15 Area classification code of practice for petroleum installations, Model code of safe practice: part 15

Section 8.7 Combustion Engines

The Institution of Gas Engineers

IGE/UP/3 Gas fuelled spark ignition and dual fuel engines

Section 8.1.7 Electrical Equipment and Supplies

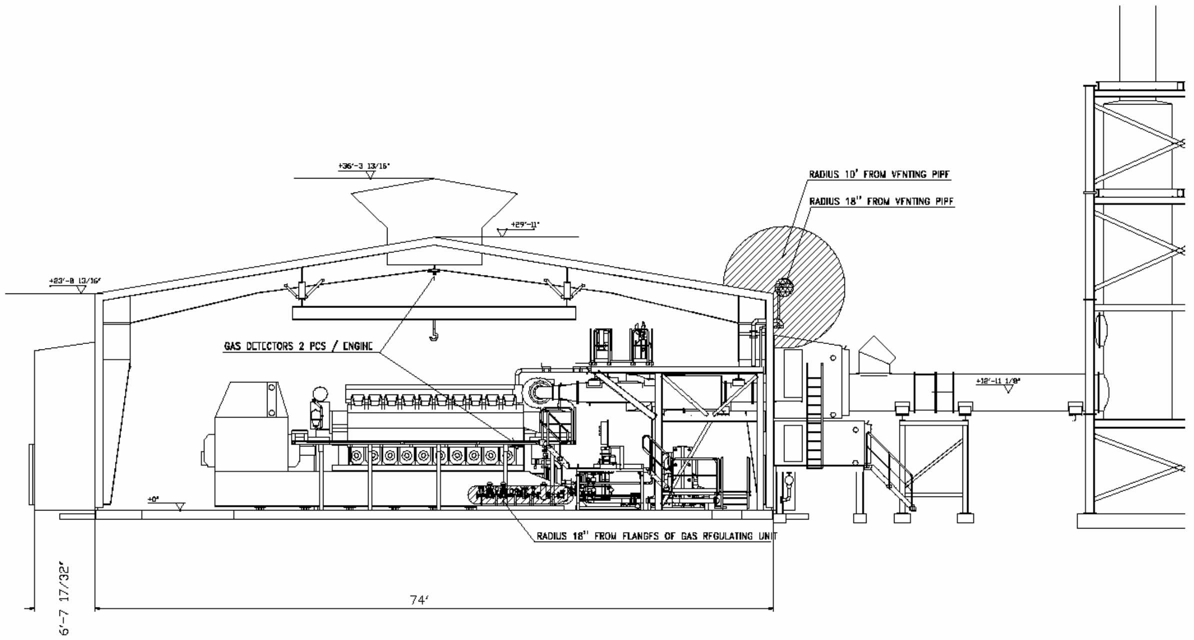
2.2 Classification for auxiliary system

Regarding auxiliary gas system, the codes to be followed are EN60079-10, API500 and IGE/SR/25.

From these, it can be derived that zone 2 or class I division 2 is found in the gas piping flange joints in gas regulating unit and flow metering unit (option). The hazardous area around the flange is a sphere whose radius is typically 1 m. In addition, vent piping creates a hazardous area near the roof.

Radius should be checked for each installation, and is affected by the gas pressure and level of ventilation.

Figure 1 shows a typical example of hazardous area classification for gas engine power plant.



HAZARDOUS SUBSTANCES: Natural gas

Flash Point	Explosion Group	Autoignition Temp. F	Ignition Group	Vapour density
	D	1076	T1	0,6 x Air (lighter than air)

Hazardous Area Classification

Class I division 1 — A location in which ignitible concentrations of flammable gas are expected to exist under normal conditions.

Class I division 2 — A location in which flammable gas may be present, but normally are confined within closed systems and are prevented from accumalating by adequate ventilation.

Standards and guidelines
API500

Figure 1 **Hazardous area classification for a gas engine power plant according to API500.**

3 Control philosophy

There are different control modes for the power plant. These are:

- Start
- Run
- Stop
- Shut down
- Emergency
- Stand-by

These are discussed briefly below. In addition, different causes for stop, shut down and emergency from power plant as well as different consequences regarding power plant safety are discussed below.

3.1 Start

In start mode certain checks are gone through in order to ensure a safe start. The plant control system (PLC) checks for start blocks before engine is allowed to start. After the engine is started following the start sequence the engine mode is changed to running.

3.2 Run

In run mode engine output is maintained at the level required by the plant and all engine parameters are monitored and controlled to ensure a safe and reliable operation.

3.3 Stop

Stop is activated from WOIS giving an order for engine to stop or it can be done by pressing the stop button in M1 panel. The engine is unloaded and when the load has reached a set value, the generator breaker is opened and a stop command for WECS is given.

The gas regulating unit is closed. See chapter gas regulating unit for more details.

3.4 Shut down

Shut down is otherwise the same as the stop mode except that it is initiated by a failure detected by WECS or PLC.

Causes for shut down are:

- start sequence failure
- gas system abnormal
- electrical system fault
- safety relay trip
- WECS shut down signal
- WECS communication failure
- Project specific trip

Main consequences are:

- Generator breaker opens
- Stop command for WECS is given
- Gas regulating unit is closed

3.5 Emergency

Emergency mode is initiated by a hardwired signal. Emergency mode for power plant is shown in Figure 2.

Emergency can be initiated either by pressing emergency stop push buttons in:

- common panel, which means a plant emergency mode is initiated and all the engines are shut down or
- by engine wise panels, which means an emergency mode is initiated for that engine only

or

by a fire or gas detector.

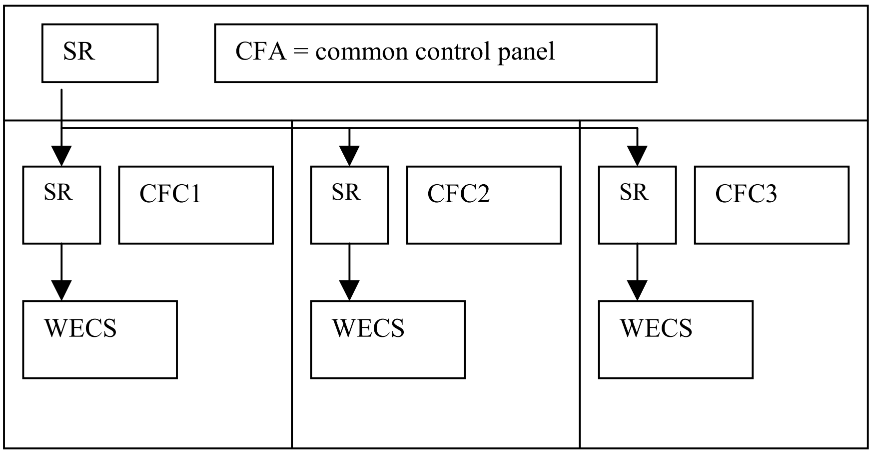


Figure 2 A schematic diagram for emergency mode of control system.

SR = safety relay

CFC = engine wise control panel

3.6 Stand-by

Stand-by is a mode in which the power plant waits to be started. To enter this mode, plant needs to be stopped. In case of a shut down or emergency all the faults and alarms need to be cleared before start can proceed.

4 Fire fighting and gas detection system

Each country has it's own fire protection legislation and codes of practise. Therefore, project design is to be reviewed with the local authorities and the system is chosen on a case by case basis.

The power plant is subdivided into separate fire areas for the purpose of limiting the spread of fire, protecting personnel and limiting the resultant consequential damage to the plant.

Fire areas are separated from each other with fire barriers, spatial separation or other approved means.

Media capable of burning in a gas power plant are:

- Gas
- Cables
- Lubrication oil

The main method to prevent a gas fire is to design the gas system safe.

- Main manual gas shut off valve is located outside the engine room
- Automatic shut off valves located inside engine room will shut off the engine specific fuel supply in an engine stop.
- A flexible connection is placed between engine gas piping and auxiliary gas piping. This is required due to vibrations and possible movement of the piping.
- Optionally engine specific gas shut off outside engine room (see chapter 5)

Burning gas must not be extinguished since the remaining unburned gas may explode.

Other possible causes for a fire are taken care of with a fire detecting and fighting system.

4.1 Fire detectors

There are normally at least two fire detectors per location. Fire detector types used are:

- Differential heat detectors
- Optical smoke detectors

The type used and the locations for the detectors will depend on the project and standards to be followed.

4.2 Fire fighting equipment

Fire fighting system consists of:

- Portable dry powder and/or CO_2 extinguishers
- Fire hydrants for fire hoses
- Loose fire hose equipment to be connected to fire hydrants
- Permanently connected fire hose reels

4.3 Gas detectors

The gas detectors are required to detect any gas leak. These are located in a position where a gas leak is most likely to occur and be detected. See Figure 1. These are normally:

- Above gas regulating unit
- At ventilation air outlet at the roof level

4.4 Alarm and shut down system description

The gas and fire detection system has a control unit, which receives information from detectors placed in critical locations. If a detector is activated, a fire or a gas leak alarm is given locally and/or remotely, to ensure evacuation of personnel and to initial emergency procedures.

An alarm is given when a gas detector is sensing 10 % of LEL (lower explosion limit).

When a gas detector is sensing 20 % of LEL or above, normally an automatic emergency is initiated for the plant shutting down the gas supply at the engine specific gas regulating units and closing the main shut of valve outside the engine room or engine cell. In case of a fire alarm a plant shut down is initiated, as well.

Gas detectors can also be of the type with one level alarm. In this case exceeding an alarm level of 20 % of LEL an emergency mode is initiated.

An option is that the gas detector or fire detector gives an alarm and the necessary actions are taken by operating personnel.

5 Engine room ventilation

The engine room ventilation system is required in order to supply sufficient combustion air to the engine and to maintain the temperature in the engine room at a suitable level.

Ventilation can be classified as inadequate or adequate. The prerequisite for an engine room to be unclassified area regarding explosion safety is that ventilation shall be adequate at all times including stand by.

An option is that gas system is of special design. In this case the gas supply is closed per each engine outside the engine room. This is done to keep the gas inventory low inside the engine room and thus ventilation is not required in a stand by mode. (See chapter 7.1). In addition, in this design the gas system components up to the gas regulating unit are done with welded joints and thus a possibility of a gas leak is negligible.

6 Emergency lighting

Emergency lighting shall be ex-classified in zoned areas and in engine room or engine cell to reduce the risk of igniting any possible gas/air mixture in the power plant during any emergency.

7 Gas supply system

The gas supply is an essential part for the engine operation. It should be regularly inspected and maintained for correct function and safety.

Before gas is supplied to the engine it passes through the following units:

- flow measuring unit (optional). Either plant specific or engine specific flow meter.
- gas compressor upstream the gas regulating unit if the inlet pressure is too low for the engine (optional)
- a plant specific pressure reduction station (PRS) upstream the GRU when inlet pressure to the GRU is over 16 bar (optional)
- engine specific gas regulating unit (GRU)

GRU has normally only one connection to the engine and the gas is divided into two streams at the engine

- main combustion chamber (MCC) gas
- pre-combustion chamber (PCC) gas.

In some cases, the GRU has separate line for pre-chamber gas and thus there are two connections to the engine. In this case MCC and PCC gas may have different pressure.

The outlet pressure is controlled by the engine control system according to engine load.

Figure 3 shows a schematic diagram of the gas fuel system.

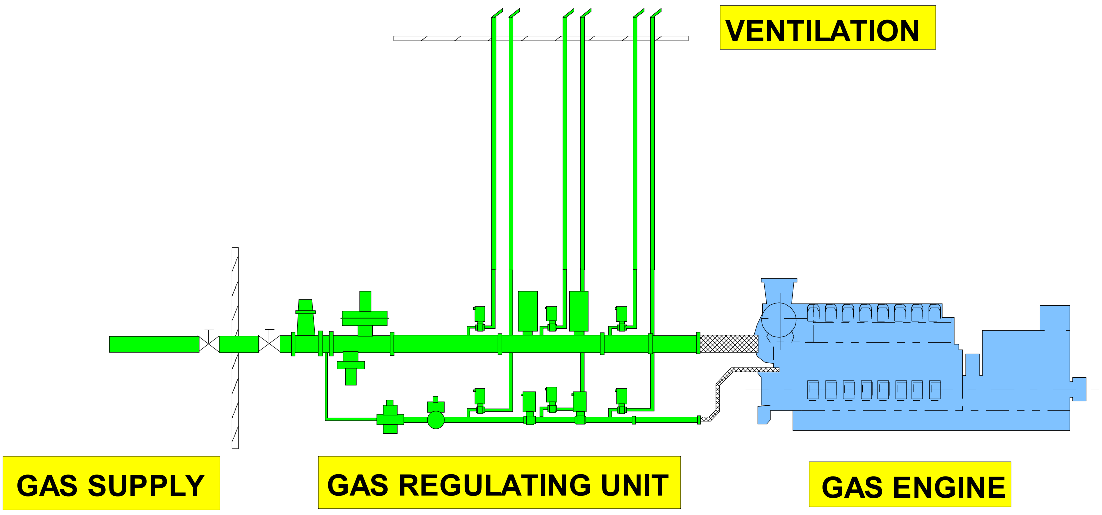


Figure 3 Gas fuel system illustrating main shut off valve, gas regulating unit and gas engine.

7.1 Main shut off valve

Regarding fuel gas system there are two alternatives:

- System with a common gas shut off
- System with a separate gas shut off

Normal design is to have the common gas shut off. It means that there are two main shut off valves outside the engine room and the gas supply is divided for all the engines inside the engine room.

The main shut-off valve isolates the gas feed line to the plant. Of the two valves, one is manually operated valve and the other is automatically operated shut off valve, which is of fail safe type and is closed either in loss of power or control air.

The main shut off valves are located outside the building and marked clearly according to local regulations. In the event of a gas leak, fire or gas explosion the valve should always be closed. In the case of a plant emergency, the automatically operated main shut off valve is closed by a hardwired signal.

An engine specific emergency does not close the main shut off valve. It only closes the slam shut off valves on the GRU and ventilates the gas pipe between the engine and the GRU.

An option is the design that each engine has main shut off valve(s) outside the engine room, i.e., a system with separate gas shut off. In this case the automatic valve is closed in the operating modes:

- Stop
- Shut down
- Emergency shut down
- Plant emergency shut down

7.2 Gas regulating unit

Natural gas is supplied from the distribution system and passes through a gas regulating unit - or the "gas train". The gas regulating unit provides the correct gas admission to the engine by regulating gas feed pressure depending on the engine load. In addition, gas regulating unit performs a leakage test of the main slam shut off valves prior to every engine start.

7.2.1 Design

The main components of the GRU are (see Figure 4 and Figure 5):

- Manual ball valve: V01
- Inert gas line, closed with a cap.
- Filter
- Instrumentation such as pressure and temperature gauges and transmitters
- Pressure regulating valve of diaphragm type, pilot operated, self regulating: V07
- Main slam shut-off valves: V15 and V18, fail close
- Ventilating valves: V14, V16, V19 (V14 is of fail close type while the others are of the fail open type)

The electrical components are ex-classified to be suitable for installation in zone 2 or class I division 2, respectively. This is due to possible small leaks in the flanges or other connection, which makes a small hazardous area around the unit flanges or connections.

Gas regulating unit layout drawing is illustrated in Figure 4 and the P&ID is shown in Figure 5.

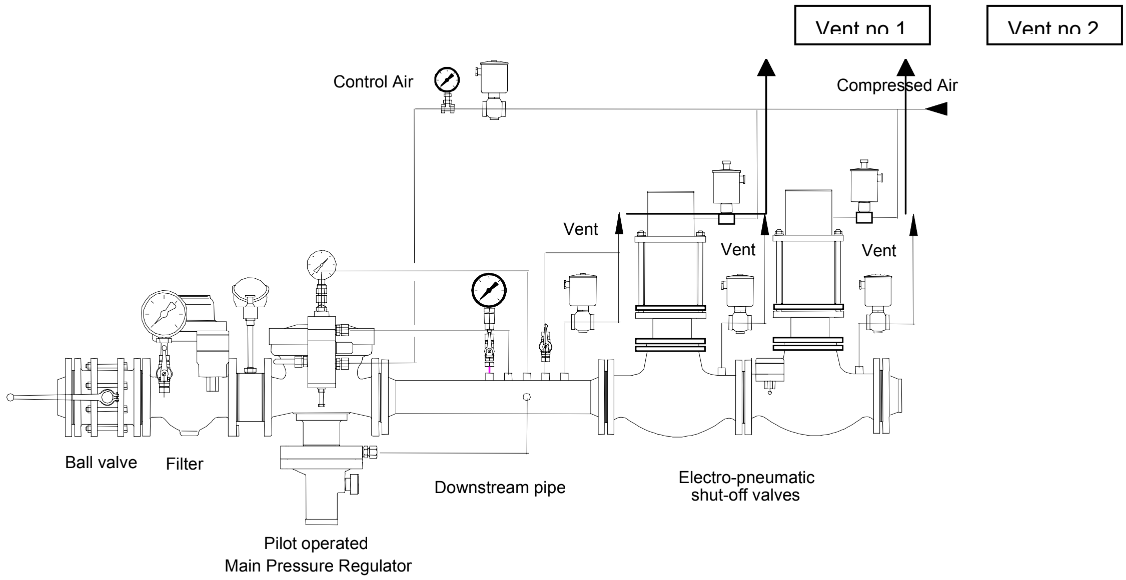


Figure 4 **Typical gas regulating unit layout.**

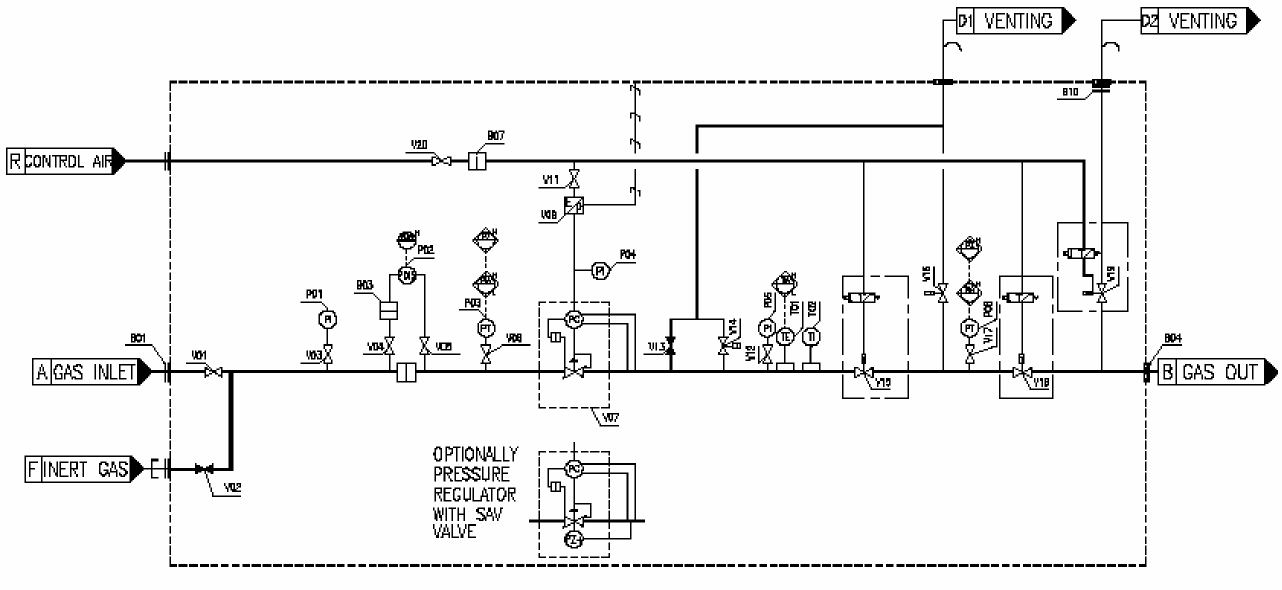


Figure 5 **The P&ID of the gas regulating unit.**

The GRU includes shut-off valves and ventilation valves, which are located in the vent pipes. These vent pipes are drawn as two separate lines up to the roof (see Figure 5). This is a hazardous area and it is marked on the layouts as such (see Figure 1).

Figure 6 shows the pressure regulator in the GRU.

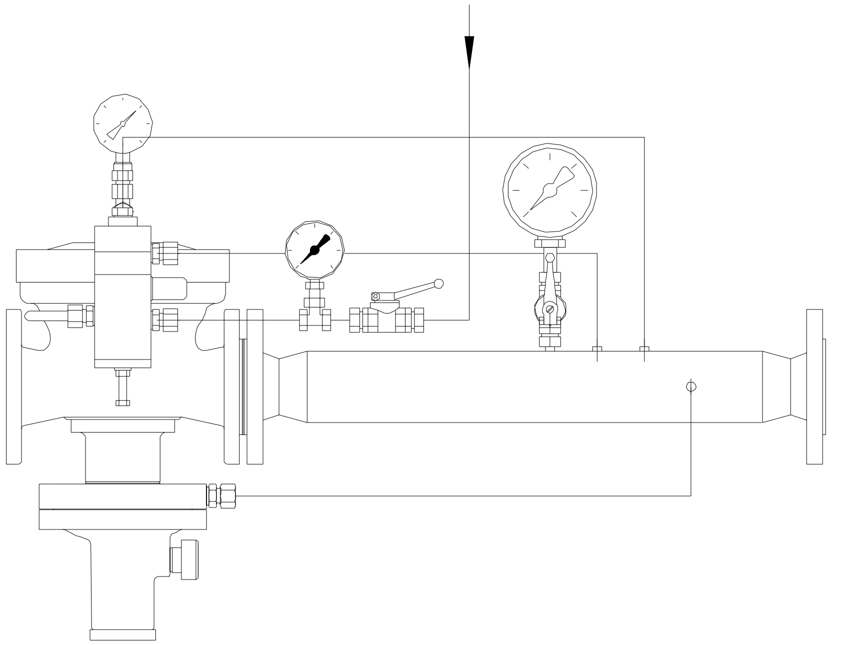


Figure 6 The pressure regulator with functional units regulator, pilot valve and SAV valve.

The pilot operated pressure regulator is operated using control air from I/P converter.

The regulator consists of the main valve body and the functional units “regulator”, “pilot valve” and “safety shut-off valve” (SAV).

Safety shut-off valve (SAV)

An additional safety shut-off valve may be installed if the inlet pressure to the GRU is higher than 6 bar. The control element of the safety shut-off valve is installed on the inlet side of the body and shuts off the gas flow if the outlet pressure in the main gas line rises above the pre-set limits. On detecting high pressure the SAV measuring diaphragm and the switching bush move into the release position and the ball mechanism set the valve stem free to close the SAV valve.

The safety shut-off valve can *only be reopened by hand*, after the outlet pressure at the measuring point has been restored to a value *below* the re-engagement differential. If the SAV valve is closed, it will lead to a shut down of the engine and depressurisation of the piping after regulating valve V07 resulting is the pressure automatically decreased below the re-engagement differential.

Thus the following shall be done:

- Reopen the SAV valve first slowly by dragging slightly (pressures will equalise)
- After equalising open the valve completely

This is required to enable a safe and easy re-engagement of the SAV valve.

There is a feedback signal in the SAV to monitor the valve.

Figure 7 shows the main slam shut off valves in the GRU.

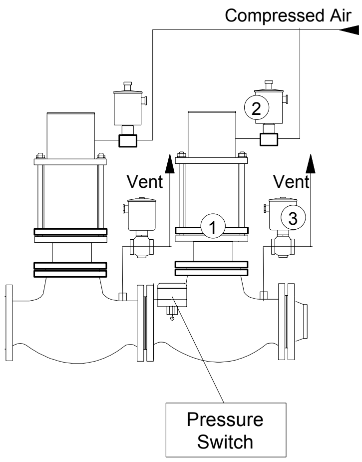


Figure 7 The shut-off valves with actuator (1), solenoid operated air valve (2) and solenoid operated vent valve (3).

The GRU is equipped with two shut-off valves, installed in series. The valves are operated by admitting compressed air into the actuator cylinders. The valves are closed by a spring when control voltage is cut off and control air released from the actuator cylinders.

Gas trapped between the valves and in the pipe between the last shut off valve and the engine is vented to the atmosphere through the solenoid operated vent valves (3). The vent valves V16 and V19 (additionally V26 and V29 for PCC line) are closed as long as the operating voltage is applied. V14 (and V24 for PCC line) is open as long as the operating voltage is applied. In running mode voltage is not applied to V14 and the valve is closed.

Both the shut-off valves and the vent valves are operated by the PLC.

7.2.2 Function

Gas is mixed with the combustion air only in the intake channels in the cylinder head (see Figure 8). This design ensures that only air is present in the charge air manifold, and thus the risk for explosions in the engine's charge air intake system is minimised.

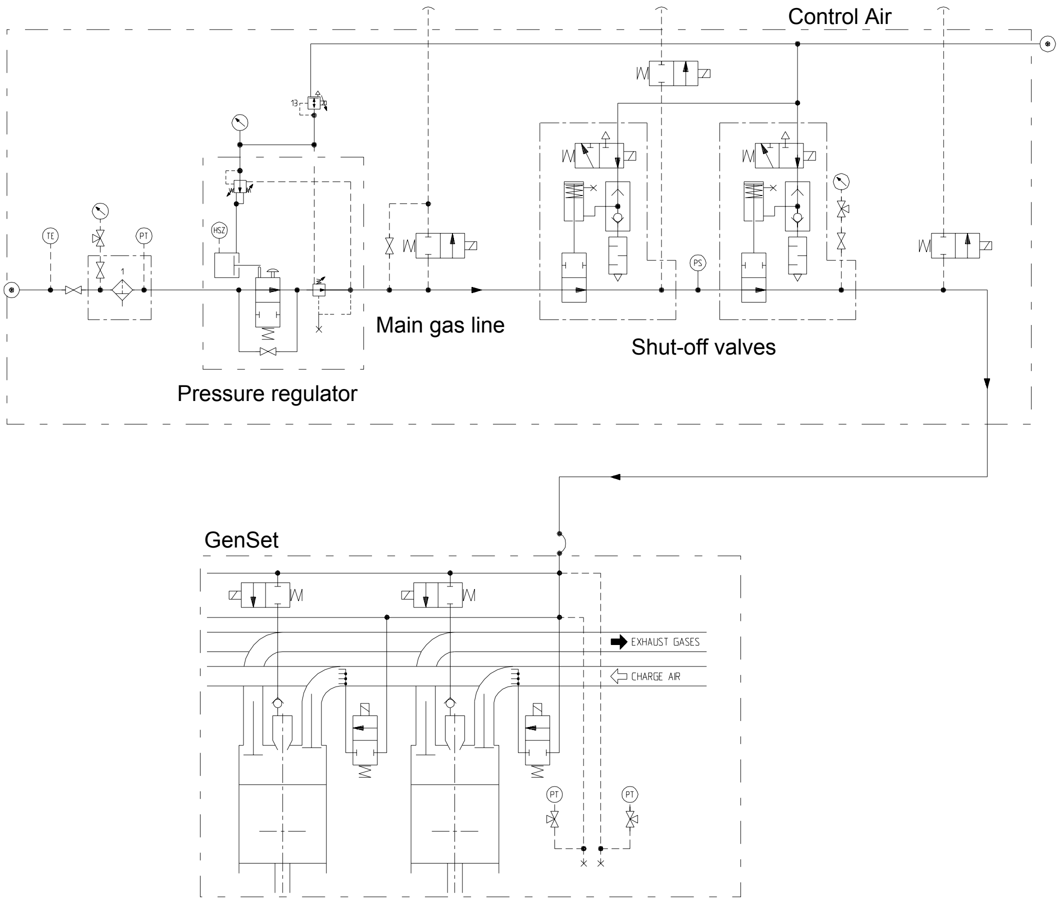


Figure 8 **The flow chart of gas regulating unit.**

The gas pressure must always remain higher than the charge air pressure. There is a minimum and maximum offset for the pressure difference. If the difference is outside the limits the engine will be shut down.

Opening, closing and venting of the gas regulating unit is electrically controlled through the PLC, while the gas at the engine intake is regulated by solenoid valves controlled by WECS (Wärtsilä engine control system).

The gas regulating unit operates "fail safe", i.e. the shut-off valves are closed and the vent valves V16 and V19 are opened in the event of a loss of electricity. Table I shows the alarm and shut down limits for gas regulating unit.

Table I **Normal operation for gas regulating unit. Normally the maximum inlet pressure to the GRU is 6 bar g and optionally 16 bar g when regulating valve V07 is supplied with safety shut off valve (SAV). In latter case, alarm and shut down are higher.**

Alarm	Shut down
P03=inlet pressure • High:6.3 bar g • Option: 16.0 bar g • Low: depending on engine type P06 =after V07 • High: 4.5 bar g	P03=inlet pressure • High: 7.2 bar g • Option: 16.8 bar g • Low: depending on engine type P06 = after V07 • High: 5.0 bar g

There is also a safety feature regarding rapid large load reductions. If for example a generator breaker opens and load is decreased instantly to 0 %, V19 is opened for a certain period of time, normally for 20 seconds.

7.2.2.1 Normal stop or shut down

Normal stop occurs when an intentional stop command is given for the engine to stop. Shut down occurs when it is necessary to stop the engine to prevent any damage for the equipment. The action for gas regulating unit shut off valves and ventilating valves is identical for normal stop and shut down.

The shut-off valves in the gas regulating unit are closed during a normal stop sequence. Gas venting is done the following way:

1. V14 is opened for 5 seconds to relieve the overpressure between V07 and V15.
2. V16 is opened and will remain so
3. V19 is opened normally for 30 seconds to relieve the overpressure between the gas regulating unit and the engine and after that the valve is closed to prevent air to get into the gas piping.

7.2.2.2 Emergency

An emergency mode will close the shut-off valves on the gas regulating unit and open venting valves V16 and V19 ventilating space between slam shut off valves and between gas regulating unit and the engine.

At the same time the gas valves on the engine will close and the ignition is deactivated.

7.2.2.3 Plant emergency

A plant emergency mode is like a local emergency mode for all engines.

A plant emergency mode is activated by:

- a gas detector sensing 20 % of LEL (option)
- a fire detector which is activated
- from a common panel by pressing emergency button

In addition, the main shut off valve outside the engine room or engine cell will be closed automatically by PLC.

Option is that a gas detector only gives an alarm and the operator takes the necessary actions. In this case, a plant emergency mode would only be possible to activate only by pressing emergency button in a common control panel.

7.2.3 Operation of the gas regulating unit

7.2.3.1 Activation of the gas regulating unit

It is assumed that all units are shut down but that power is available from the main grid (or an emergency generator). It is also assumed that all units are in operational condition, that the various components of the gas regulating unit have been properly adjusted with the correct control elements (springs, etc.) installed, gas of sufficient quantity, quality and pressure available, and the engine is ready for the start.

Before the planned start of the gas fuel system for the engine, the following should be checked:

1. Make a visual check of the entire unit.
   - Check that no work is being performed on the unit, and that all flanges are bolted together and that all connections are installed and secured.
2. Dispose of any unsecured items or debris near the unit that may inhibit operation or could cause injury.
3. Ensure that the engine room is well ventilated and gas free.
4. Check that the main gas valve (manual ball valve) on the gas regulating unit is closed.
5. Check that the gas inlet pressure is normal.
6. Check that the control air pressure is sufficient to operate the system.
7. Check that the manual vent valve on the gas train is closed.
8. Open up all manual shut-off valves to instruments and control units.
9. Check that the safety shut-off function on the pressure regulator is reset.
10. Check that the electrical control system is active and power available.
11. Open the gas main shut-off valve outside the building.
12. Open the main gas valve on the gas regulating unit.
13. Control: that the gas regulating unit is functioning properly.
14. Control: that the shut-off valves are gas tight.
15. Check that the engine is ready for start.

The gas fuel system is now ready and the engine can be started provided that the start blocking circuits for the gas fuel system have not been activated.

> ***Caution!*** *If the gas regulating unit has been opened for maintenance or repair, it is essential to have the unit well purged to remove any trace of air before going ahead with the starting process.*

7.2.3.2 Monitoring of the gas regulating unit

Note! The following is supplied as general information only. The operating personnel must decide what actions are appropriate for the whole plant, while taking all equipment into consideration.

The normal operation and supervision of the gas fuel system consist mainly of simple daily checks, such as:

1. Check temperature and pressures in the system.
2. Check the pressure drop over the filtration unit.
   - The condition of the filter is important for the reliable operation of the engine.
   - The filter should be replaced/cleaned when the condition deteriorates.
   - The pressure drop over the filter is 0.05 to 0.1 bar when the filter is new.
   - The filter should be cleaned at or before the pressure drop has increased to 0.2 bar (1 bar pressure drop mentioned in the manufacturer's instructions is too high considering the low gas pressure in the main supply line).
3. Check for leakage.

Caution! If gas is found to be leaking into the engine room, it is essential that the engine and the gas supply system are shut down immediately. Leave the engine room and do not enter until the room has been properly ventilated to remove any traces of gas.

7.2.3.3 Shutting down the gas regulating unit for maintenance

During normal shutdown, perform the following checks (see Figure 9):

1. Close the main gas valve V01 on the gas train
2. Close the main shut-off valve outside the building.
3. Open the manual ventilation valve V13 if the gas regulating unit is to be shut down for any prolonged time.

> ***Caution!*** *If maintenance is to be performed on any part of the system, this may require closing and locking of the main gas valve V01 (see* Figure 5*) and ventilating the other parts of the system.*

These actions will be decided and taken by local operating personnel.

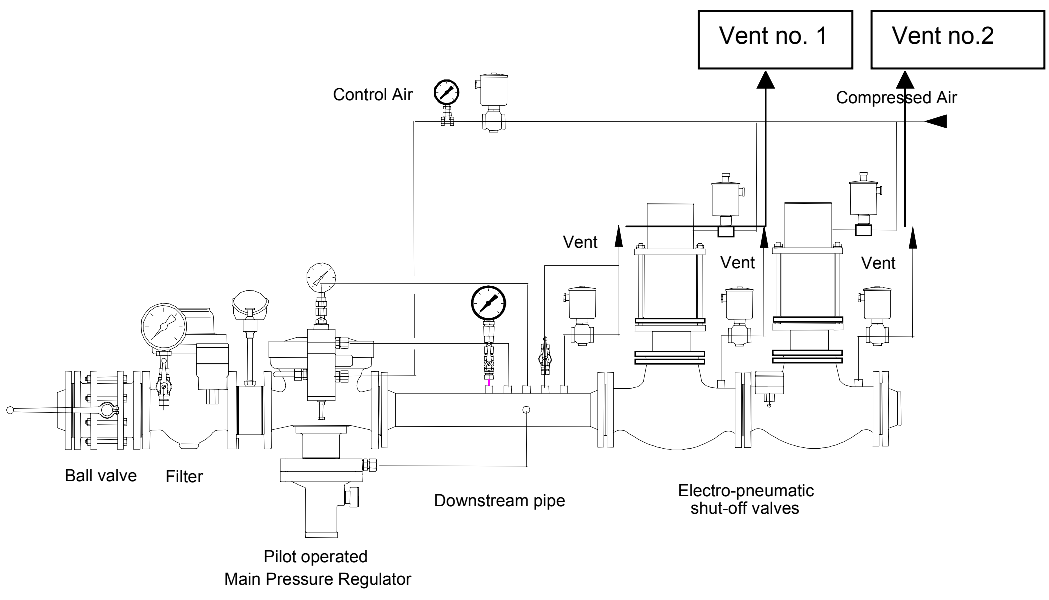


Figure 9 Gas regulating unit.

7.2.3.4 Emergency stop of the gas regulating unit

If the operating condition of the power plant requires an immediate stop of the gas supply to the engine room or engine cell, an emergency stop must be performed as follows:

1. Shut down the engine
   - Use any of the emergency stop buttons (installed on the engine control cabinet above the flywheel and on the wall inside the engine room and the control room).
2. Close the main gas valve V01 (see Figure 9: ball valve).

   Caution! *If the shutdown of the system has been caused by a gas leak it is imperative that all personnel evacuate the room in question immediately. They are not allowed to re-enter the room until it has been properly ventilated to remove any traces of gas.*

8 Exhaust gas system

8.1 General

The protection of the exhaust gas system is essential part for the safe operation of lean burn gas engine equipped power plant. Main protection methods are:

- Correct design of the system
- Explosion vents (rupture discs) installed in the system
- Exhaust gas ventilation fan operation

In addition, explosion vents should be visually inspected periodically.

8.2 Piping design

The exhaust system is mainly a passive component, i.e. it contains no controllable parts concerning gas safety. The only exception is the ventilation fan that is operated either in engine stop or start sequence.

To minimise the risk of gas explosions in the exhaust system certain safety features are recommended for the design. The following describes the exhaust system design as recommended by Wärtsilä Corporation. For more details, see WDAAA247530.

To minimise the risk of gas building up in the exhaust system it has been designed to contain only upward slopes. Any downward slope creates a pocket where gas can collect in certain circumstances causing a danger of an explosion. However, since the system always contains a silencer, and may be equipped with boiler(s) and catalytic converter(s), all pockets can not be avoided and other means must be used.

8.3 Exhaust gas system ventilation

The exhaust system is equipped with a ventilation system. The system consists of a centrifugal fan, a flow switch and a butterfly valve equipped with a limit switch. This valve is opened and the fan is started either after every engine stop or before every engine start ventilating the exhaust system. However, in an emergency mode the fan is not operating.

The flow switch confirms that the fan is rotating. The capacity of the fan and the running time of it is chosen such that it is able to change the volume in the exhaust system at least three times during the ventilation run.

Figure 10 shows exhaust gas ventilation system.

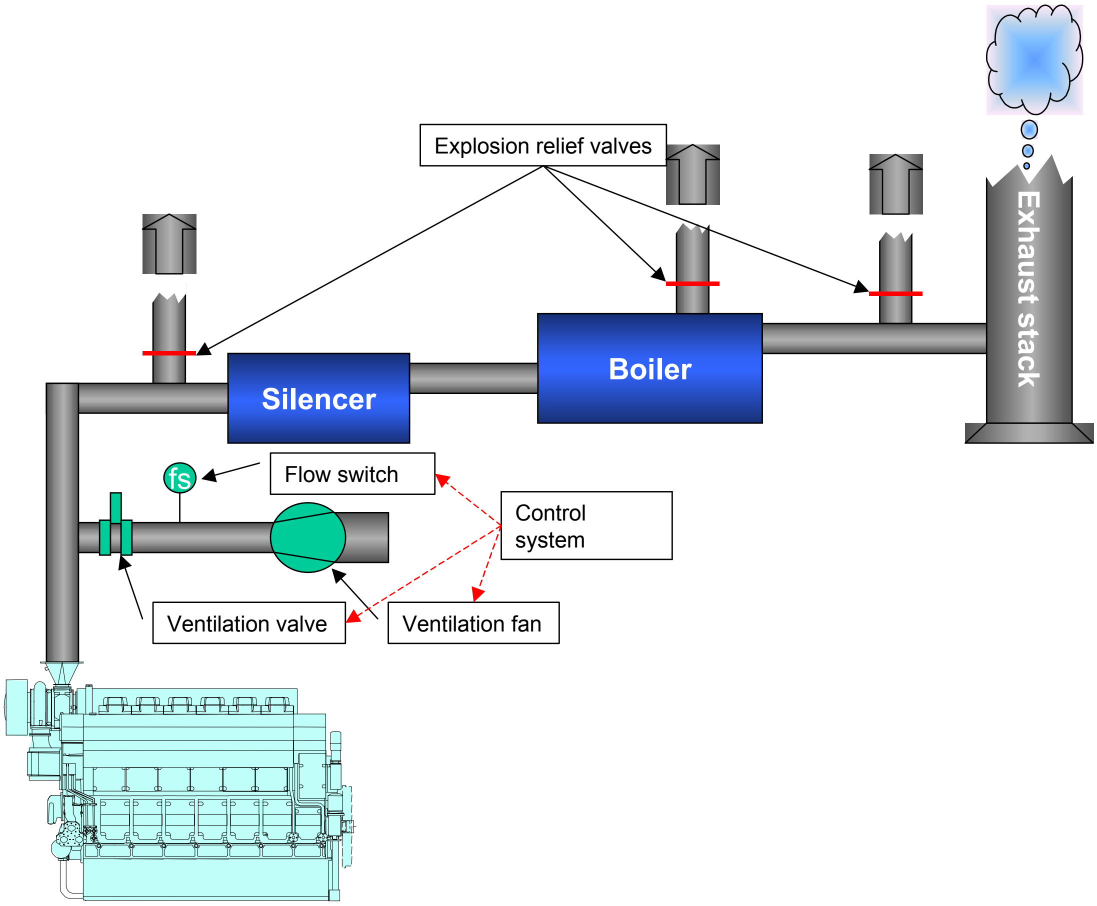


Figure 10 **Exhaust gas ventilation system.**

8.4 Explosion vents

The exhaust system is also equipped with explosion vent valves to relief the excess pressure in the exhaust system in the event of an explosion. The general rule is that the diameter of the explosion vent is at least of the same as the exhaust gas pipe diameter. In addition, the vent duct above the explosion vent is of the same diameter as the explosion vent. The length of the vent duct shall be minimised in order to reduce the back pressure from the vent duct in an explosion. The explosion vent valve is designed to open at an excess pressure of 0.5 $\pm$ 0.05 bar at operating temperature.

The first explosion vent valve is located after the turbochargers. In a straight pipe, explosion vent valves shall be installed every ten diameters.

The silencer inlet and outlets are also equipped with explosion vents. The explosion vent in the inlet may have been omitted if the distance from the previous explosion vent is less than 5 times the diameter. Only absorption silencers with straight-through design are used. Reactive type silencers with internal chambers are not allowed for lean-burn engines due to their disadvantages during an explosion. Gas may collect in the reactive part in the chambers and thus a violent explosion is possible if unburnt gas is present.

The boiler is equipped with integrated explosion vents at the inlet and outlet of the boiler. The size of these vents is dependent on the boiler design, but should as a minimum be of the same size as the inlet duct to the boiler. If it is impossible to integrate these valves into the boiler, corresponding explosion vents are located in the exhaust gas duct close to inlet and outlet of the boiler.

Explosion vents are ducted outdoors with a duct of at least the same size as the explosion vent. The duct is covered with light-weight noise and weather protection.

The outlet of the duct is located so that personnel are not present during normal operation, and the proximity of the outlet is clearly marked as a hazardous area.

Due to the gas velocities created by a possible explosion, under pressure may be created in the latter parts of the system. Therefore, the stack is dimensioned to sustain an under pressure of 0.3 bar without collapse.

Also, available are active extinguishing systems for explosion prevention, such as explosion suppression. These, however, are not a standard option for lean-burn engine equipped power plants, but have to be considered case by case for special applications. A problem with these is that the actual position of the ignition is not known. Thus the extinguishing system is nearly impossible to design.

Note! *After a gas explosion the safety equipment shall be inspected and damaged parts changed for new ones according to manufacturers' instructions. The reason for explosion must be clarified and eliminated before the next start.*

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Subject: Wärtsilä safety manual for lean burn gas engine

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TABLE OF CONTENTS (GENERAL)

1 General

This Wärtsilä® lean-burn gas engine safety manual gives general information on natural gas properties and hazards of using it together with description of safety equipment and measures both on site and on embedded in equipment. The aim of this manual is to make the operating personnel acquainted with the plant and its safety systems. To ensure safe operation of the plant the user must read this manual before operating the plant.

As the plant design may vary depending on auxiliary system's design and use of different suppliers, it is necessary to obtain detailed information on the engine and plant components. The user should therefore always read the manuals delivered.

> *NOTE ! This manual does not include any local laws, regulations or instructions concerning gas safety. Please refer to local documentation and legislation to fulfil them.*

In engine part of this manual, the description of the engine operation is given in different stages to give the operator a clear view of how the safety system controls the engine. Refer to engine manual for instructions on normal engine operation.

As it is not possible to handle all possible danger situations in this manual, the user should always consider possible error situations with a safety perspective. A gas fire or explosion may result in considerable material damage and, in the worst case, human injury. Therefore, instructions given in this manual must be followed. In addition, any local regulations and laws must be obeyed.

2 Natural gas

Natural gas is a mixture of combustible and inert gases, each with varying physical properties. Many of the fuel gas properties and the gas suitability to be used as a fuel for internal combustion engines can be determined from the component gas properties.

2.1 Composition

Composition of the natural gas varies substantially between the various production fields. Gases having composition according to the table below are called natural gases.

Table 1. Composition of natural gases (by volume).

Methane	CH_4	70 – 90 %
Ethane	C_2H_6	0 – 7 %
Propane	C_3H_8	0 – 2 %
Butane	C_4H_{10}	0 – 0.5 %
Hydrogen	H_2	Traces
Carbon dioxide	CO_2	0 – 10 %
Oxygen	O_2	0 – 0.2 %
Nitrogen	N_2	0 – 15 %
Hydrogen sulphide	H_2S	0 – 10 ppm

2.2 Properties

Natural gas properties vary slightly according to its composition. Yet, most of its properties are attributed to methane, the main constituent.

Natural gas is a combustible, non-odorous, colourless and tasteless gas, and therefore difficult to detect. To make it sensible, it is normally scented with tetra hydro thiophene (THT, C_4H_8S). Using this additive, natural gas can be detected by smell already at as low concentrations as 0.05 – 0.2 vol.-%.

The density of natural gas is around 0.75 – 0.85 g/cm^3. Thus, it is lighter than air and tends to rise in closed, draughtless space.

Natural gas requires certain concentration to be ignited or burned. At 0 °C the concentration has to be 5 – 15 vol.-%, lower or higher concentrations do not ignite or burn. At higher temperature this area is slightly enlarged and at 500 °C it is 3 – 20 vol.-%. Previous values apply to, if gas is mixed with air. If oxygen only is present instead of air, the limit is 5 – 60 vol.-% at 0 °C.

The auto-ignition temperature for natural gas is around 600 °C. At this temperature natural gas will self-ignite and burn independent of concentration as long as any oxygen is present.

Complete burning of natural gas yields carbon dioxide (CO_2) and water (H_2O). If there is not enough air, carbon monoxide (CO) will build up.

3 General health and safety aspects

Dangerous situations with natural gas are caused by gas leakage and its consequences. These include gas fires and explosions as well as ihnalation of natural gas or carbon monoxide, which forms in cases where natural gas is burning without a sufficient oxygen supply.

3.1 Breathing natural gas

Natural gas in itself is not poisonous. With high concentrations it displaces air and may therefore cause suffocation. Inhaling small amounts and concentrations of natural gas does not pose any danger. Higher concentrations will cause sleepiness, headache and drowsiness. In even higher concentrations, it causes suffocation.

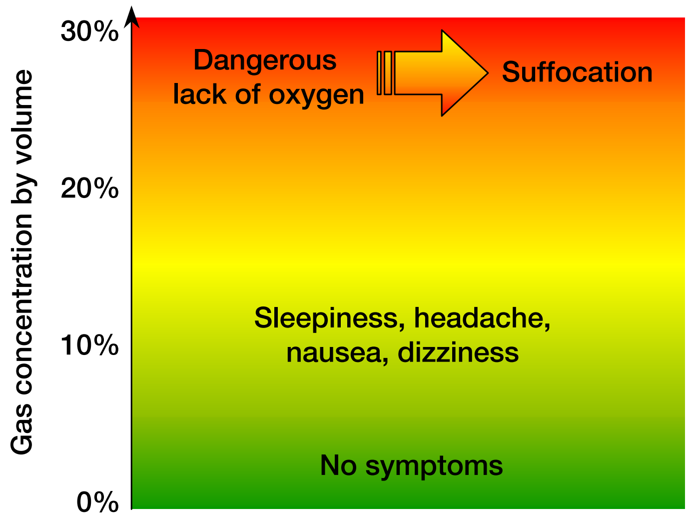

Figure 1. Symptoms of natural gas inhalation.

Normally natural gas has been odorised to facilitate its detection in case of leak. The odorant has a repulsive smell and it can be detected readily when the concentration of the gas is well below the ignition limit. However, there is no way to tell the concentration by the smell.

First aid for natural gas exposure depends on the symptoms. Slight breathing difficulties normally disappear when moving the person to fresh air. Serious breathing difficulties or unconsciousness will call for revival actions and medical attention.

3.2 Breathing carbon monoxide

Generally, most of the deaths associated with natural gas accidents are caused by carbon monoxide, CO. Carbon monoxide is a gas which is formed when natural gas is burning without sufficient amount of oxygen (incomplete burning). Carbon monoxide often forms during gas fires.

Carbon monoxide is highly poisonous, odourless and tasteless gas, which is slightly lighter than air. Relative density is 0.967. This makes it a very dangerous gas: It is very difficult to observe without proper measurement equipment and it tends to be at the level of relief.
Carbon monoxide’s poisonous effect is based on that it very effectively replaces oxygen in blood circulation. Carbon monoxide quickly binds with haemoglobin with an affinity 200 to 250 times greater than that of oxygen to form COHb. This happens already in very low concentrations and severe symptoms are quickly developed.

The first symptom of carbon monoxide poisoning is a cheerful, happy feeling and headache. At this point, it is very important to realise the symptoms and leave the area immediately.

If the exposure to carbon monoxide continues, the person will soon loose his ability to control his/her muscles, effectively paralysing him/her and soon followed by unconsciousness. At this point, the person will need aid to get out from the area. Further exposure quickly leads to death.

First aid for symptoms, like breathing difficulties and headache, caused by carbon monoxide is moving the patient to fresh air. Unconsciousness requires proper revival actions and immediate medical attention.

4 Gas leaks and fires

A gas leak into a building may lead to a gas fire and explosion. Therefore, it is important to prevent any leaks by examining regularly and carefully the gas system for leakage. This should be done using a leak detection liquid and/or a gas detector. If any of the connections in the gas system is opened, new sealing should be used when reassembling.

The following safety instructions should be distributed to all personnel working at the Lean burn gas engine power plant, to ensure that proper and safe counter measures are taken in case of a gas leak or fire. The instructions should also be posted in a visible place in the plant.

In case of fire or gas leak:

- *Close the main gas valve (or any valve upstream the fire).* This will stop the gas leak and eventually extinguish the gas fire. In case of fire, do NOT close valves on both sides of a pipe caught in the fire. This would cause the pressure to rise and eventually the pipe to explode. If the gas supply system contains a gas compressor, press the gas compressor emergency button to close down and ventilate the compressor.
- *Do NOT put out a gas fire with water or fire extinguisher.* A gas fire should be put out EXCLUSIVELY by shutting off the gas supply. If a gas fire is extinguished by other means, a gas explosion may occur when the out flowing gas makes contact with hot residues.
- *Evacuate the affected area.* Evacuate people from fire or gas explosion risk areas.
- *Arrange proper ventilation.* Open doors and windows, avoid using electrical switches and equipment, do not smoke. Natural gas in high concentration has a slight narcotic effect that disappears when breathing fresh air. Carbon monoxide possibly created in a fire is highly poisonous, causes first dizziness and headache then quickly paralyses, and leads to death. If a person is suspected to have inhaled carbon monoxide, bring him out into fresh air and call for medical attention immediately.
- *Call local emergency number.* Inform authorities of the fire or gas leak so that proper measures may be taken.

All Lean burn gas engine power plants provided by Wärtsilä are equipped with suitable detection and alarm system for gas leaks and fire.

5 Gas explosions

It is necessary to realise that gas is not explosive by it self, but some preconditions must be fulfilled before an explosion can occur. There are three main preconditions to fulfil:

- adequate gas air relation
- sufficient mixing
- ignition source

Gas explosion is a quick chemical reaction between gas and oxygen, that is the gas is burning rapidly. Contrary to explosives, natural gas does not consist of any chemically bound oxygen. Thus, additional oxygen (air) is necessary for a gas explosion to take place. Explosion only takes place with certain proportions of gas and air (for natural gas typically 5...15 vol.-% gas in air). A too lean mixture and a too rich mixture will not ignite.

Gas and oxygen (air) must be sufficiently mixed, too. Mixing ensures that each gas molecule has oxygen molecules in close range to react with. The gas explosion itself tends to mix the yet unburned gas and air due to turbulence, thus further assisting the propagation.

Finally there must be an ignition source. This may be any particle with high enough energy (temperature) to start the reaction. After the reaction has started, it will produce enough energy (heat) to continue by itself until all gas has reacted or circumstances otherwise turned unfavourable to explosion.

To get an idea what is happening during an explosion, a basic situation can be examined. An explosion can be thought to start in a situation where gas and oxygen are mixed in a long container, open at one end, and the mixture is motionless. An ignition source ignites the gas oxygen mixture at the closed end and the reaction starts.

The reaction starts with a slow burning and a flame propagation velocity in order of 5 m/s. Increasing pressure and turbulence cause the flame propagation velocity to increase to detonation. At this point the velocity may reach 2000 m/s. The reaction continues until either of the reactants have run out or circumstances otherwise turn unfavourable to explosion propagation.

The explosion causes a pressure wave at the propagation front. This high local pressure may damage structures. Behind the explosion front the reacted gases cool down quite rapidly and, together with mass inertia of the high velocity gas, may cause a negative pressure especially in long piping. This negative pressure may also cause damage to equipment.

If a gas explosion for some reason happens all systems affected by the explosion must be thoroughly inspected both mechanically and functionally. All damaged parts must be repaired or changed for new ones. Safety equipment and system must be inspected with special care and if necessary new components must be installed. Refer to manufacturers' instructions. Before the next start the reason for explosion must be clarified and eliminated.

5.1 Prevention of gas explosions and minimising the consequences

It is of utmost importance, that plant staff realises the risks associated with all gas applications and minimises these by careful working practices and consideration.

In preventing gas explosions at the plant or in the engine, the most important thing is to prevent the gas from reaching the explosive concentration. It is the only way to avoid gas explosions completely.

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

Wärtsilä® Lean burn gas engine power plants and compressor stations are equipped with high quality safety system to prevent gas explosions. All reasonable measures have been employed to prevent gas build-up, ignition and explosion. With proper and careful working practices and regular inspections, the plant is a safe place to work.

In a Lean burn gas engine power plant and a compressor station, the most probable place for gas explosion is in the exhaust system. Unburned gas may escape into exhaust system in an engine malfunction. Engine safety system aims to prevent this from happening.

The pressure build up in exhaust system is minimised by using explosion vents. Vent size, number and position must be carefully considered and selected during the design stage in order to get a safe and properly functioning system. See chapter “exhaust gas system”.

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Name: Engine

Subject: Wärtsilä safety manual for lean burn gas engine

1 Safety features in Wärtsilä® lean burn gas engines

Wärtsilä® lean burn engines have built-in safety features to ensure the safest possible operation. The aim is to avoid any operating situations where gas could pose a danger and, if such occasions occur, to ensure a safe handling of the situation. In the following chapters, the different safety features are described based on the operating phase. It is expected that the reader is familiar with the engine and its operation.

1.1 Start

Before starting the engine, possible maintenance and service operations must have been completed and all persons should have left the risk areas. Normal duties preceding the start (refer to engine manual section 3 "Start, Stop, Operation") should be carried out and the gas regulating unit be prepared for use.

Engine start can only be attempted when engine is stopped and ready for start. Several start blocks must be cleared before the engine is ready for start. For detailed list of start blocks, see engine manual section 23.7 "Alarm and safety system".

The purpose of the start blocks is to prevent the engine from being started before it is safe to do so. The blocks concerning the safety are:

- *Exhaust system ventilation*. Exhaust system is ventilated when the engine has stopped due to a stop signal or if a shutdown or emergency stop has occurred. An option is to ventilate the exhaust gas system in the start sequence before engine start.
  - This is made to ensure that possible gas in the exhaust system is discharged. For more details, see chapter “exhaust gas system”
- *Tripped safety valve in the gas regulating unit*. There is a safety valve in the gas regulating unit. If it has been tripped, the engine can not be started.
- *Low or high gas supply pressure at gas regulating unit*. Gas pressure must be within limits to start the engine. Too high or too low gas pressure may lead to incorrect air fuel mixture or gas admission valve malfunction. In both cases the proper ignition can not be guaranteed and the start is prohibited.
- *Low or high gas supply temperature at gas regulating unit*. Gas temperature affects the gas density. If the temperature is not within the limits, the amount of gas admitted to cylinder may be wrong and consequently the mixture may not ignite, thus the start is blocked.

After all start blocks have been cleared and a start command is accepted, start order is given from operator interface (WOIS, Wärtsilä Operator Interface System) either automatically (timer or other plant control request) or manually by clicking the "Start" button. In both cases the following tasks are performed automatically:

- *A gas leak test.*
- *The control air system is activated.*
- *Engine is started* according to Table 1, depending on engine type.

Table 1. Engine events during start sequence

Rpm	*SG engine*	*DF engine*
0	– Starter motors/start air valves are engaged – Waste gate closed	– Starter motors engaged – Main diesel fuel ramp to stop position
X	– Ventilation turns completed	– Ventilation turns completed
50	– Ignition started – Pre combustion chamber gas injection started – Main combustion chamber gas injection started	– Pilot fuel injection started
135	– Starting motors/start air valves disengaged – Waste gate taken into operation	
140		– Starting motors disengaged
175	– Engine to RUN-mode control – Main combustion chamber gas injection from start fuel limiter to PID control	– Engine to RUN-mode control
350		– Main diesel fuel ramp released from stop position – Engine ready for gas operation – Cylinder boost (pilot fuel injection) on
730	– Exhaust gas temperature balancing started – Cylinder boost on – Ignition map to use	– Cylinder boost (main gas injection) on – Exhaust gas temperature balancing started

Start sequence (SG) is graphically presented in Figure 1.

Detailed descriptions of all the safety features are in the following sections.

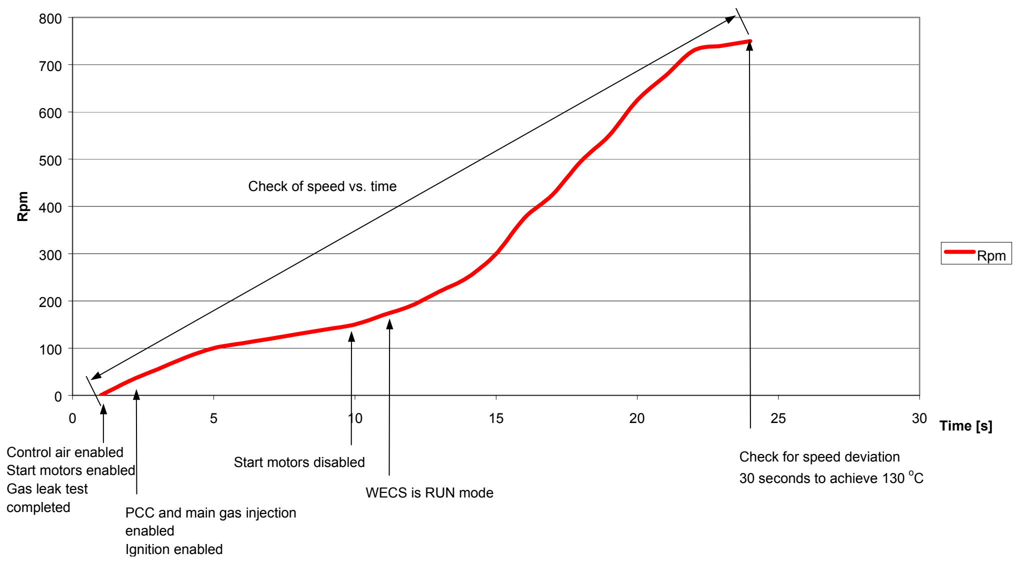

Figure 1. Start sequence (SG).

1.1.1 Gas leak test

A gas leak test is part of the start sequence. It tests the tightness of the shut-off valves on the gas regulating unit. If gas is leaking through the valves, the start sequence will not continue. After the test has been successfully performed, the plant control system (PLC) gives the engine a start command. Then the engine is ventilated, both shut-off valves are opened, and gas is supplied to the main (and PCC) gas valves.

1.1.2 Engine ventilation

During the first five engine revolutions the gas valves on the engine and shut-off valves on gas regulating unit are closed and ignition is not active. This is to ensure that possible gas in the cylinders and exhaust pipes on the engine is discharged. During these revolutions, air is pushed to the exhaust system by the cylinders, roughly corresponding to 1.5 times the volume of exhaust pipes on the engine.

1.1.3 Start fuel limiter

To prevent excessive gas admission during the start-up the speed dependent start fuel limiter limits the amount of admitted gas. This start fuel limiter is active until engine speed is 20 rpm below the idle or nominal speed. The speed dependent limiter gives a smooth start and ensures that no excess gas is admitted at any speed.

1.1.4 Engine speed control

If the engine does not reach the nominal speed within a certain time from engaging the start motors/start air valves, it indicates a possible misfiring of cylinder(s). This may lead to gas flowing through the misfiring cylinder into the exhaust system. In this case an engine shutdown will occur.

To stop the engine as fast as possible in case of malfunction, several speed checkpoints are controlled during the speed increase. See section 4.2.1.

1.1.5 Exhaust gas temperature monitoring

After the start the exhaust gas temperature in each cylinder should rise quite rapidly to the normal value (depending on the engine load). If the temperature is low, it also indicates possible misfiring of cylinder(s). If a specified minimum exhaust gas temperature for any cylinder is not reached in a specified time after idle or nominal speed is reached, the main gas duration for that cylinder will be immediately increased. If the cylinder still is under the specified minimum exhaust gas temperature after a specified time, the engine will be shut down.

Together with the engine speed control this limits the running time of the engine to minimum in the event of any cylinders not firing.

1.1.6 Redundant speed measuring

Engine speed is measured with a redundant system. It consists of a rotary encoder on the camshaft and a back-up speed pick-up on the flywheel or separate speed pick-ups on flywheel and camshaft. The speed signal is used to determine the timing and duration of the gas admission and ignition. Fault in this system may lead to the wrong gas admission- and ignition timing and possibility to unburned gas escaping into the exhaust system.

During one camshaft revolution, the encoder/speed pick-up sends a certain number of pulses and one marker pulse at A1 cylinder TDC. Pulses are calculated and if their number deviates more than a specified number from nominal, emergency mode will be activated.

WECS calculates the speed from the signal in several different units. The calculated speed signals are cross-checked and any deviations will cause a shutdown. This feature is active after the engine has entered the run mode.

NOTE ! To avoid possible accidents, it is not recommended to stay in the engine room and boiler/silencer room during an engine start and no-load running.

NOTE ! A prolonged or repeated start attempt may lead to gas being discharged to exhaust system and as a consequence a gas explosion.

If it becomes obvious during the start, that engine will not start normally and the safety system is not responding, the user should immediately interrupt the start attempt by giving the engine a stop order on the operator interface or by pushing any of the emergency buttons.

1.2 Loading

1.2.1 Idling duration limit

After the engine has been successfully started and the nominal speed has been reached the engine is ready for loading. The combustion at no load or at low load is incomplete due to low cylinder pressure and low combustion temperature. Therefore, unburned gas is fed into the exhaust system. It is also more difficult to detect abnormalities (misfiring) when the combustion is poor.

Running time is limited in the unloaded condition, where combustion efficiency is low. If the loading does not occur during this time engine shutdown will occur.

A minimum load (approximately 10 % of the maximum load) is immediately applied in base load operation plants to stabilise the combustion and to avoid reverse power.

1.3 Run

1.3.1 Exhaust gas temperature monitoring

During the engine operation, the system monitors the exhaust gas temperature of each cylinder. This is to ensure that all cylinders are ignited and combusting correctly.

If the temperature of any cylinder is lower than or higher than the specified limit, a shutdown occurs. In addition, if the temperature deviates more than a specified value from the exhaust gas average temperature, a shutdown occurs.

The average gas temperature is also monitored and compared to a reference value in the engine control program. Deviation from the reference value indicates deviation in the air fuel ratio and engine load is reduced.

1.3.2 Redundant speed measuring

Redundant speed measuring is always active during engine operation. See chapter 1.1.6.

1.3.3 Load deviation check

If the actual load deviates too much from set load, while running against the grid, the engine will be shut down.

1.3.4 Gas pressure check

Gas pressure is monitored during the run to ensure proper gas supply and air fuel ratio. If the gas pressure is too low or too high compared to charge air pressure, the engine is shut down. Too high gas pressure may prevent the gas valves from functioning and too low gas pressure may cause too lean fuel mixture.

1.4 Stop/Shutdown

Stop and shutdown procedures are equal regarding the engine functions. The difference between these two is in the initiation. Stop is initiated by the operator or PLC. Shutdown is initiated by engine control system (WECS) or by PLC and is caused by some parameter or measured value exceeding shutdown limit. In both cases the actual procedure is the same but varies between engine types.

When the stop request is activated, the PLC first unloads the engine and then shuts off the gas supply from gas regulating unit to the engine. The PLC then tells the WECS to shut down the engine.

In case of engine initiated shutdown, the PLC shuts off the gas supply to engine immediately after WECS signal. Note that the engine is not unloaded in this case. In both cases the engine sequence is as follows varying by engine type:

Table 2. Engine stop and shut-downs sequence.

Rpm	*SG engine*	*DF engine*
720	Main combustion chamber gas injection is cut off. Stop command is sent to PLC if engine activated shutdown.	Main diesel fuel ramp is taken to stop position. Stop command is sent to PLC if engine activated shutdown.
500	Pre combustion chamber gas injection is cut off. Ignition is cut off.	Pilot fuel pump is shut down. Main gas injection is cut off.
50		Pilot fuel injection is cut off.
0	Engine condition is checked.	Engine condition is checked.

After the engine has stopped the exhaust system is ventilated to discharge any unburned gas. If the stop has been caused by an alarm, the engine will not be ready for start before the reason has been cleared and alarm has been reset.

Stop sequence (SG) is graphically presented in Figure 2.

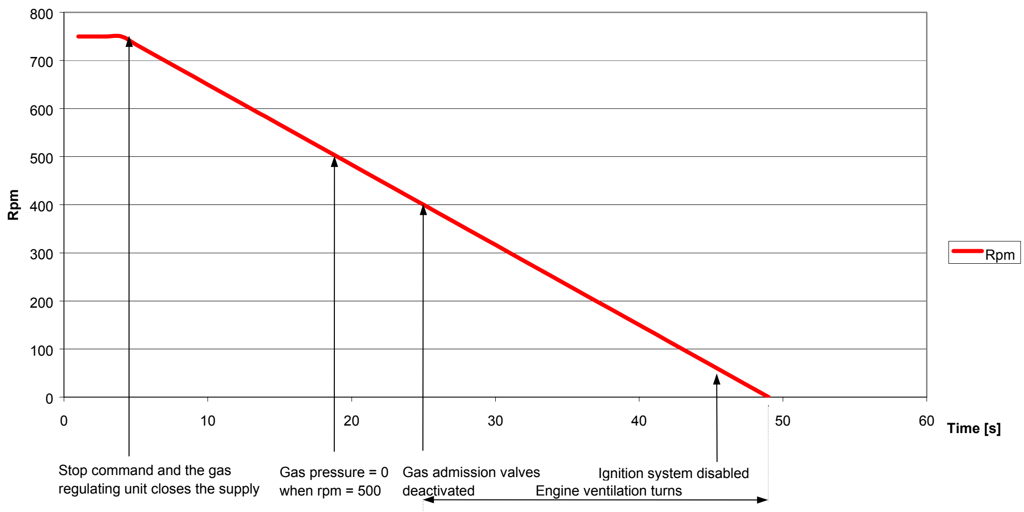

Figure 2. Stop sequence (SG).

1.4.1 Exhaust system ventilation

When the engine has been stopped the exhaust system is ventilated. It also acts as a start block. See chapter “exhaust gas system”.

1.5 Emergency

Emergency mode is initiated either manually by the operator or automatically by the control system in case of critical fault on the engine or auxiliary equipment. In emergency mode the gas supply to the engine is shut off and all engine controls (ignition, gas injection, pilot fuel injection etc.) are disabled immediately.

NOTE ! After an emergency the reason must be clarified.

When the operator has reset the emergency indications the engine is ready for a new start if no start blocks are active.

Emergency sequence is graphically presented in Figure 3.

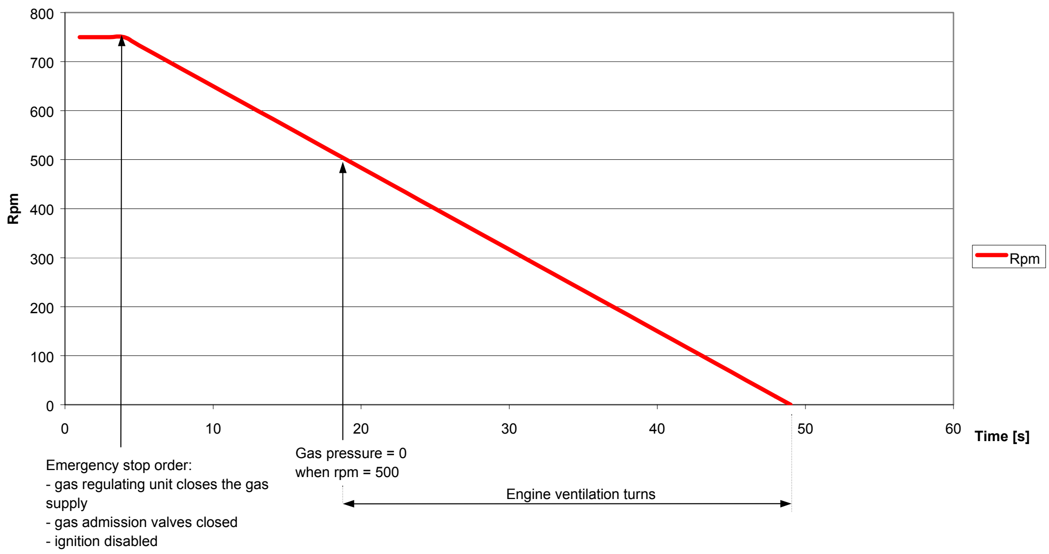

Figure 3. Emergency sequence.

1.6 Alarm system

1.6.1 Start blocks

Before the PLC activates a start request the engine must be ready for start. The following is a list of the start blocks concerning gas safety:

- *Shutdown or emergency signal not reset*.
- *Exhaust system ventilation not finished*.
- *Start air pressure below the start block limit*. If the start air pressure is too low, the start will be unreliable.
- *Main* (and pre combustion chamber) combustion chamber *gas pressure below start block limit* after the start signal.
- *Low or high gas temperature*.
- *Safety valve* in the gas regulating unit is *tripped*.

Refer to engine manual, section 23.7.1 for detailed list of start blocks.

1.6.2 Alarms

Following is a list of the alarms concerning gas safety:

- *Sensor failure*. All sensors connected to WECS are monitored. If the signal level or value is abnormal (out of range) an alarm will be initiated. Sensors with digital signals are wired so that they normally give a high (NC) signal to a measuring unit. If a wire breaks, it will initiate an alarm. Some sensors of vital importance to the engine performance or safety will activate a shutdown request. All other sensor failures cause an alarm. See engine manual for further information.
- *Gas pressure deviation*. The actual gas pressure is compared with the charge air pressure. If the gas pressure is less than a pre-set level over the charge air pressure, an alarm is activated. Low pressure will lead to too lean mixture, misfiring and thus, gas discharging into exhaust system.
- *Low control air pressure*. If the control air pressure is too low, it will lead to malfunction of the exhaust waste gate valve. This in turn leads to uncontrolled gas air mixture. Load is reduced 25% to avoid this.
- *High exhaust gas temperature after any cylinder*. High exhaust gas temperature indicates too rich gas air mixture, which may lead to knocking.
- *High exhaust gas temperature deviation between cylinders*. This may indicate that part of the cylinders are not firing, or that part of the cylinders have too rich fuel air mixture. In both cases gas may be discharged into exhaust system.
- *Start attempt failed*

Alarms can only be reset by the operator. They will not be reset automatically if engine conditions return to normal.

Refer to engine manual, section 23.7.2 for detailed list of alarms.

1.6.3 Gas trips (DF)

In addition to normal alarms and shutdowns, the DF engine can be tripped from gas operation to diesel operation in case of problem. Reasons to trip the engine are following:

- *Charge air pressure sensor failure*, which may cause incorrect A/F-ratio and misfiring.
- *Heavy knocking*, may indicate too much gas being admitted to cylinder
- *Pilot fuel pressure sensor failure* may cause misfiring due to incorrect pilot fuel pressure
- *Low/high pilot fuel pressure* may cause misfiring
- *Gas pressure build up time elapsed*. Gas pressure has not risen to correct value within time limit.
- *Gas pressure deviation*. May lead to misfiring due to incorrect A/F-ratio.
- *High load swing*. May indicate gas valve malfunction.
- *Exhaust gas temperature deviation*. May indicate improper A/F-ratio
- *Low exhaust gas temperature from pilot fuel injection*. Not enough pilot fuel is being injected to cylinder.
- *MFI duration max time*. Gas admission not working properly as the maximum duration is not enough.
- *Max idle time*. As with SG engine

1.6.4 Shutdowns

There are a number of reasons for a shutdown of the engine. The shutdown is generated in the WECS because of a shutdown request. The status of the shutdowns is sent to the PLC. Following is a list of the shutdown requests concerning gas safety:

- Start failure.
- High charge air temperature
- High exhaust gas temperature after any cylinder
- Low exhaust gas temperature after any cylinder
- High exhaust gas temperature deviation between cylinders
- High deviation of gas pressure

Refer to engine manual, section 23.7.3 for detailed list of shutdowns.

1.6.5 Emergency

There are a number of reasons for an emergency of the engine. The emergency is generated in the WECS because of an emergency request. Below is a list of emergency requests concerning gas safety:

- Emergency push button, on engine or external, pressed
- Rotary encoder /speed sensor failure
- Over speed from rotary encoder
- Over speed from speed pick-up
- Speed deviation between rotary encoder and engine speed pick-up
- Number of encoder pulses per revolution deviate more than allowed from nominal value.
- Degassing failure in auto stop mode. Activated if the gas pressure is still present after the shutdown control task has disabled the inlet gas pressure control.

Refer to engine manual section 23.7.4 for detailed list of emergency.

Operating troubles and troubleshooting concerning the gas components and control system are described in the engine manual, section 8 "Operating Troubles, Emergency Operation".

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Name: Compressor station

Subject: **Wärtsilä safety manual for lean burn gas engine**

1 General

This section of manual describes mainly the safety features of auxiliary components i.e. outside engine in the compressor station.

2 Hazardous area classification

2.1 Classification for engine

In the case of an adequately ventilated enclosure containing gas-fuelled engines it need not be classified solely by reason of the engine fuel. This is the case with a normal power plant installation.

In the case of a gas compressor driven by a gas engine, the engine is seen as an ignition source and the gas compressor is a source of possible gas leak. The possibility of a gas leak is considered to be higher in a gas compressor, thus, a gas engine driven compressor is classified as hazardous area, normally zone 2 or class I division 2.

In special designs (see paragraph 2.2) the hazardous area can be limited to a compressor room provided that the fuel gas do not enter to engine room. In this case engine is not classified.

The above mentioned statement is based on the following standards:

2.1.1 American Codes

American Petroleum Institute

API 500: Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2

- Section 8.2.5 Hydrocarbon-fuelled Prime Movers

National Fire Protection Association

NFPA 37: Standard for Stationary Combustion Engines and Gas Turbines

NFPA 850: Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

2.1.2 European Codes

EN-60079-10 Electrical apparatus for explosive gas atmospheres; part 10 Classification of hazardous areas

EN-1834-1 Reciprocating internal combustion engines – Safety requirements for design and construction of engines for use in potentially explosive atmospheres – Part II engines for use in flammable gas and vapour atmospheres.

There are no current EU guidelines for gas engine power generation installations; in such a case Internationally recognised codes are accepted.

2.1.3 UK Codes

The Institute of Petroleum

IP15 Area classification code of practice for petroleum installations, Model code of safe practice: part 15

Section 8.7 Combustion Engines

The Institution of Gas Engineers

IGE/UP/3 Gas fuelled spark ignition and dual fuel engines

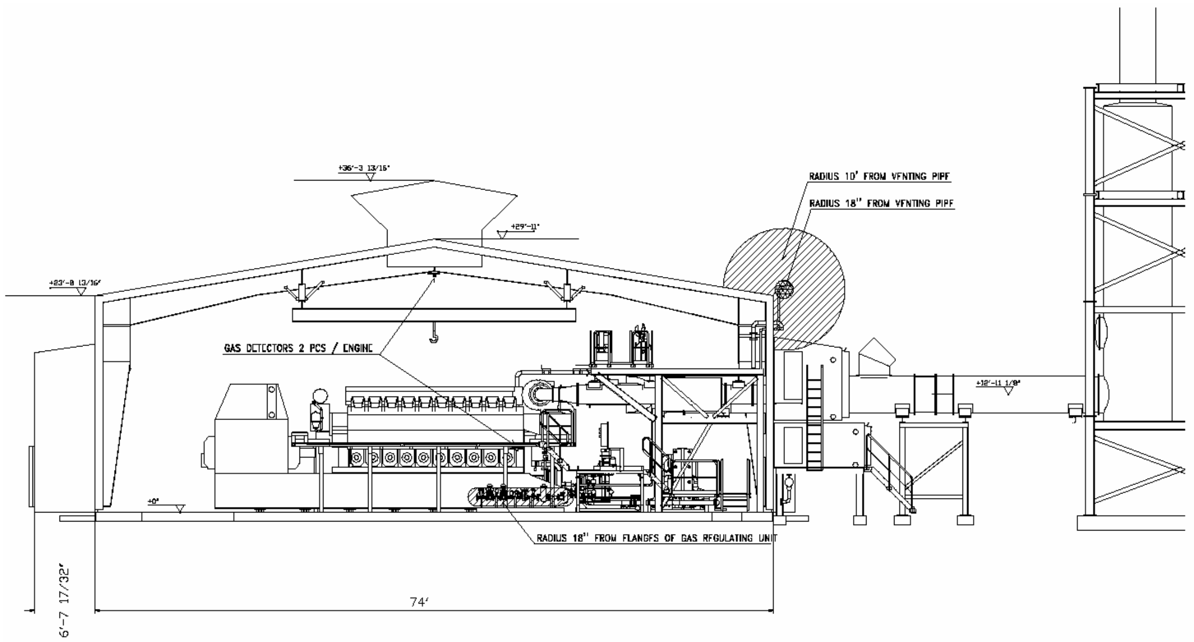
Section 8.1.7 Electrical Equipment and Supplies

2.2 Classification for auxiliary system

The codes to be followed are EN60079-10, API500 and IGE/SR/25.

In case a gas compressor is separated with a wall from the space in which engine is located, then the engine room is not classified as hazardous area. On the contrary, zones are existing but are limited to small spaces. Zone 2 according to EN60079-10 or class I division 2 according to API500 is found in the gas piping flange joints in fuel gas regulating unit and flow metering unit (option). The hazardous area around the flange is a sphere whose radius is typically 1 m. In addition, vent piping creates a hazardous area near the roof. Radius should be checked for each installation, and is affected by the gas pressure and level of ventilation.

Figure 1 shows a typical example of hazardous area classification for gas engine power plant.



HAZARDOUS SUBSTANCES: Natural gas

Flash Point	Explosion Group	Autoignition Temp. F	Ignition Group	Vapour density
	D	1076	T1	0,6 x Air (lighter than air)

Hazardous Area Classification

Class I division 1	A location in which ignitible concentrations of flammable gas are expected to exist under normal conditions.
Class I division 2	A location in which flammable gas may be present, but normally are confined within closed systems and are prevented from accumalating by adequate ventilation.

Standards and guidelines
API500

Figure 1 **Example of hazardous area classification for a gas engine power plant according to API500.**

In case a gas compressor is in the same space than the engine, the whole space is classified as Zone 2 or class I division 2.

3 Control philosophy

There are different control modes for the power plant. These are:

- Start
- Run
- Stop
- Shut down
- Emergency
- Stand-by

These are discussed briefly below. In addition, different causes for stop, shut down and emergency from power plant as well as different consequences regarding power plant safety are discussed below.

3.1 Start

In start mode certain checks are gone through in order to ensure a safe start. The plant control system (PLC) checks for start blocks before engine is allowed to start. After the engine is started following the start sequence the engine mode is changed to running.

3.2 Run

In run mode engine output is maintained at the level required by the plant and all engine parameters are monitored and controlled to ensure a safe and reliable operation.

3.3 Stop

Stop is activated from WOIS giving an order for engine to stop or it can be done by pressing the stop button in M1 panel. The engine is unloaded and when the load has reached a set value, a stop command for WECS is given.

The fuel gas regulating unit is closed. See chapter fuel gas regulating unit for more details.

3.4 Shut down

Shut down is otherwise the same as the stop mode except that it is initiated by a failure detected by WECS or PLC.

Causes for shut down are:

- start sequence failure
- fuel gas system abnormal
- electrical system fault
- safety relay trip

- WECS shut down signal
- WECS communication failure
- Project specific trip

This includes also shut down command for the fuel gas compressor and the related valves. These valves will be set to default according to project specific documents e.g. with the help of risk assessments.

Main consequences for shut down are:

- Stop command for WECS is given
- Fuel gas regulating unit is closed

3.5 Emergency

Emergency mode is initiated by a hardwired signal. Emergency mode for compressor station is shown in Figure 2.

Emergency can be initiated either by pressing emergency stop push buttons in:

- common panel, which means a plant emergency mode is initiated and all the engines are shut down or
- by engine wise panels, which means an emergency mode is initiated for that engine only

or

by a fire or gas detector.

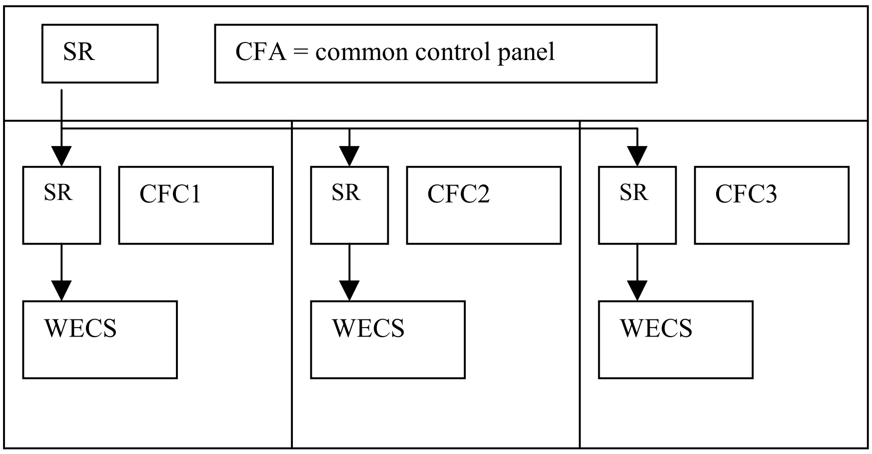


Figure 2 A schematic diagram for emergency mode of control system.

SR = safety relay (or safety PLC)

CFC = engine wise control panel

3.6 Stand-by

Stand-by is a mode in which the power plant waits to be started. To enter this mode, plant needs to be stopped. In case of a shut down or emergency all the faults and alarms need to be cleared before start can proceed.

4 Fire fighting and gas detection system

Each country has it's own fire protection legislation and codes of practise. Therefore, project design is to be reviewed with the local authorities and the system is chosen on a case by case basis.

The power plant is subdivided into separate fire areas for the purpose of limiting the spread of fire, protecting personnel and limiting the resultant consequential damage to the plant.

Fire areas are separated from each other with fire barriers, spatial separation or other approved means.

Media capable of burning in a gas power plant are:

- Gas
- Cables
- Lubrication oil

The main method to prevent a gas fire is to design the fuel gas system safe.

- Main manual gas shut off valve is located outside the engine room
- Automatic shut off valves located inside engine room will shut off the engine specific fuel supply in an engine stop.
- Optionally engine specific gas shut off outside engine room (see chapter 5)

Burning gas must not be extinguished since the remaining unburned gas may explode.

Other possible causes for a fire are taken care of with a fire detecting and fighting system.

4.1 Fire detectors

There are normally at least two fire detectors per location. Fire detector types used are:

- Differential heat detectors
- Optical smoke detectors

The type used and the locations for the detectors will depend on the project and standards to be followed.

4.2 Fire fighting equipment

Fire fighting system consists of:

- Portable dry powder and/or CO_2 extinguishers
- Fire hydrants for fire hoses
- Loose fire hose equipment to be connected to fire hydrants
- Permanently connected fire hose reels

4.3 Gas detectors

The gas detectors are required to detect any gas leak. These are located in a position where a gas leak is most likely to occur and be detected. See Figure 1. These are normally:

- Above fuel gas regulating unit
- At ventilation air outlet at the roof level

4.4 Alarm and shut down system description

The gas and fire detection system has a control unit, which receives information from detectors placed in critical locations. If a detector is activated, a fire or a gas leak alarm is given locally and/or remotely, to ensure evacuation of personnel and to initial emergency procedures.

An alarm is given when a gas detector is sensing 10 % of LEL (lower explosion limit).

When a gas detector is sensing 20 % of LEL or above, normally an automatic emergency is initiated for the plant shutting down the gas supply at the engine specific fuel gas regulating units and closing the main shut of valve outside the engine room or engine cell. In case of a fire alarm a plant shut down is initiated, as well.

Gas detectors can also be of the type with one level alarm. In this case exceeding an alarm level of 20 % of LEL an emergency mode is initiated.

An option is that the gas detector or fire detector gives an alarm and the necessary actions are taken by operating personnel.

5 Engine room ventilation

The engine room ventilation system is required in order to supply sufficient combustion air to the engine and to maintain the temperature in the engine room at a suitable level.

Ventilation can be classified as inadequate or adequate. The prerequisite for an engine room to be unclassified area regarding explosion safety is that ventilation shall be adequate at all times including stand by. Ventilation fans shall be zone 2 or class I div 2 approved.

An option is that fuel gas system is of special design. In this case the gas supply is closed per each engine outside the engine room. This is done to keep the gas inventory low inside the engine room and thus ventilation is not required in a stand by mode. (See chapter 7.1). In addition, in this design the fuel gas system components up to the fuel gas regulating unit are done with welded joints and thus a possibility of a gas leak is negligible.

6 Emergency lighting

Emergency lighting shall be ex-classified in zoned areas including engine and compressor room to reduce the risk of igniting any possible gas/air mixture in the power plant during any emergency.

7 Gas supply system

The gas supply is an essential part for the engine operation. It should be regularly inspected and maintained for correct function and safety.

Before gas is supplied to the engine it passes through the following units:

- flow measuring unit (optional). Either plant specific or engine specific flow meter.
- gas compressor upstream the fuel gas regulating unit if the inlet pressure is too low for the engine (optional)
- a plant specific pressure reduction station (PRS) upstream the GRU when inlet pressure to the GRU is over 16 bar (optional)
- engine specific fuel gas regulating unit (GRU)

GRU has normally only one connection to the engine and the gas is divided into two streams at the engine

- main combustion chamber (MCC) gas
- pre-combustion chamber (PCC) gas.

In some cases, the GRU has separate line for pre-chamber gas and thus there are two connections to the engine. In this case MCC and PCC gas may have different pressure.

The outlet pressure is controlled by the engine control system according to engine load.

Figure 3 shows a schematic diagram of the fuel gas system.

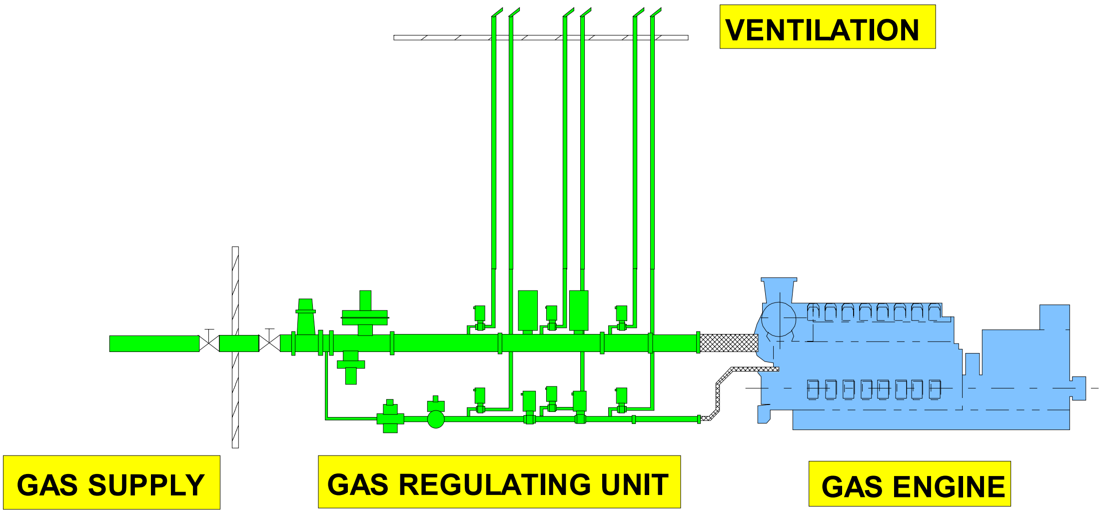


Figure 3 **An example of a fuel gas system illustrating main shut off valve, fuel gas regulating unit and gas engine.**

7.1 Main shut off valve

Regarding fuel gas system there are two alternatives:

- System with a common gas shut off
- System with a separate gas shut off

Normal design is to have the common gas shut off. It means that there are two main shut off valves outside the engine room and the gas supply is divided for all the engines inside the engine room.

The main shut-off valve isolates the gas feed line to the plant. Of the two valves, one is manually operated valve and the other is automatically operated shut off valve, which is of fail safe type and is closed either in loss of power or control air.

The main shut off valves are located outside the building and marked clearly according to local regulations. In the event of a gas leak, fire or gas explosion the valve should always be closed. In the case of a plant emergency, the automatically operated main shut off valve is closed by a hardwired signal.

An engine specific emergency does not close the main shut off valve. It only closes the slam shut off valves on the GRU and ventilates the gas pipe between the engine and the GRU.

An option is the design that each engine has main shut off valve(s) outside the engine room, i.e., a system with separate gas shut off. In this case the automatic valve is closed in the operating modes:

- Stop
- Shut down
- Emergency shut down
- Plant emergency shut down

7.2 Fuel gas regulating unit

Natural gas is supplied from the distribution system and passes through a fuel gas regulating unit - or the “gas train”. The fuel gas regulating unit provides the correct gas admission to the engine by regulating gas feed pressure depending on the engine load. In addition, fuel gas regulating unit performs a leakage test of the main slam shut off valves prior to every engine start.

7.2.1 Design

The main components of the GRU are (see Figure 4 and Figure 5):

- Manual ball valve: V01
- Inert gas line, closed with a cap.
- Filter
- Instrumentation such as pressure and temperature gauges and transmitters
- Pressure regulating valve of diaphragm type, pilot operated, self regulating: V07
- Main slam shut-off valves: V15 and V18, fail close
- Ventilating valves: V14, V16, V19 (V14 is of fail close type while the others are of the fail open type)

The electrical components are ex-classified to be suitable for installation in zone 2 or class I division 2, respectively. This is due to possible small leaks in the flanges or other connection, which makes a small hazardous area around the unit flanges or connections.

Fuel gas regulating unit layout drawing is illustrated in Figure 4 and the P&ID is shown in Figure 5.

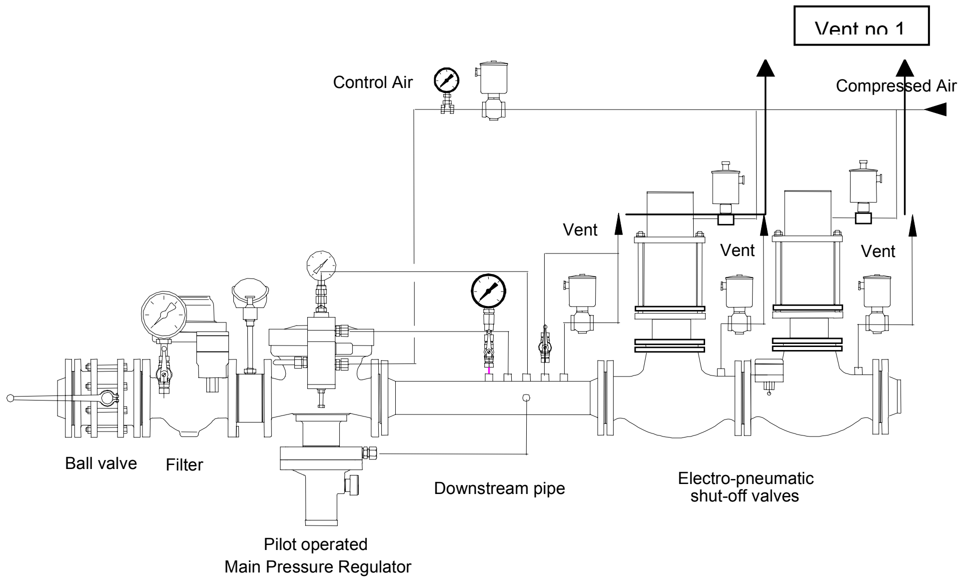


Figure 4 **Typical fuel gas regulating unit layout.**

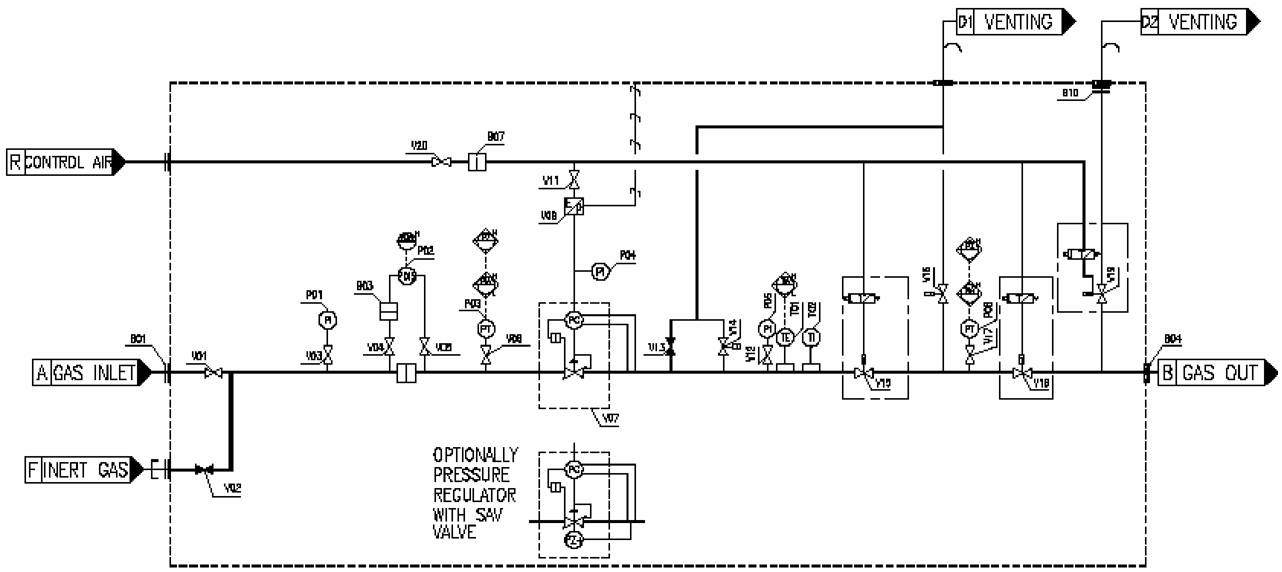


Figure 5 **The P&ID of the fuel gas regulating unit.**

The GRU includes shut-off valves and ventilation valves, which are located in the vent pipes. These vent pipes are drawn as two separate lines up to the roof (see Figure 5). This is a hazardous area and it is marked on the layouts as such (see Figure 1).

Figure 6 shows the pressure regulator in the GRU.

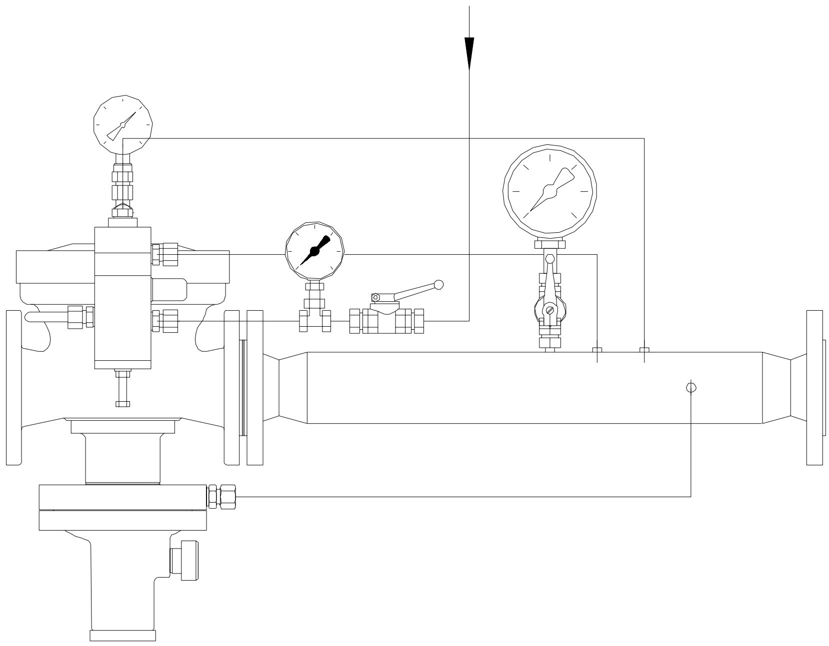


Figure 6 The pressure regulator with functional units regulator, pilot valve and SAV valve.

The pilot operated pressure regulator is operated using control air from I/P converter.

The regulator consists of the main valve body and the functional units “regulator”, “pilot valve” and “safety shut-off valve” (SAV).

Safety shut-off valve (SAV)

An additional safety shut-off valve may be installed if the inlet pressure to the GRU is higher than 6 bar. The control element of the safety shut-off valve is installed on the inlet side of the body and shuts off the gas flow if the outlet pressure in the main gas line rises above the pre-set limits. On detecting high pressure the SAV measuring diaphragm and the switching bush move into the release position and the ball mechanism set the valve stem free to close the SAV valve.

The safety shut-off valve can *only be reopened by hand*, after the outlet pressure at the measuring point has been restored to a value *below* the re-engagement differential. If the SAV valve is closed, it will lead to a shut down of the engine and depressurisation of the piping after regulating valve V07 resulting is the pressure automatically decreased below the re-engagement differential.

Thus the following shall be done:

- Reopen the SAV valve first slowly by dragging slightly (pressures will equalise)
- After equalising open the valve completely

This is required to enable a safe and easy re-engagement of the SAV valve.

There is a feedback signal in the SAV to monitor the valve.

Figure 7 shows the main slam shut off valves in the GRU.

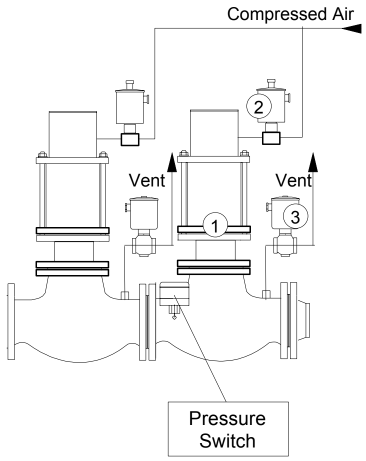


Figure 7 **The shut-off valves with actuator (1), solenoid operated air valve (2) and solenoid operated vent valve (3).**

The GRU is equipped with two shut-off valves, installed in series. The valves are operated by admitting compressed air into the actuator cylinders. The valves are closed by a spring when control voltage is cut off and control air released from the actuator cylinders.

Gas trapped between the valves and in the pipe between the last shut off valve and the engine is vented to the atmosphere through the solenoid operated vent valves (3). The vent valves V16 and V19 (additionally V26 and V29 for PCC line) are closed as long as the operating voltage is applied. V14 (and V24 for PCC line) is open as long as the operating voltage is applied. In running mode voltage is not applied to V14 and the valve is closed.

Both the shut-off valves and the vent valves are operated by the PLC.

7.2.2 Function

Gas is mixed with the combustion air only in the intake channels in the cylinder head (see Figure 8). This design ensures that only air is present in the charge air manifold, and thus the risk for explosions in the engine's charge air intake system is minimised.

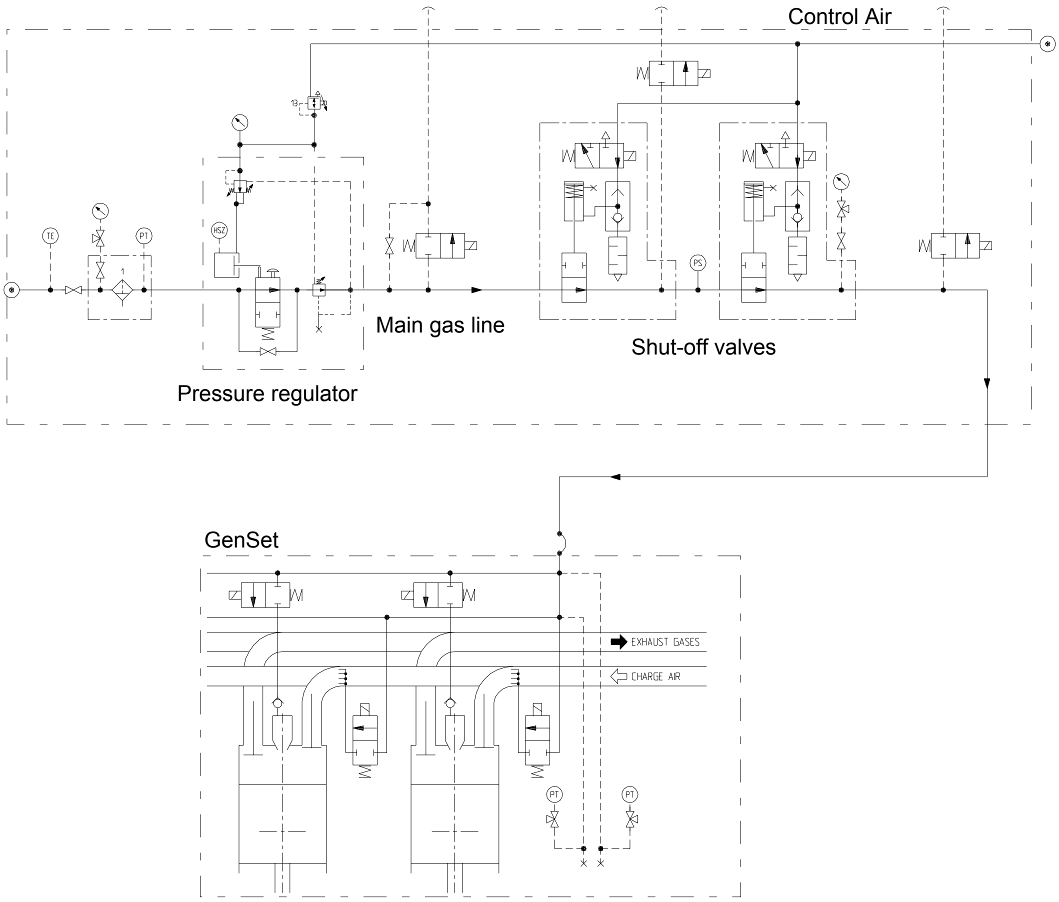


Figure 8 **The flow chart of fuel gas regulating unit.**

The gas pressure must always remain higher than the charge air pressure. There is a minimum and maximum offset for the pressure difference. If the difference is outside the limits the engine will be shut down.

Opening, closing and venting of the fuel gas regulating unit is electrically controlled through the PLC, while the gas at the engine intake is regulated by solenoid valves controlled by WECS (Wärtsilä engine control system).

The fuel gas regulating unit operates "fail safe", i.e. the shut-off valves are closed and the vent valves V16 and V19 are opened in the event of a loss of electricity. Table I shows the alarm and shut down limits for fuel gas regulating unit.

Table I **Normal operation for fuel gas regulating unit. Normally the maximum inlet pressure to the GRU is 6 bar g and optionally 16 bar g when regulating valve V07 is supplied with safety shut off valve (SAV). In latter case, alarm and shut down are higher.**

Alarm	Shut down
P03=inlet pressure • High:6.3 bar g • Option: 16.0 bar g • Low: 1.5 P06=after V07 • In case of PS: - • In case of PT: High: 4.5 bar g	P03=inlet pressure • High: 7.2 bar g • Option: 16.8 bar g • Low: - P06 = after V07 • In case of PS: - • In case of PT: 5.0 bar g

7.2.2.1 Normal stop or shut down

Normal stop occurs when an intentional stop command is given for the engine to stop. Shut down occurs when it is necessary to stop the engine to prevent any damage for the equipment. The action for fuel gas regulating unit shut off valves and ventilating valves is identical for normal stop and shut down.

The shut-off valves in the fuel gas regulating unit are closed during a normal stop sequence. Gas venting is done the following way:

1. V14 is opened for 5 seconds to relieve the overpressure between V07 and V15.
2. V16 is opened and will remain so
3. V19 is opened normally for 30 seconds to relieve the overpressure between the fuel gas regulating unit and the engine and after that the valve is closed to prevent air to get into the gas piping.

7.2.2.2 Emergency

An emergency mode will close the shut-off valves on the fuel gas regulating unit and open venting valves V16 and V19 ventilating space between slam shut off valves and between fuel gas regulating unit and the engine.

At the same time the gas valves on the engine will close and the ignition is deactivated.

7.2.2.3 Plant emergency

A plant emergency mode is like a local emergency mode for all engines.

A plant emergency mode is activated by:

- a gas detector sensing 20 % of LEL (option)
- a fire detector which is activated
- from a common panel by pressing emergency button

In addition, the main shut off valve outside the engine room or engine cell will be closed automatically by PLC.

Option is that a gas detector only gives an alarm and the operator takes the necessary actions. In this case, a plant emergency mode would only be possible to activate only by pressing emergency button in a common control panel.

7.2.3 Operation of the fuel gas regulating unit

7.2.3.1 Activation of the fuel gas regulating unit

It is assumed that all units are shut down but that power is available from the main grid (or an emergency generator). It is also assumed that all units are in operational condition, that the various components of the *fuel gas regulating* unit have been properly adjusted with the correct control elements (springs, etc.) installed, gas of sufficient quantity, quality and pressure available, and the engine is ready for the start.

Before the planned start of the fuel gas system for the engine, the following should be checked:

1. Make a visual check of the entire unit.
    - Check that no work is being performed on the unit, and that all flanges are bolted together and that all connections are installed and secured.
2. Dispose of any unsecured items or debris near the unit that may inhibit operation or could cause injury.
3. Ensure that the engine room is well ventilated and gas free.
4. Check that the main gas valve (manual ball valve) on the *fuel gas regulating* unit is closed.
5. Check that the gas inlet pressure is normal.
6. Check that the control air pressure is sufficient to operate the system.
7. Check that the manual vent valve on the gas train is closed.
8. Open up all manual shut-off valves to instruments and control units.
9. Check that the safety shut-off function on the pressure regulator is reset.
10. Check that the electrical control system is active and power available.
11. Open the gas main shut-off valve outside the building.
12. Open the main gas valve on the *fuel gas regulating* unit.
13. Control: that the *fuel gas regulating* unit is functioning properly.
14. Control: that the shut-off valves are gas tight.
15. Check that the engine is ready for start.

The fuel gas system is now ready and the engine can be started provided that the start blocking circuits for the fuel gas system have not been activated.

> ***Caution!*** *If the fuel gas regulating unit has been opened for maintenance or repair, it is essential to have the unit well purged to remove any trace of air before going ahead with the starting process.*

7.2.3.2 Monitoring of the fuel gas regulating unit

Note! The following is supplied as general information only. The operating personnel must decide what actions are appropriate for the whole plant, while taking all equipment into consideration.

The normal operation and supervision of the fuel gas system consist mainly of simple daily checks, such as:

1. Check temperature and pressures in the system.
2. Check the pressure drop over the filtration unit.
   - The condition of the filter is important for the reliable operation of the engine.
   - The filter should be replaced/cleaned when the condition deteriorates.
   - The pressure drop over the filter is 0.05 to 0.1 bar when the filter is new.
   - The filter should be cleaned at or before the pressure drop has increased to 0.2 bar (1 bar pressure drop mentioned in the manufacturer's instructions is too high considering the low gas pressure in the main supply line).
3. Check for leakage.

Caution! If gas is found to be leaking into the engine room, it is essential that the engine and the gas supply system are shut down immediately. Leave the engine room and do not enter until the room has been properly ventilated to remove any traces of gas.

7.2.3.3 Shutting down the fuel gas regulating unit for maintenance

During normal shutdown, perform the following checks (see Figure 9):

1. Close the main gas valve V01 on the gas train
2. Close the main shut-off valve outside the building.
3. Open the manual ventilation valve V13 if the *fuel gas regulating* unit is to be shut down for any prolonged time.

> ***Caution!*** *If maintenance is to be performed on any part of the system, this may require closing and locking of the main gas valve V01 (see* Figure 5*) and ventilating the other parts of the system.*

These actions will be decided and taken by local operating personnel.

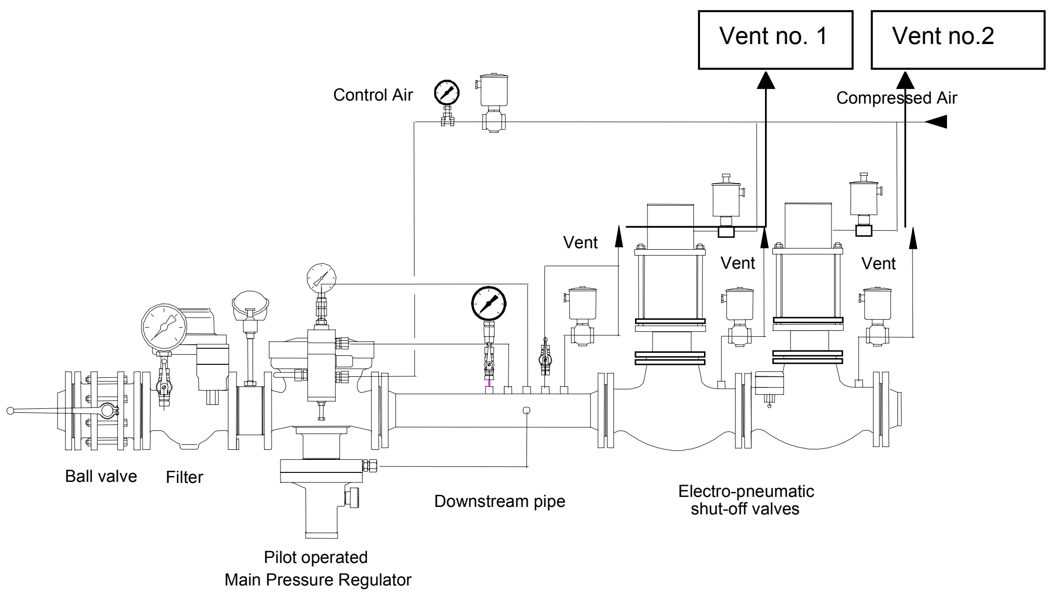


Figure 9 **Fuel gas regulating unit.**

7.2.3.4 Emergency stop of the fuel gas regulating unit

If the operating condition of the power plant requires an immediate stop of the gas supply to the engine room or engine cell, an emergency stop must be performed as follows:

1. Shut down the engine
   - Use any of the emergency stop buttons (installed on the engine control cabinet above the flywheel and on the wall inside the engine room and the control room).
2. Close the main gas valve V01 (see Figure 9: ball valve).

   Caution! *If the shutdown of the system has been caused by a gas leak it is imperative that all personnel evacuate the room in question immediately. They are not allowed to re-enter the room until it has been properly ventilated to remove any traces of gas.*

8 Exhaust gas system

8.1 General

The protection of the exhaust gas system is essential part for the safe operation of lean burn gas engine equipped power plant. Main protection methods are:

- Correct design of the system
- Explosion vents (rupture discs) installed in the system
- Exhaust gas ventilation fan operation

In addition, explosion vents should be visually inspected periodically.

8.2 Piping design

The exhaust system is mainly a passive component, i.e. it contains no controllable parts concerning gas safety. The only exception is the ventilation fan that is operated either in engine stop or start sequence.

To minimise the risk of gas explosions in the exhaust system certain safety features are recommended for the design. The following describes the exhaust system design as recommended by Wärtsilä Corporation. For more details, see WDAAA247530.

To minimise the risk of gas building up in the exhaust system it has been designed to contain only upward slopes. Any downward slope creates a pocket where gas can collect in certain circumstances causing a danger of an explosion. However, since the system always contains a silencer, and may be equipped with boiler(s) and catalytic converter(s), all pockets can not be avoided and other means must be used.

8.3 Exhaust gas system ventilation

The exhaust system is equipped with a ventilation system. The system consists of a centrifugal fan, a flow switch and a butterfly valve equipped with a limit switch. This valve is opened and the fan is started either after every engine stop or before every engine start ventilating the exhaust system. However, in an emergency mode the fan is not operating.

The flow switch confirms that the fan is rotating. The capacity of the fan and the running time of it is chosen such that it is able to change the volume in the exhaust system at least three times during the ventilation run.

Figure 10 shows exhaust gas ventilation system.

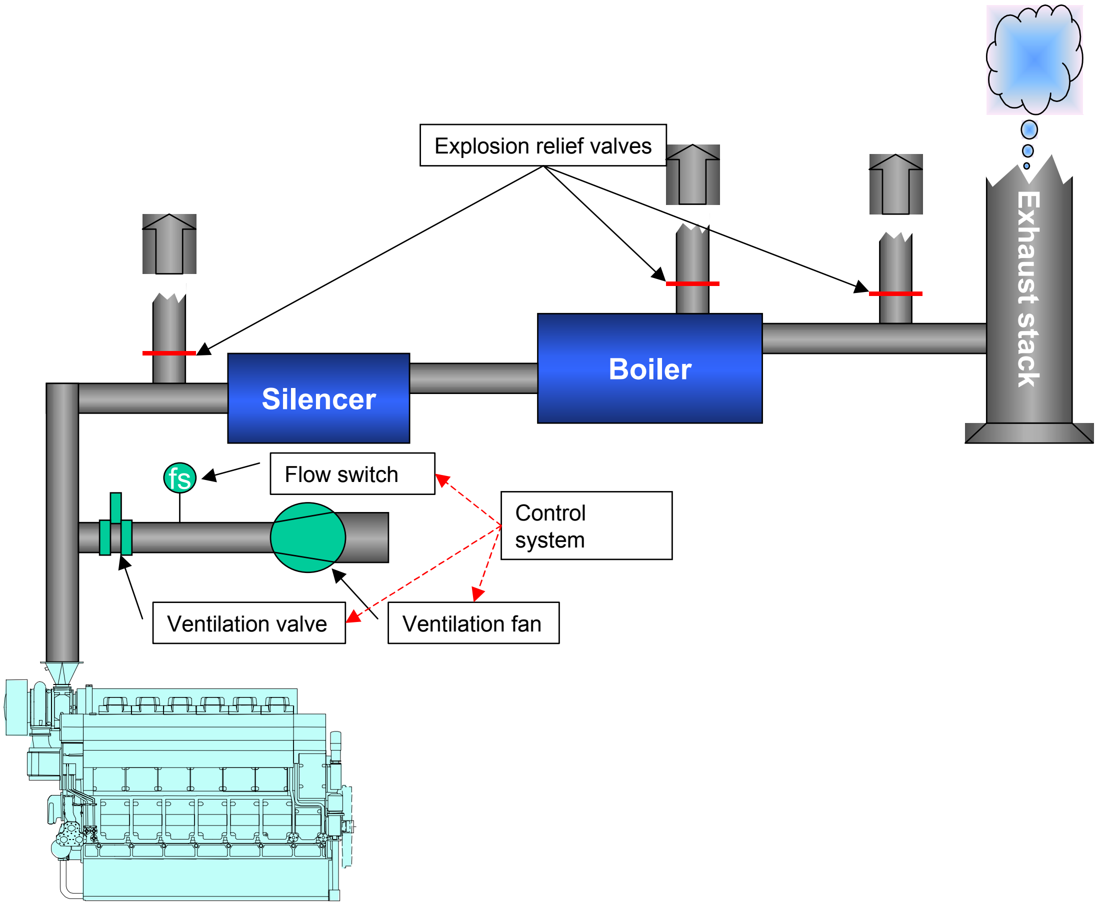


Figure 10 **Exhaust gas ventilation system.**

8.4 Explosion vents

The exhaust system is also equipped with explosion vent valves to relief the excess pressure in the exhaust system in the event of an explosion. The general rule is that the diameter of the explosion vent is at least of the same as the exhaust gas pipe diameter. In addition, the vent duct above the explosion vent is of the same diameter as the explosion vent. The length of the vent duct shall be minimised in order to reduce the back pressure from the vent duct in an explosion. The explosion vent valve is designed to open at an excess pressure of 0.5 $\pm$ 0.05 bar at operating temperature.

The first explosion vent valve is located after the turbochargers. In a straight pipe, explosion vent valves shall be installed every ten diameters.

The silencer inlet and outlets are also equipped with explosion vents. The explosion vent in the inlet may have been omitted if the distance from the previous explosion vent is less than 5 times the diameter. Only absorption silencers with straight-through design are used. Reactive type silencers with internal chambers are not allowed for lean-burn engines due to their disadvantages during an explosion. Gas may collect in the reactive part in the chambers and thus a violent explosion is possible if unburnt gas is present.

The boiler is equipped with integrated explosion vents at the inlet and outlet of the boiler. The size of these vents is dependent on the boiler design, but should as a minimum be of the same size as the inlet duct to the boiler. If it is impossible to integrate these valves into the boiler, corresponding explosion vents are located in the exhaust gas duct close to inlet and outlet of the boiler.

Explosion vents are ducted outdoors with a duct of at least the same size as the explosion vent. The duct is covered with light-weight noise and weather protection.

The outlet of the duct is located so that personnel are not present during normal operation, and the proximity of the outlet is clearly marked as a hazardous area.

Due to the gas velocities created by a possible explosion, under pressure may be created in the latter parts of the system. Therefore, the stack is dimensioned to sustain an under pressure of 0.3 bar without collapse.

Also, available are active extinguishing systems for explosion prevention, such as explosion suppression. These, however, are not a standard option for lean-burn engine equipped power plants, but have to be considered case by case for special applications. A problem with these is that the actual position of the ignition is not known. Thus the extinguishing system is nearly impossible to design.

> ***Note!*** *After a gas explosion the safety equipment shall be inspected and damaged parts changed for new ones according to manufacturers' instructions. The reason for explosion must be clarified and eliminated before the next start.*

04. Maintenance Schedule

04.1 General

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

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

2 **Note the Risk Reduction** in chapter 00A.

3 **Note the Environmetal Hazards** in chapter 02A.

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

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

6 **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.

7 **Always renew all gaskets, sealing rings and O-rings** at maintenance work. **Note!** The O-rings in the cooling water system must not be lubricated with oil based lubricants, use soap or similar.

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

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

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

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

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

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

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

04.5	Interval: 500 operating hours	
Cooling water	**Check water quality** Check content of additives.	19.2 02.3
Lubricating oil	**Take oil sample** In a new installation or after change to use of a new lubricating oil brand, take samples for analyzing.	02.2.3

04.6	Interval: 1000 operating hours	
Air filter (on-built)	**Clean turbocharger air filter** Remove the filter(s) and clean according to instructions of the manufacturer (more often, if necessary).	15.2
El. lubricating oil pump	**Regrease prelubricating pump** Regrease the pump under running condition.	18.9
Flexible coupling Geislinger (Oil filled)	**Oil change/check of the coupling** At first interval, change oil of the coupling. Following (1000h) intervals, check oil level.See manufacturers instructions.	
Gas filter Engine mounted On gas regulating unit	**Replace gas filter cartridges** Clean the filter housing. The engine mounted filter cartridge can be cleaned by pressurized air from inside, replace cartridge if necessary. Gas regulating unit, replace the filter cartridges. Following intervals for both filters 4000 hours .	17.1 17.2
Ignition system	**Clean and check the condition of the extension** Replace O-rings.	16.4.4
Ignition system	**Replace spark plugs**	16.4.3
Prechamber non-return valve	**Clean and check the non-return valve** Clean the valve. Replace the spring. Check for wear, replace parts if necessary.	16.3

04.7	Interval: 2000 operating hours	
Air cooler(s)	**Check water side of charge air cooler(s)** The first time check and possible cleaning of the **waterside.** If in good condition and deposits insignificant: future intervals 4000 running hours.	15.9
Centrifugal filter	**Clean centrifugal filter(s)** Clean more often if necessary. Remember to open the valve before the filter after cleaning.	18.8.2
Gas system	**Maintenance of gas system** Make the leak test.	17.3
Lubricating oil filter	**Replace lub. oil filter cartridges** Drain the filter housings. Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced when the pressure difference indicator shows too high pressure drop.) Continue	18.7.2 18.2

Lubricating oil	**Change lubricating oil** Change oil in a new installation (wet sump installations). Take samples for analyzing. If the analyzing values are positive and if the oil supplier or engine manufacturer so recommend, the intervals between changes can be based on regular analyzing. In wet sump installations the oil change intervals may be in the order of 6000 hours or more. Clean all oil spaces when changing lub. oil.	18.2 02.2
Valves	**Check valve clearances** Check valve clearances.	12.2.4

04.8	**Interval: 4000 operating hours**	
Air cooler(s)	**Clean the charge air cooler(s)** Clean and pressure test. Look carefully for corrosion. Measure the pressure difference over the charge air cooler before and after cleaning. Use U-gauge.	15.9
Automation	**Check connectors and cables** Check mounting and connections. Apply contact lubricant to contact surfaces. Check tightness of connections. Check condition of cables, wires and cable glands. Replace damaged connectors and cables.	23.13 23.14
Camshaft	**Inspect contact faces of camshaft** Check the contact faces of the cams and tappet rollers. Check that the rollers rotate. Rotate the engine with the turning gear.	14.1.3 03.1
Cooling water spaces	**Inspect jacket water spaces on engine with cooled turbocharger** Inspect turbocharger cooling water ducts for possible deposits. If the deposits are 1mm or thicker, inspect the water side of one cylinder liner through the plug in the engine block. If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.2 19.2 19.1.2 02.3 10.5
	Inspect jacket water spaces on engine with uncooled turbocharger Inspect the water side of one cylinder through the plug in the engine block. If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.2 19.2 19.1.2 02.3 10.5
Crankshaft	**Check crankshaft alignment** Check alignment, use form No. WV98V036. Alignment check is performed on a warm engine.	11.2.2
Crankshaft	**Check thrust bearing clearance** Check axial clearance.	11.2.3 06.2
Flexible coupling Geislinger (Oil filled)	**Oil change of the coupling** Change oil of the coupling. See manufacturers instructions.	
Gas filter Engine mounted On gas regulating unit	**Replace gas filter cartridges** Clean the filter housing. Replace the engine mounted filter cartridge. Gas regulating unit, replace the filter cartridges. Continue	17.1 17.2

Starting air system	**Clean the starting air filter** Clean the filter and replace sealing's.	
Valves and piston rings	**Check cylinder tightness** Check cylinder tightness (valves, piston rings) with a pneumatic test.	12.A

04.9	Interval: 8000 operating hours	
Exhaust manifold	**Check for leaks** Replace parts if necessary.	20.
Gas admission valves Hoerbiger	**Replace the main and prechamber gas admission valves** Replace also the female connector.	17.4 17.5
Gas regulating unit	**Overhaul of gas pressure regulating and safety shut-off valves** See manufacturers instructions.	
Lube oil coolers	**Clean the lube oil cooler** If the lube oil temperature before the engine is within normal operating values (Section 01.1), the interval can be prolonged. Unnecessary opening of the plate cooler should be avoided. Clean the lube oil cooler before the alarm limit is reached. Examine carefully for corrosion.	18.5 19.2
Starting motors	**Check the starting motors** Check the starting motors gear wheels and flywheel gear rim. Check oil level, and look for leaks. See manufacturers instructions.	21.2
Wastegate	**Check the function of the wastegate valve and actuator** Replace the positioner pilot valve.	

04.10	Interval: 12000 operating hours	
HT-water pump	**Inspect HT-water pump** Dismantle and check. Replace worn parts.	19.3.1 19.3.2
HT-water pump driving gear	**Inspect HT-water pump driving gear** Replace parts if necessary.	19.3.1 06.2
HT-water thermostatic valve	**Clean and inspect HT-water thermostatic valve** Clean and check the thermostatic element, valve cone-casing and sealing's.	19.1
LT-water pump	**Inspect LT-water pump** Dismantle and check. Replace worn parts.	19.3.1 19.3.2
LT-water pump driving gear	**Inspect LT-water pump driving gear** Replace parts if necessary.	19.3.1 06.2
LT-water thermostatic valve	**Clean and inspect LT-water thermostatic valve** Clean and check the thermostatic element, valve cone-casing and sealing's.	19.4.1 19.4.2
Lube oil pump	**Inspect the lube oil pump** Replace parts if necessary. Continue	18.3.3

Lube oil pump driving gear	**Inspect lube oil pump driving gear** Replace parts if necessary.	18.3.4 06.2
Oil thermostatic valve	**Clean and inspect oil thermostatic valve** Clean and check the thermostatic element, valve cone-casing and sealing's.	18.6
Turbocharger Napier NA-chargers	**Inspect turbocharger bearings** Check and change if necessary. See manufacturers instructions.	15.2
Turbocharger ABB TPL-chargers	**Inspect turbocharger bearings** Check and change if necessary. See manufacturers instructions.	15.2
Turbocharger Hispano Suiza-chargers	**Inspect turbocharger bearings** Check and change if necessary. See manufacturers instructions.	15.2

04.11	**Interval: 16000 operating hours**	
Camshaft	**Inspect camshaft bearings** Replace if necessary.	10.4.1 06.2
Camshaft driving gear	**Inspect intermediate gears** Replace parts if necessary.	13.1 06.2
Connecting rods	**Replace big end bearing** Replace big end bearing. Inspect mating surfaces. Measure the big end bore, use form No. 3211V012.	11.3.3 06.2
Connecting rods	**Inspect the small end bearings** Inspect the small end bearings. Replace if necessary.	11.3.3 06.2
Crankshaft	**Inspect main bearings** Inspect one main bearing. If in bad condition, check/change all main bearings. Note the type of bearing in use and do the inspection accordingly.	10.2.2 06.2
Cylinder heads	**Overhaul of cylinder head** Dismantle and clean the underside, inlet and exhaust valves and ports. Inspect cooling spaces and clean, if necessary. Grind the valves. Inspect the valve rotators. Check rocker arms. Replace the O-rings in the valve guides and on the exhaust valve seat rings. Replace the O-rings at bottom of cylinder head screws at **every overhaul**. Replace the knocking sensors by new ones.	12.2.3 12.2 12.3 14.1.3
Cylinder liners	**Inspect the cylinder liners** Measure the bore using form No. 3410V019, replace liner if wear limits are exceeded. **Hone the liners.** Renew the anti-polishing ring.	10.5.1 06.2
Cylinder liners	**Inspect cylinder liner water side** Pull all cylinder liners. If the deposits are thicker than 1 mm, clean all liners and the engine block water space. Replace the O-rings in the bottom part by new ones at every overhaul Continue	19.2 10.5

Flexible coupling (Oil filled)	**Check the flexible coupling** Dismantle and check flexible coupling acc. to manufacturers recommendations.	
Gas admission valves Woodward	**Replace the main and prechamber gas admission valves** In installations where connectors used, replace also the female connector.	17.4 17.5
Gas admission valves Woodward	**Clean the main gas admission valve filter insert** Clean the main gas admission valve filter insert. Replace if needed.	17.4 17.5
Gas system	**Maintenance of gas system** Replace sealing's in pipe connections, check sealing faces for wear and corrosion. Make the leak test.	17.3
Hydraulic jack	**Check function** Replace O-rings in the hydraulic jack if they are leaking when lifting the main bearing cap.	10.2.1
Pistons	**Inspect the pistons** Composite pistons must be dismantled for inspection of mating surfaces between piston skirt and piston crown. Inspect and clean oil spaces.	11.B
Pistons, piston rings	**Inspect pistons and replace piston rings** Pull, inspect and clean. Check the height of the ring grooves, use form No. 3410V023. Check the retainer rings of the gudgeon pins. Replace complete set of piston rings. Note the running-in programme.	11.3.3 11.3 06.2 03.8
Prechamber	**Clean the nozzles** Clean the nozzles and check for wear and cracks. Replace prechamber if necessary. Replace the O-rings and the bottom sealing ring.	16.3
Turning device	**Change oil in turning device** Regrease the drive shaft.	02.2.5 03.9
Valve mechanism	**Check valve mechanism parts** Check tappets.	14.1.3 06.2
Vibration damper Viscous type	**Take oil sample from vibration damper** Take oil sample for analyzing.	11.2.1

04.12	**Interval: 24000 operating hours**	
Engine fastening bolts	**Check tightening of engine fastening bolts** Replace if necessary.	07.3
Exhaust manifold	**Check expansion bellows** Replace if necessary.	20.2
Flexible coupling (Oil supply from engine)	**Check the flexible coupling** Dismantle and check flexible coupling acc. to manufacturers recommendations.	
Turbocharger	**Replace turbocharger bearings** Replace turbocharger bearings. See manufacturers instructions.	15.2

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

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

05.Maintenance Tools

05.1 General

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

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

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

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

05.1.1.Use of this list

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

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

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

05.1.2.Ordering of Maintenance tools

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

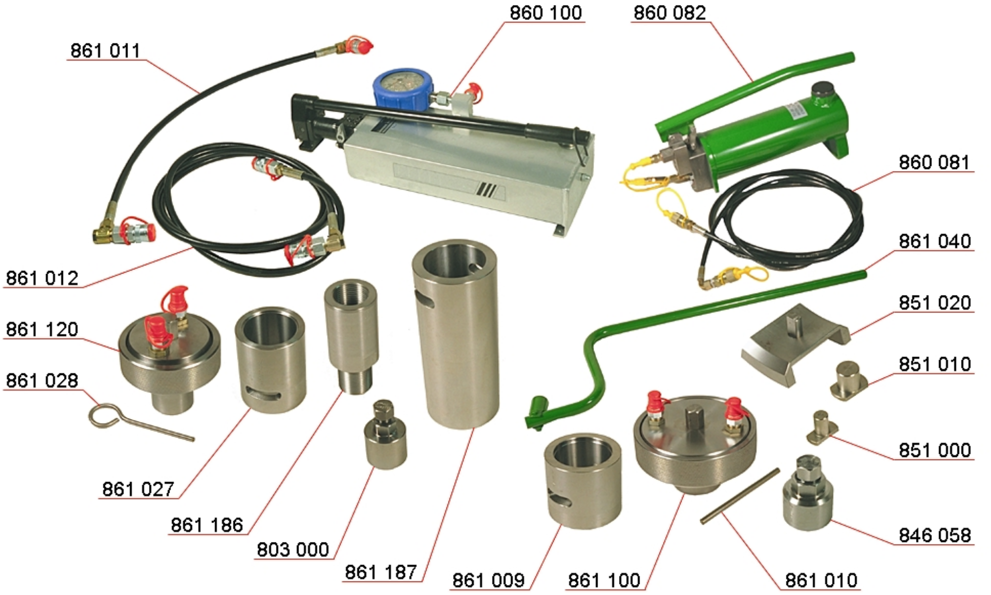
2 **Select the tools or parts required,** note that tools which are part of standard deliveries are mentioned in the installation specific delivery lists. You can use the code number in the following page when ordering.

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

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

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

Main Bearings 100

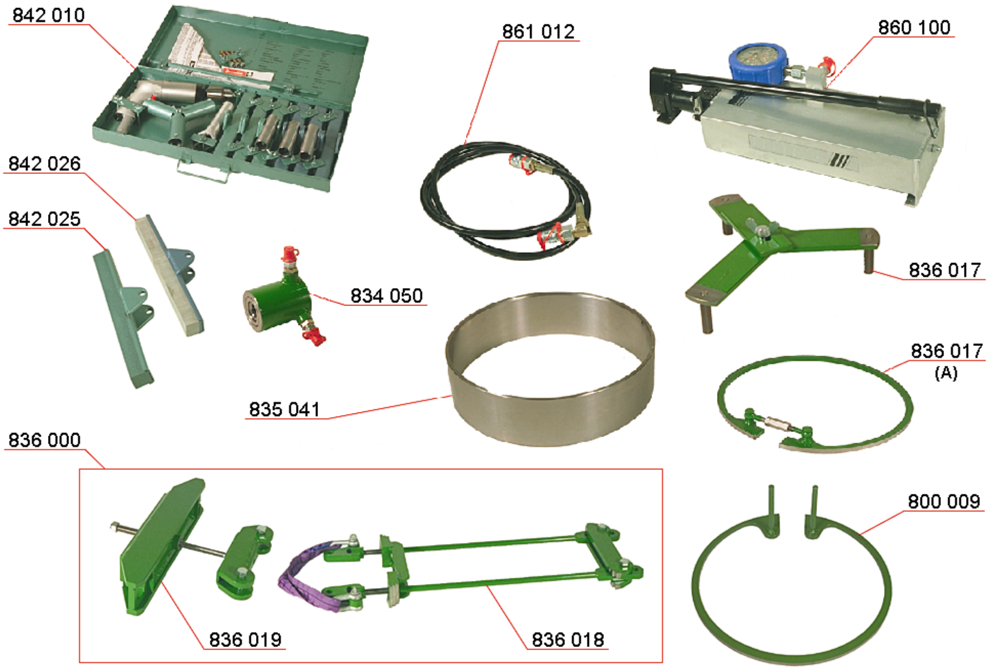


Code	Description	Drawing No.
803000	Stud remover M42	4V80D0012
846058	Stud remover M56	3V84G0189
851000	Turning tool for main bearing shell	4V85B0023
851010	Turning tool for main bearing shell	4V85B0016
851020	Turning tool for thrust washers & bearing shell	3V85B0015
860081	Flexible hose 3000 mm, (low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

(1) Including quick couplings

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

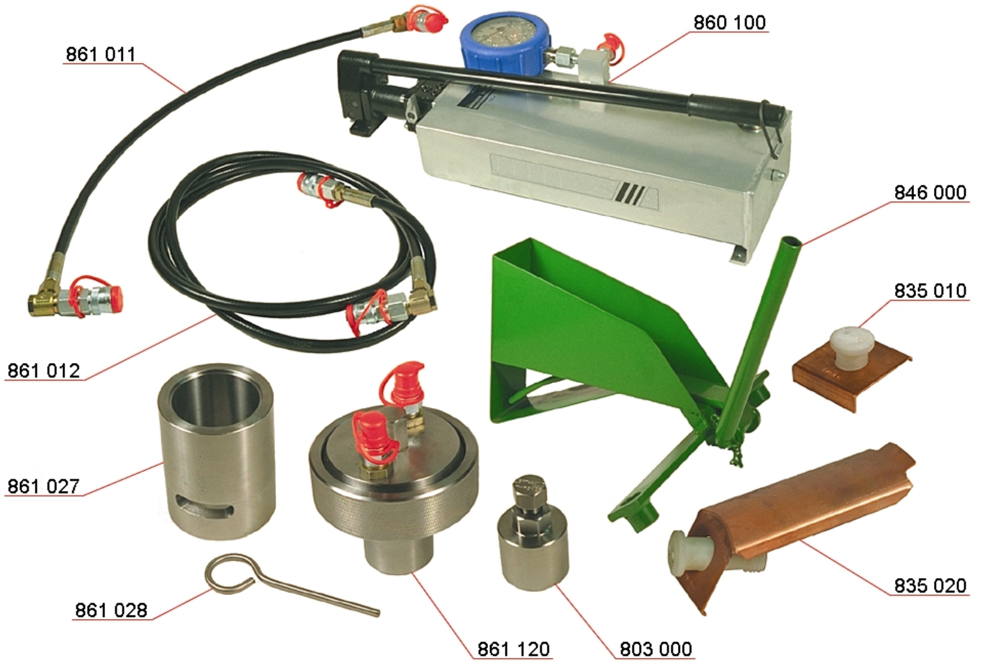
Cylinder Liner 100



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

(1) Only for 32 DF
(2) Code 836017 marked with A only for 34 SG
(3) Including quick couplings

Connecting Rod, O-Profile 110



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

(1) Only needed for V-engine

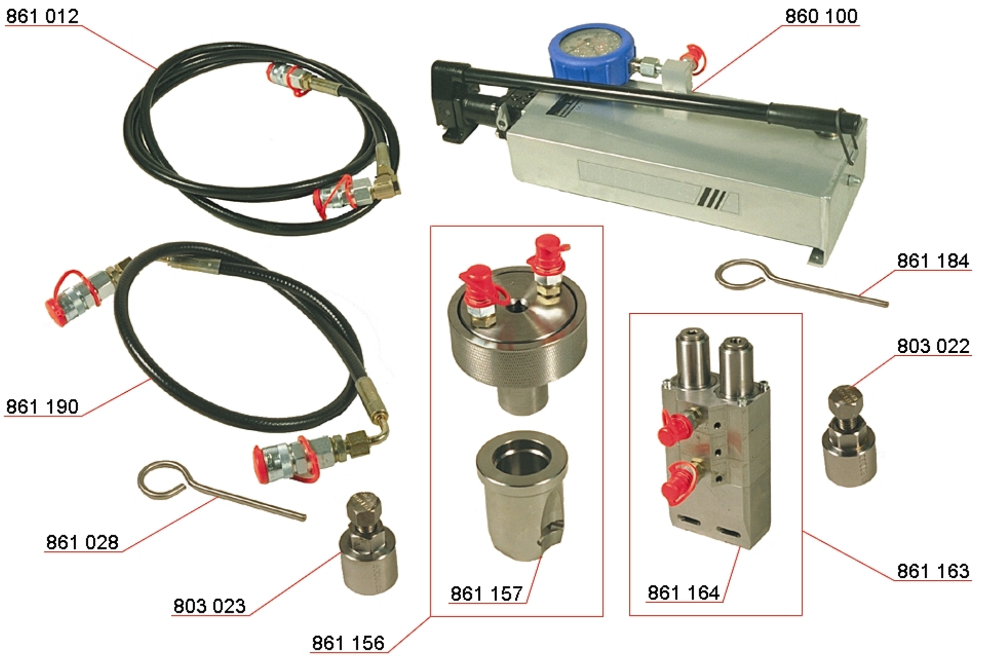
(2) Including quick couplings

Connecting Rod, H-Profile 110

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

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

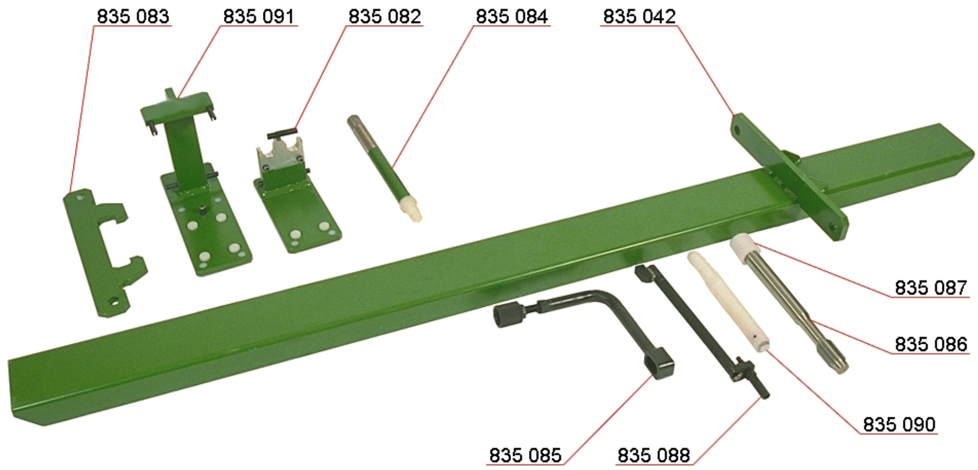
Connection Rod, Marine Head 110



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

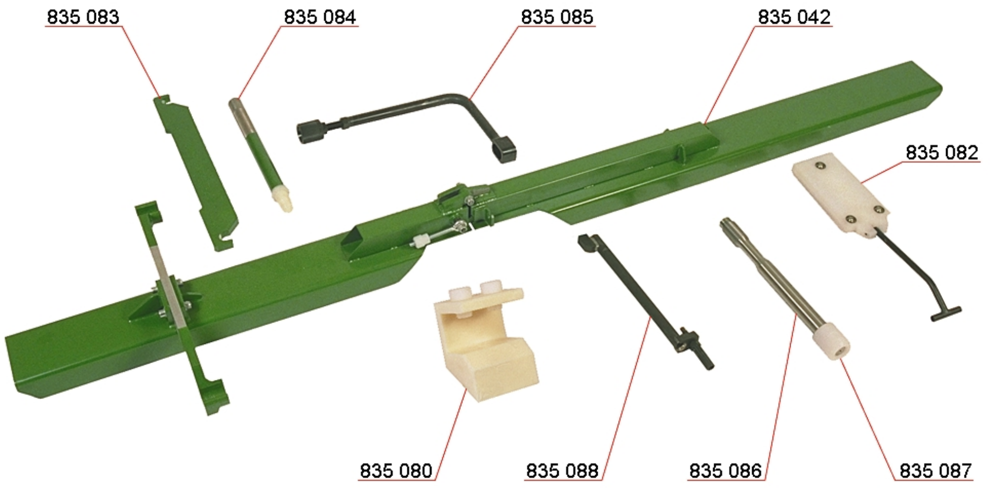
(1) Including quick couplings

Connection Rod, Marine Head, R-eng. 110



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

Connection Rod, Marine Head, V-eng. 110

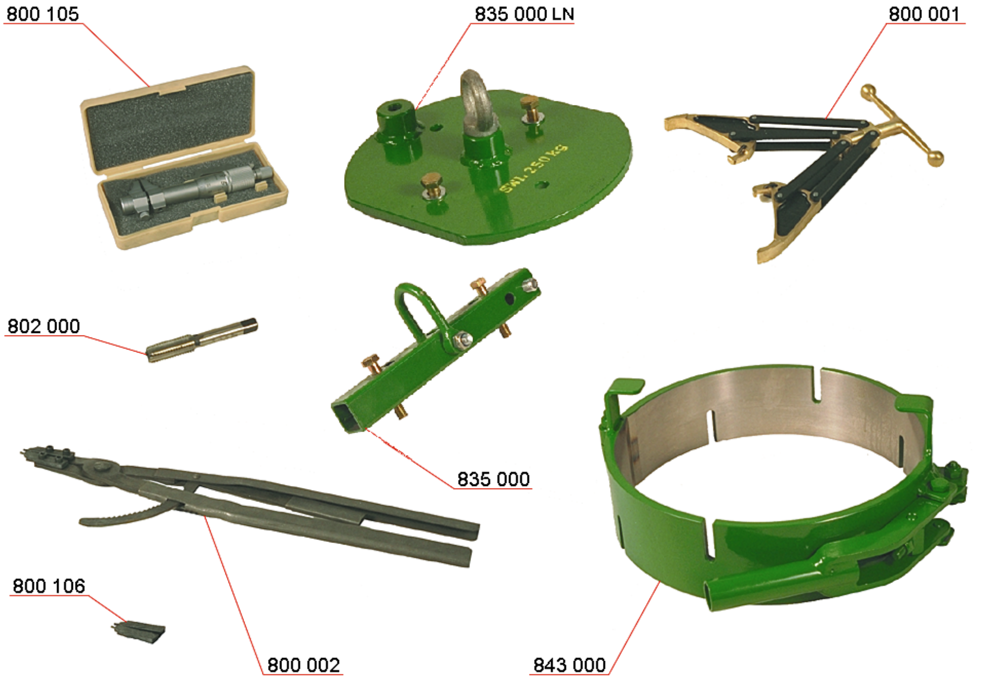


Code	Description	Drawing No.
835042	Assembly rail	2V83F0171
835080	Protecting cover **(1)**	3V11T0718
835082	Sledge	2V83F0165
835083	Support	3V83F0166
835084	Support arm	3V83F0163
835085	Support arm	3V83F0177
835086	Mounting screw M30	3V83F0180
835087	Protecting cap for screw M30	4V86B0269
835088	Limiter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

(1) Not for 32 DF and 34 SG

Piston

110

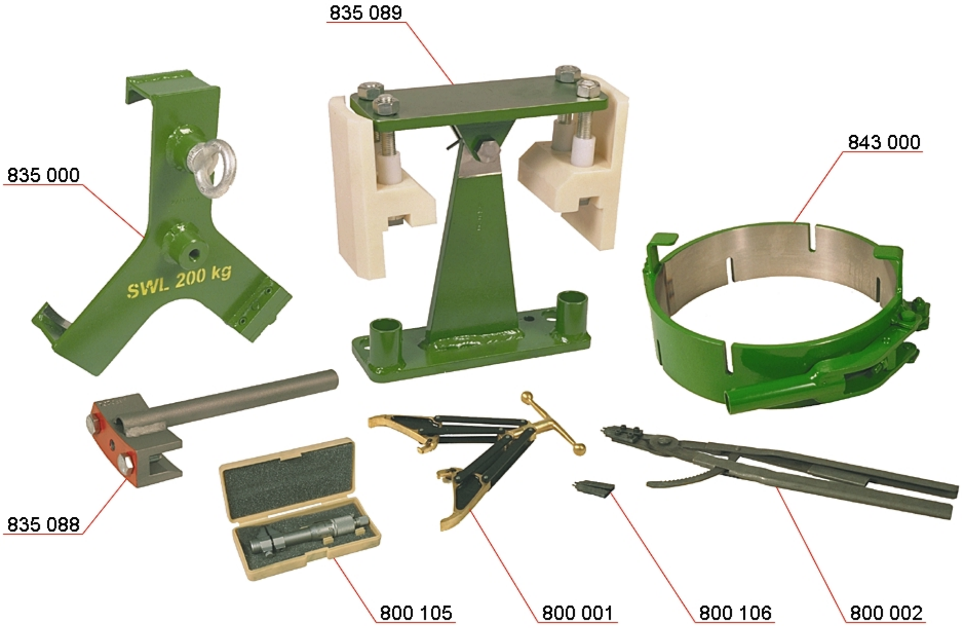


Code	Description	Drawing No.
800001	Piston ring pliers	4V84L0018
800002	Pliers for securing ring	4V84L0016
800105	Measurement tool, micrometer 5-30 mm	
800106	Spare tips for pliers 800002, straight	
802000	Tap M12	
835000	Lifting tool **(1)**	2V83F0058
835000	Lifting tool **(2)**	3V83F0159
843000	Clamp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

(1) for 32 and 32 GD

(2) for 32 LN and 32 LNGD

Piston, 32DF and 34SG 110

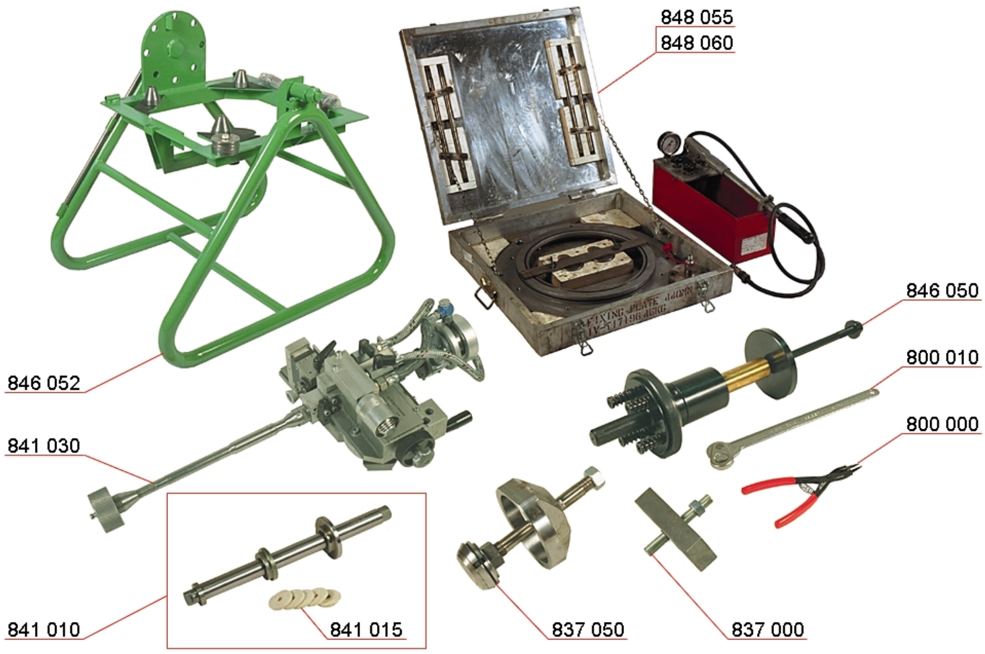


Code	Description	Drawing No.
800001	Piston ring pliers	4V84L0018
800002	Pliers for securing ring	4V84L0016
800105	Measurement tool, micrometer 5-30 mm	
800106	Spare tips for pliers 800002, straight	
835000	Lifting tool **(1)**	2V83F0192
835000	Lifting tool **(2)**	1V83F0221
835088	Limiter for piston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

(1) Only for 34 SG

(2) Only for 32 DF

Cylinder Head 120



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

(1) Not for 32 DF and 34 SG

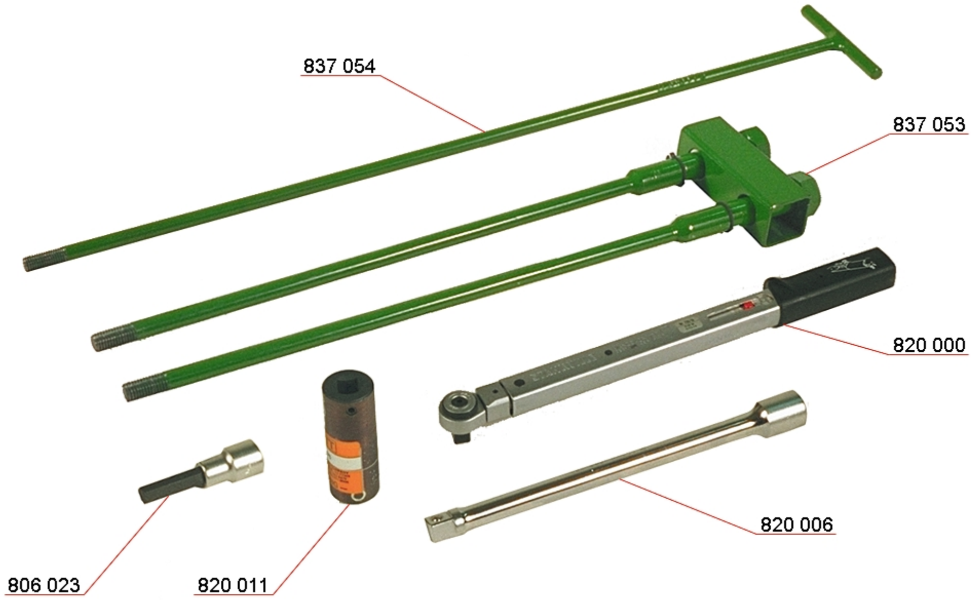
Cylinder Head 120

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

(1) Not for 32 DF and 34 SG

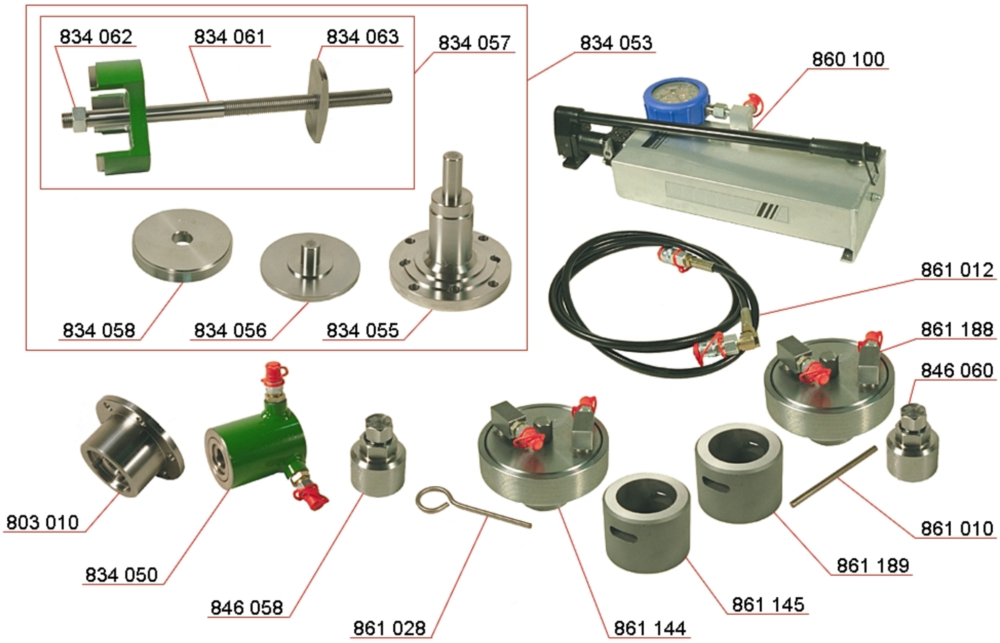
(2) Including quick couplings

Tools for Pre Chamber, V-engine 120



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

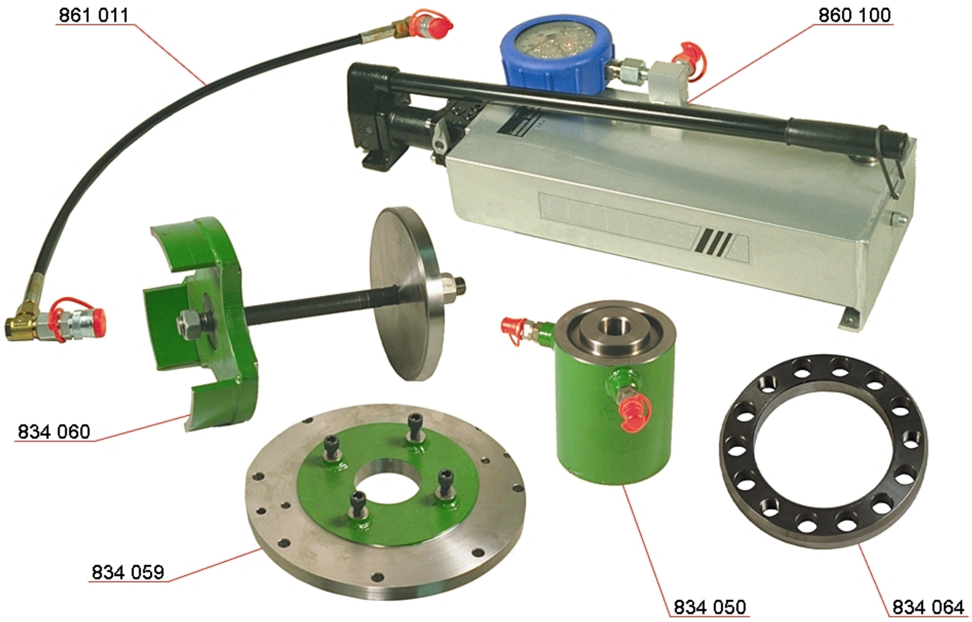
Tools for Intermediate Gear 130



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

(1) Including quick couplings

Tools for Planetary Gear, R-engine 130



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

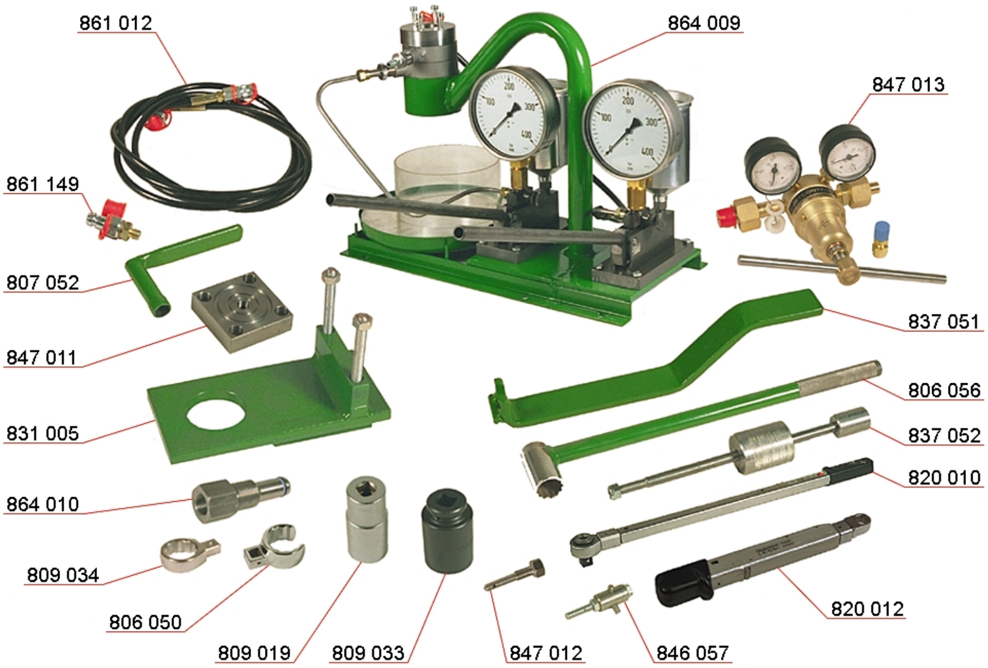
(1) Including quick couplings

Injection Equipment 160

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

(1) Only for 32 LN and 32 LNGD

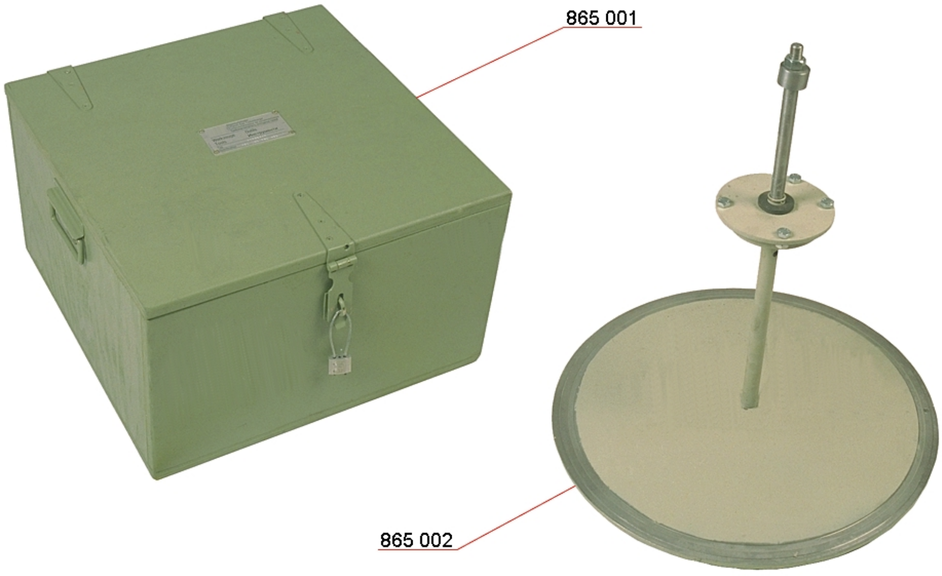
Tools for Multi-Needle injection Valve 160



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

(1) Including quick couplings

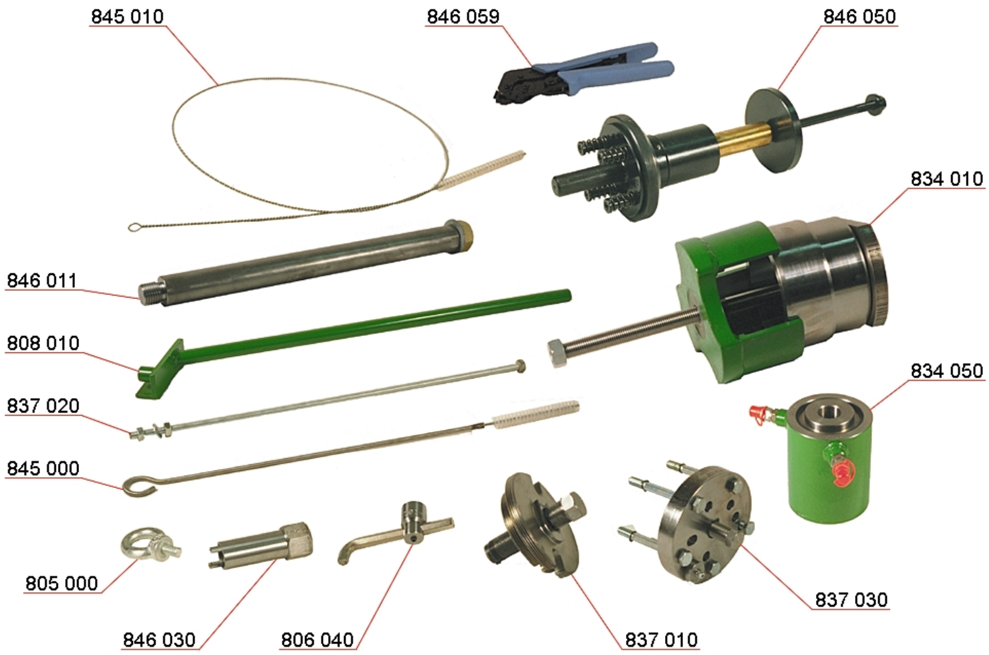
Turbocharger 372



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

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

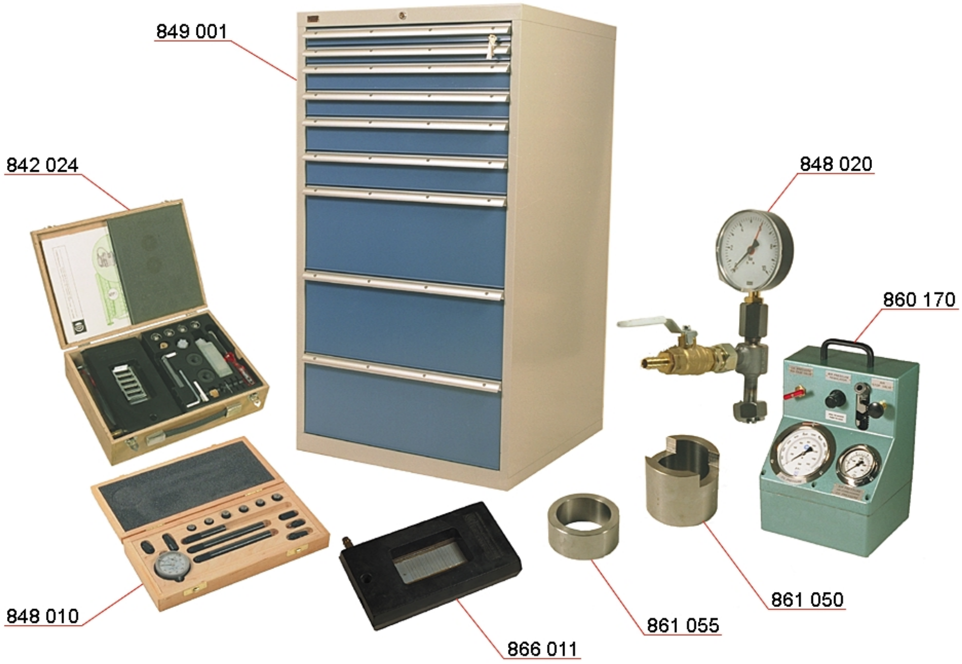
Miscellaneous Tools 900



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

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

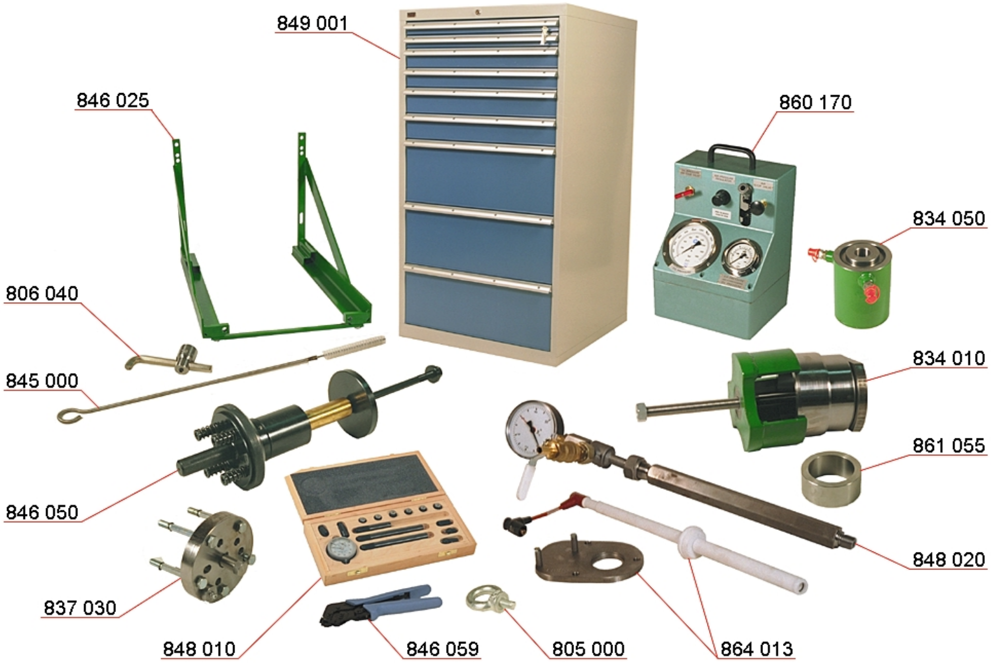
Miscellaneous Tools 900



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

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

Miscellaneous Tools for 32 DF and 34 SG 900

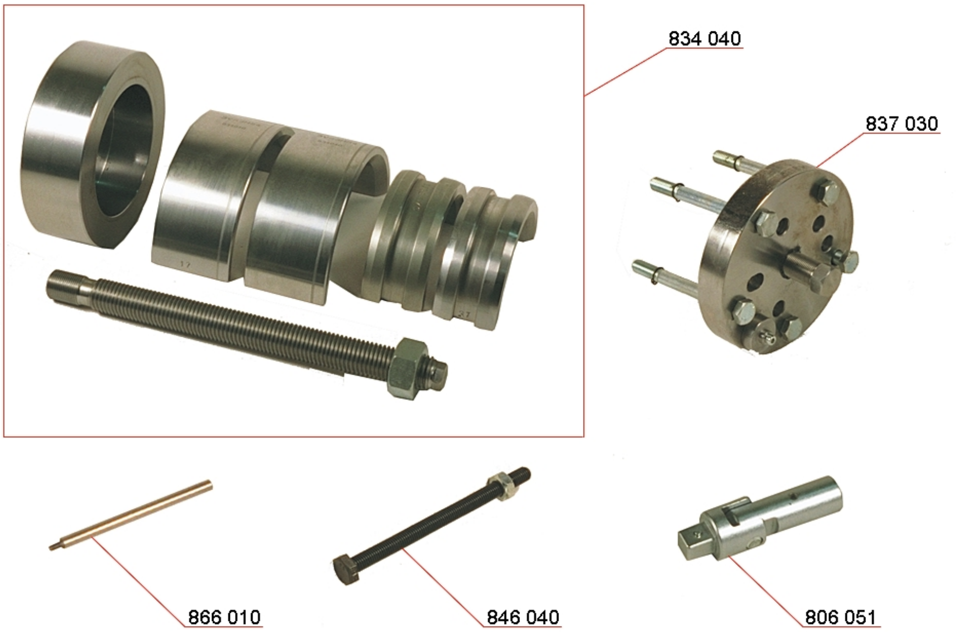


Code	Description	Drawing No.
805000	Eye bolt screw M10	
806040	Special key for camshaft flange screws	4V80G0017
808010	Mounting & removing tool bearing bush **(1)**	2V83H0173
834050	Hydraulic Extractor	3V83E0061
837030	Extractor for water pump impeller	
845000	Brushes for cleaning of charge air cooler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

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

(2) Only for 34 SG

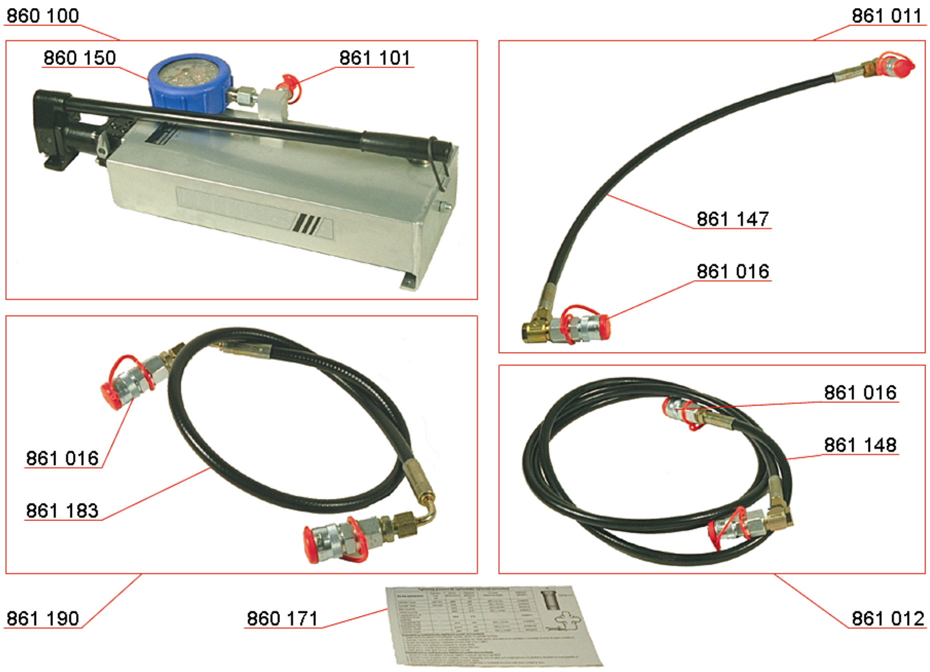
Additional Tools for V-eng. and 4R32 900



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

(1) Only for 4R32

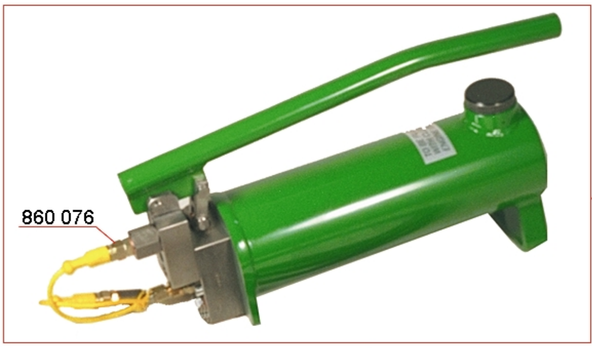
High Pressure Pump 900

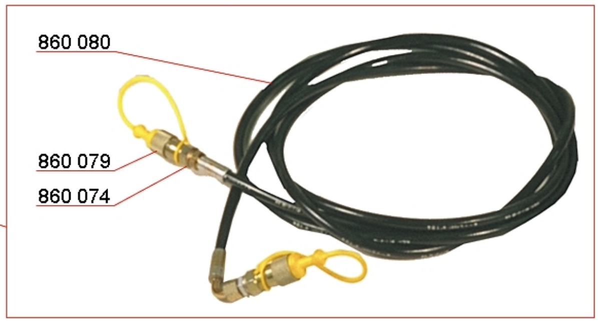


Code	Description	Drawing No.
860100	High pressure pump (1000 bar) **(1)**	4V86A0033
860150	Manometer	4V51L0085
860171	Sign plate	3V52B0126
861011	Flexible hose 800 mm **(1)**	
861012	Flexible hose 3000 mm **(1)**	
861016	Quick coupling, female	4V86A0035
861101	Quick coupling, male	4V86A0034
861147	Flexible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

(1) Including quick couplings

Low Pressure Pump 900

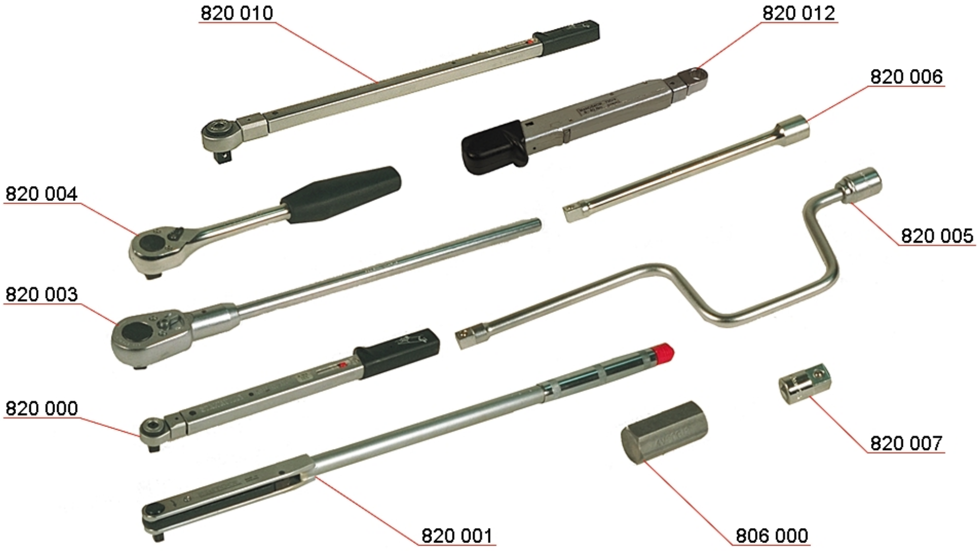




Code	Description	Drawing No.
860074	Straight male stud	4V34L0135
860076	Quick coupling, male	4V86A0012
860079	Quick coupling, female	4V86A0012
860080	Flexible hose 3000 mm	4V86A0067
860081	Flexible hose 3000 mm **(1)**	
860082	Low pressure pump (150 bar) **(1)**	1V86A0018

(1) Including quick couplings

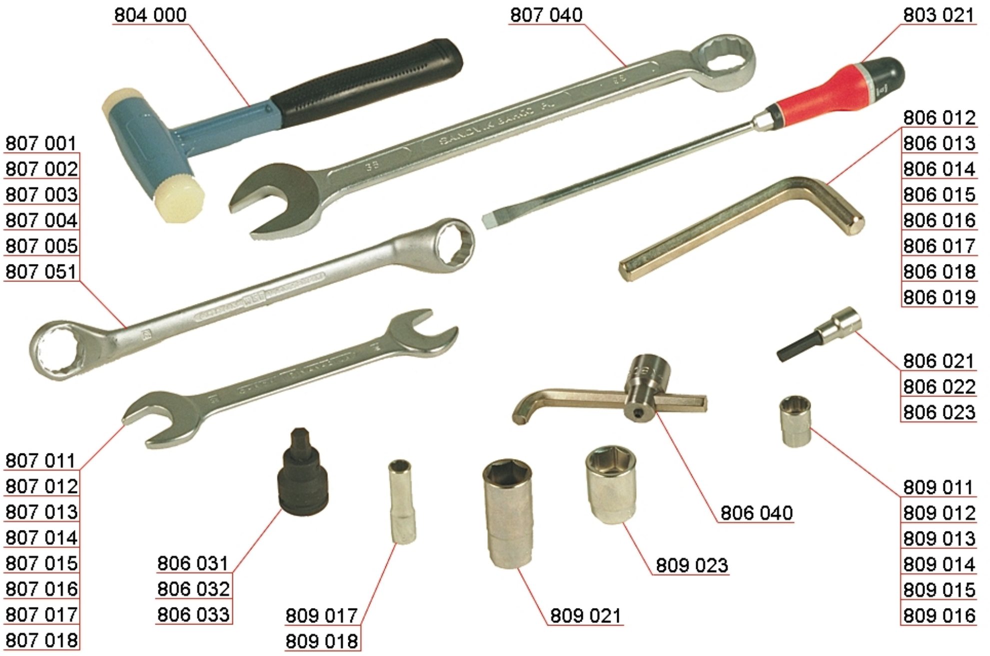
Tightening Tools 900



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

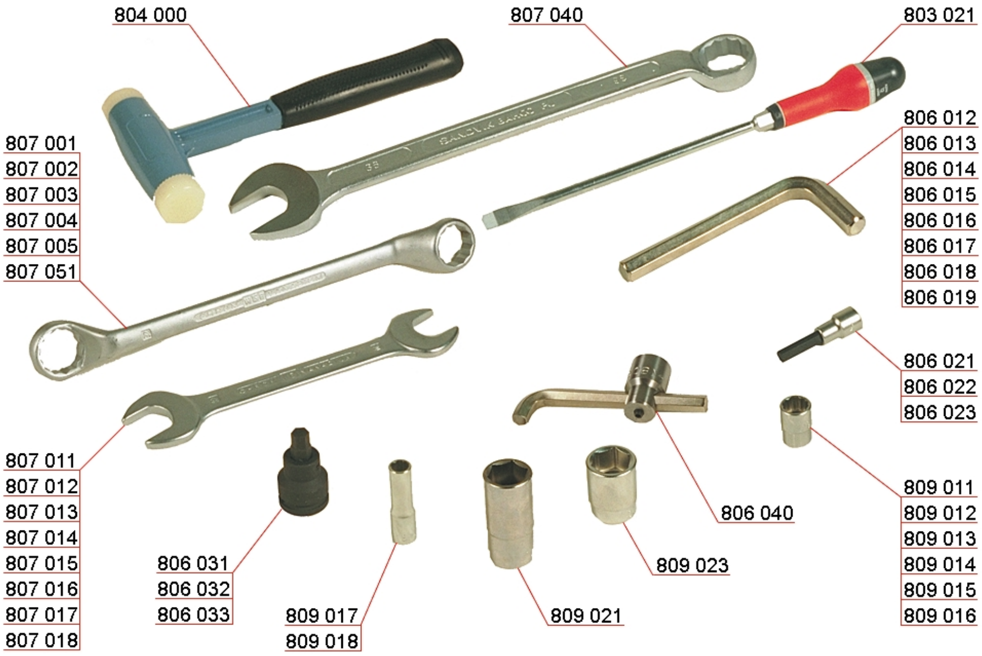
(1) Only for 32 GD and 32 LNGD

Hand Tools 900



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

Hand Tools 900



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

06. Adjustments, Clearances and Wear Limits

06.1 Adjustments

06.1.1 Valve timing

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

Schematic valve timing

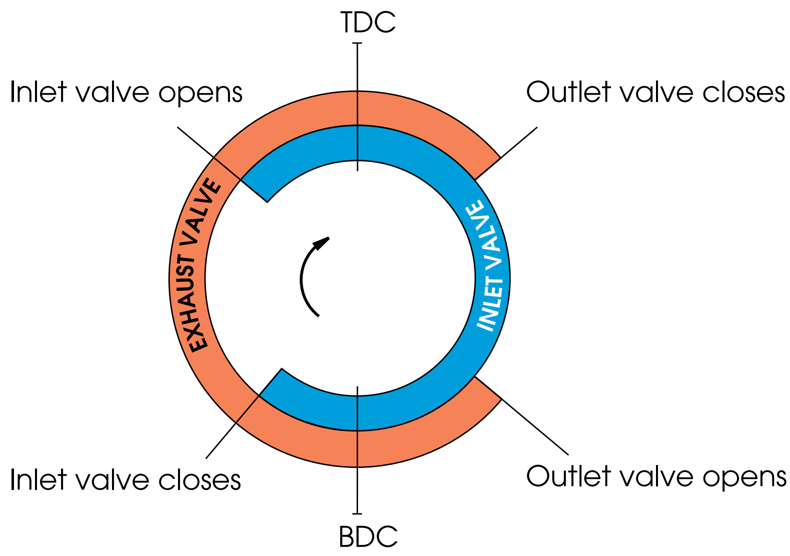


Fig 06-1 3206549232

Valve clearances, cold engine:. . . . . inlet valves 0.7 mm
. . . . exhaust valves 1.2 mm

06.1.2 Set values for overspeed trip devices

Nominal speed	Tripping speed	OTM-module
720 RPM	830 ± 10 RPM	850 ± 10 RPM
750 RPM	860 ± 10 RPM	885 ± 10 RPM

06.2 Clearances and wear limits (at 20°C)

	Part, measuring point	Drawing dimension (mm) Max.	Drawing dimension (mm) Min.	Normal clearance (mm)	Wear limit (mm)
03	Turning device driving gear backlash drive gear/ flywheel gear rim	1.20	0.30		
10	Main bearing clearance (also flywheel bearing)			0.270-0.374	
	Journal, diameter	300.000	299.968		299.8
	Journal, out of circularity	0.015			0.05
	Journal, taper	0.015/100			0.025/100
	Main bearing shell thickness Trimetal shells Bimetal shells	 7.390 7.390	 7.370 7.370		Section 10.2.2 7.32 mm
	Bore of main bearing housing	315.032	315.000		
	Assembled bearing bore	300.342	300.270		
	Thrust bearing, axial clearance			0.20-0.46	0.7
	Thrust washer thickness	14.850	14.800		14.60
	Camshaft bearing clearance			0.130-0.210	0.36
	Camshaft diameter	165.000	164.975		
	Camshaft bearing bush, thickness	7.435	7.420		
	Camshaft bearing housing, bore	180.025	180.000		
	Assembled bearing bore	165.200	165.145		165.25
	Camshaft thrust bearing housing, bore	85.035	85.000		
	Assembled bearing bore	75.125	75.060		75.25
	Camshaft thrust bearing clearance			0.060-0.144	
	Camshaft thrust bearing, axial clearance			0.250-0.700	1.0
	Cylinder liner, diameter	340.107	340.050		top: 340.80 bottom: 340.30
	Cylinder liner, out of cylindricity at TDC	0.03			0.25
	Anti-polishing ring, wall thickness	7.25	7.20		
11	Big end bearing clearance			0.210-0.304	
	Crank pin, diameter	270.000	269.968		269.920
	Crank pin, out of circularity	0.015			0.05
	Crank pin, taper	0.015/100			0.025/100
	Big end bearing shell thickness Bimetal shells (Al-based)	 5.915	 5.900		Section 11.3.3 5.84 mm
	Big end bore ovality	282.032	282.00		281.90 0.10
	Assembled bearing bore	270.272	270.210		
	Gudgeon pin bearing clearance			0.090-0.169	
	Gudgeon pin diameter	150.000	149.986		
	Small end bore	169.955	169.930		
	Assembled bearing bore	150.155	150.090		150.180
	Connecting rod axial clearance in piston			0.5 -1.0	
	Small end bearing bush, thickness	9.930	9.910		
	Clearance gudgeon pin - piston			0.010-0.036	

	Part, measuring point	Drawing dimension (mm) Max.	Drawing dimension (mm) Min.	Normal clearance (mm)	Wear limit (mm)
	Bore diameter in piston	150.022	150.010		150.050
	Compression ring end gaps (C95) (C86)			 1.00 -1.30 1.30 -1.60	
	Oil scraper ring end gaps (C87)			 1.20 -1.50	
	Piston ring height clearance: Compression ring I Compression ring II Oil scraper ring			 0.143-0.195 0.100-0.145 0.063-0.105	 0.5 0.5 0.3
	Piston ring groove height: Groove I Groove II Groove III	8.160 6.120 8.080	8.130 6.090 8.050		8.50 6.45 8.30
12	Valve guide diameter assembled	24.135	24.100		24.25
	Valve stem diameter	24.000	23.979		23.95
	Valve stem clearance			0.100-0.156	0.30
	Valve seat deviation relative guide (max. value)	0.10			
	Inlet valve seat bore in cylinder head	112.022	112.000		
	Exhaust valve seat bore in cylinder head outer bore inner bore	 122.025 110.022	 122.000 110.00		
	Prechamber nozzle holes	6.05	5.95		6.50
13	**Intermediate gear of camshaft drive** bearing clearance axial clearance			 0.102-0.179 0.33 -0.52	Section 10.2.2a 0.70
	Bearing diameter in situ	120.157	120.102		
	Bearing journal diameter	120.000	119.978		
	Camshaft driving gear backlash:				
	Crankshaft gear wheel (1)/ intermediate gear wheel (3)			0.148-0.716	
	Intermediate gear wheel / large intermediate gear wheel (10)			0.178-0.582	
	Small intermediate gear wheel (11)/ camshaft gear wheel (12)			0.178-0.582	
14	Valve tappet, diameter	79.940	79.910		
	Guide diameter	80.046	80.00		
	Diameter clearance			0.060-0.136	
	Tappet roller bore diameter	38.025	38.00		
	Bush diameter, outer	37.975	37.959		37.90
	Bush diameter, bore	30.028	30.007		30.08
	Tappet pin diameter	29.993	29.980		
	Bearing clearance roller-bush bush-tappet pin			0.025-0.066 0.014-0.048	
	Rocker arm bearing diameter, in situ	70.109	70.032		70.4
	Bearing journal diameter	70.000	69.981		
	Bearing clearance			0.032-0.128	
	Yoke pin diameter	29.935	29.922		
	Yoke bore diameter	30.021	30.000		30.1
	Diameter clearance			0.065-0.099	

Part, measuring point			Drawing dimension (mm) Max.	Min.	Normal clearance (mm)	Wear limit (mm)
18	Lubricating oil pump diameter of shaft		49.920	49.895		
	Bush hole diameter, mounted		50.039	50.000		
	Bearing clearance				0.085-0.190	0.25
	Axial clearance				0.20 -0.30	
	Backlash for driving gear	- R32 - V32			0.35-0.49 0.37-0.57	
	Base tangent length for driving gear	- R32 - V32	86.662 86.064	86.626 86.016		
19	Water pump backlash for driving gear	- R32 - V32			0.54-0.68 0.57-0.68	
	Base tangent length	- R32 - V32	53.801 61.228	53.759 61.186		53.60
21	Backlash for starting motor drive				0.5-0.8	

07. Tightening Torques and Use of Hydraulic Tools

07.1 Tightening torques for screws and nuts

Note! See section 07.3 for hydraulically tightened connections!

The position numbers in the tables below refer to the corresponding figures A to I, which are located in the engine according to Fig 07-1. Always tighten to stated torque shown in the tables. A loosen screw connection might cause serious damages/human injury.Threads and contact faces of nuts and screw heads should be oiled with lubricating oil unless otherwise stated. Note that locking fluids are used in certain cases.

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

1 Nm = 0.102 kpm

Tightening torques

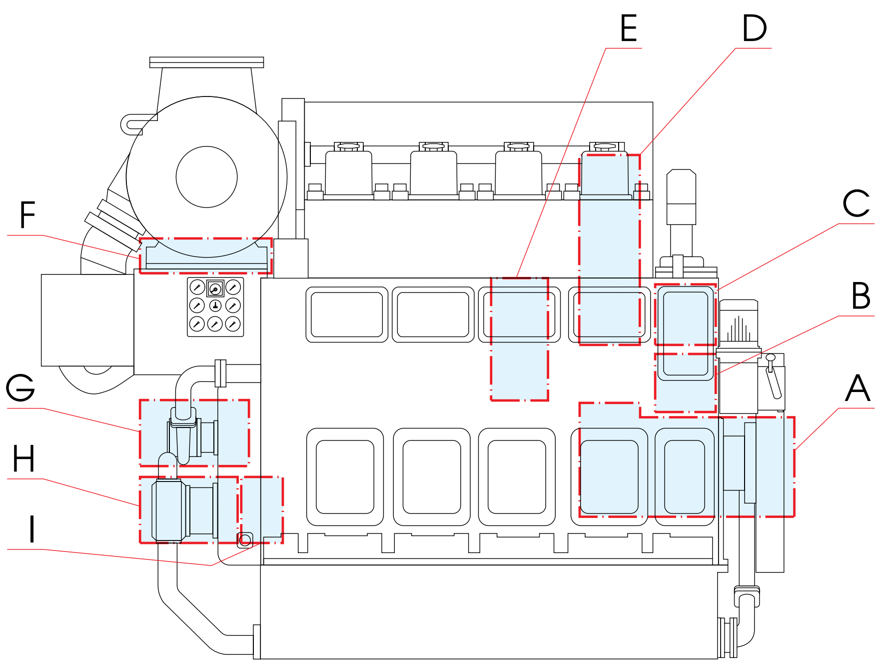


Fig 07-1 3207130338

A: Crankshaft and flywheel, Starting motor

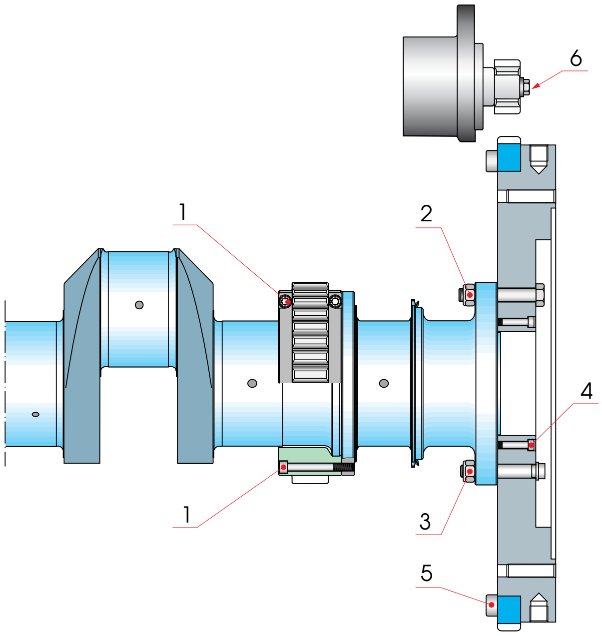


Fig 07-2

3207070338

Pos.	Screw connection	Torque (Nm)
1.	Split gear on crankshaft, all M20 screws. **Apply Loctite 262 on threads,** see section 07.2	600±30
2.	Flywheel bolts, M30	1200±60
3.	Flywheel bolts, fitted bolts	650±30
4.	Flywheel bolts, M16	200±15
5.	Gear rim bolts, M12	145±5
6.	Fastening screw for pinion. **Apply Loctite 242 on threads,** see section 07.2	105±5

B: Intermediate gear

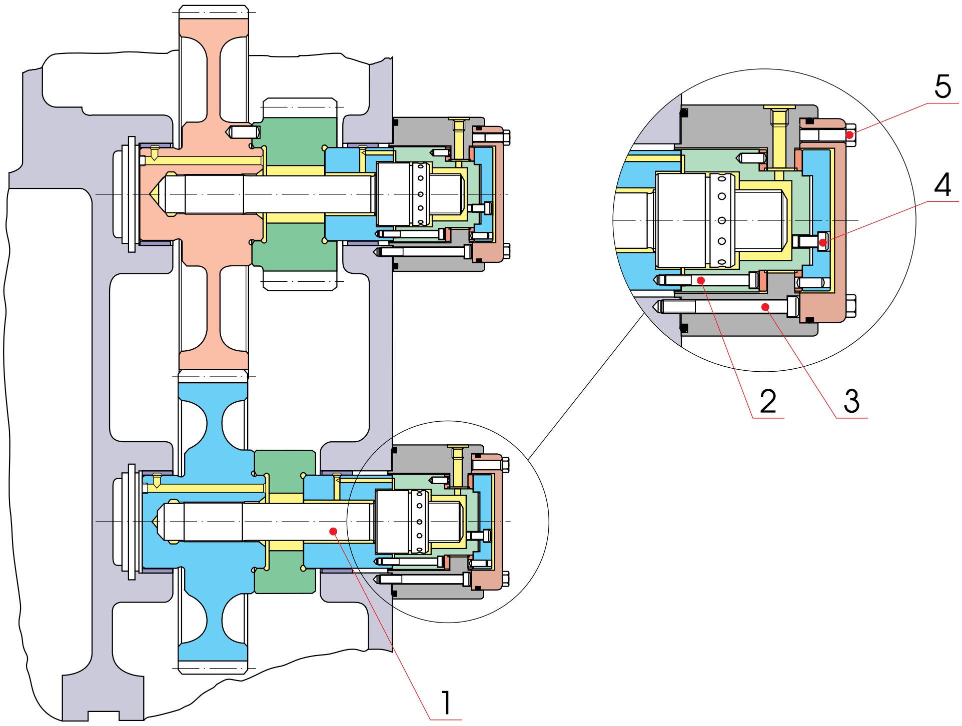


Fig 07-3

3207579045

Pos.	Screw connection	Torque (Nm)
1.	Centre bolts, M56	200±10
2.	Shaft bolts, M8	23±1
3.	Fastening bolts, M12	85±5
4.	Shaft plate bolts, M10. **Apply Loctite 243 on threads,** see section 07.2	45±5
5.	Cover bolts, M10.	45±5

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

C: Camshaft and control mechanism

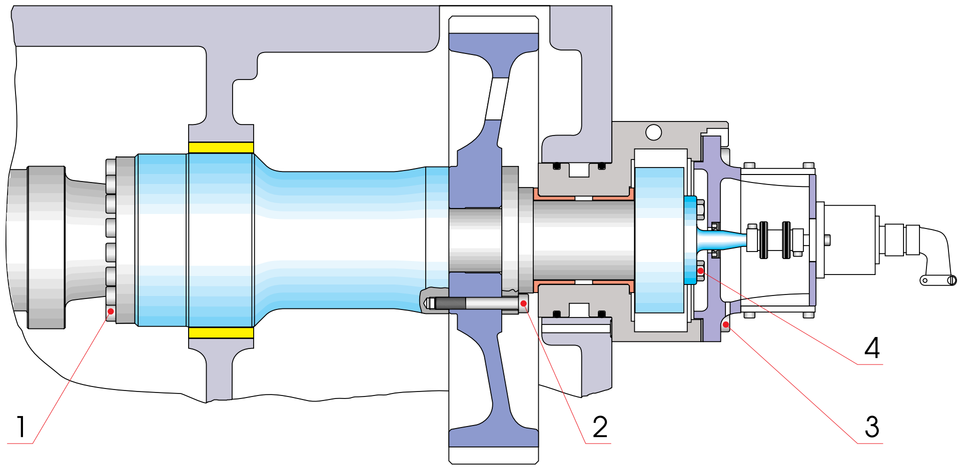
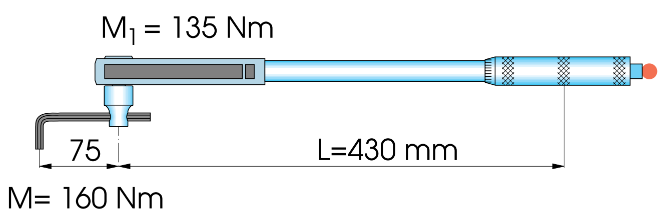


Fig 07-4

3207029720

Pos.	Screw connection	Torque (Nm)
1.	Camshaft flange connection screws. Torque wrench setting with tool 4V80G17 (806040). The screws are treated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	160±5 **135**
2.	Camshaft gear, flange connection screws. **Apply Loctite 243 on threads,** see section 07.2	130±5
3.	Housing fastening screws.	85±5
4.	Extension piece, flange connection screws. **Apply Loctite 243 on threads,** see section 07.2	45±5

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



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

D: Cylinder head

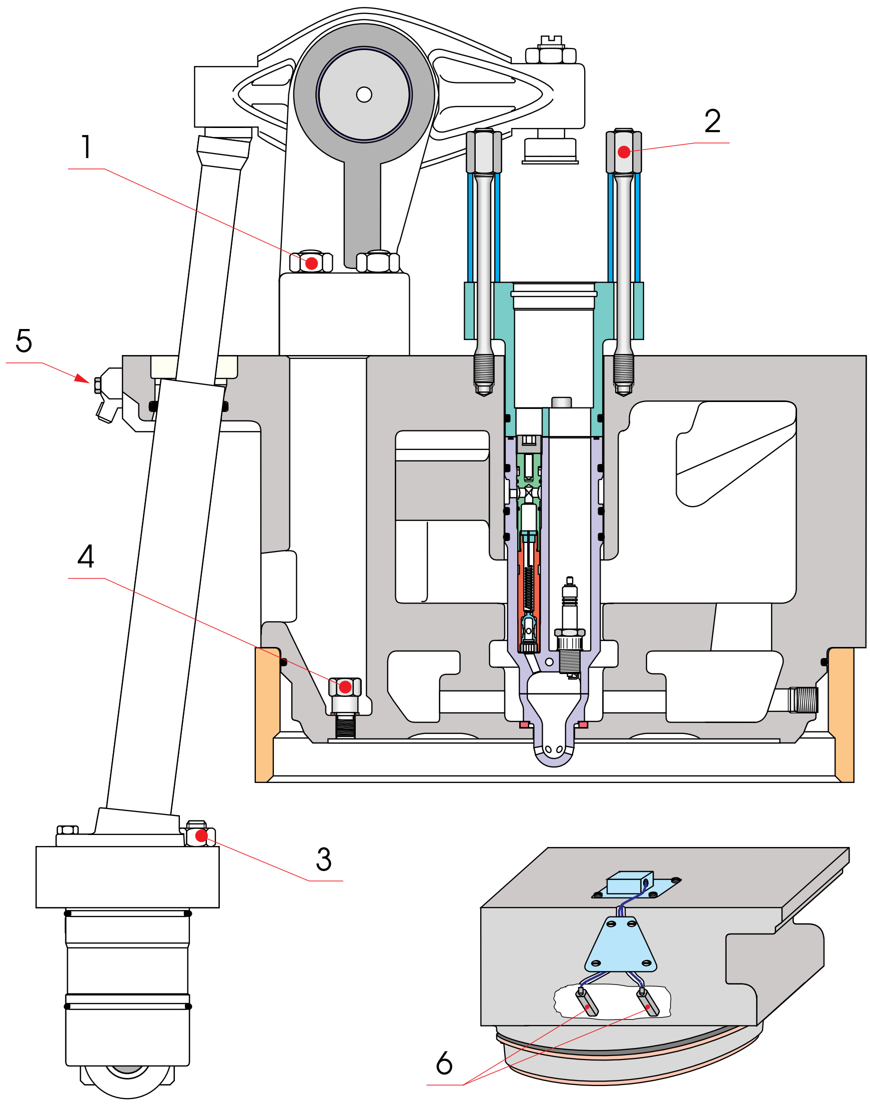


Fig 07-5

3207039720

Pos.	Screw connection	Torque (Nm)
1.	Rocker arm console, fastening nuts. When re-assembling stud bolts apply Loctite 270 on threads, see section 07.2	250±10
2.	Prechamber fastening nuts	130±5
3.	Nuts for valve tappet guide block **Note! The studs must be locked with Loctite 243.**	200±10
4.	Plug for cylinder head (with steel sealing ring)	45±5
5.	Screw for knocking sensor Bosch PCB	 20±5 6±1
6.	Sensor pockets for exhaust gas temperature. **Note! Pockets mounted in the cylinderhead.**	10±1

D: Prechamber

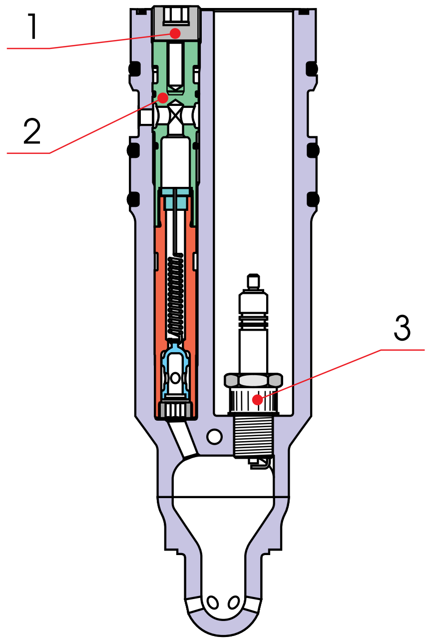


Fig 07-6

3207049720

Pos.	Screw connection	Torque (Nm)
1.	Locking screw for check valve	55±5
2.	Upper body/lower body	55±5
3.	Spark plug **No lubricating on the threads.**	44±4

Note! **Do not lubricate the spark plug threads. Lubrication will reduce the heat transfer from the spark plug which will reduce the spark plug life time and may cause pre-ignition.**

D: Main gas admission valve

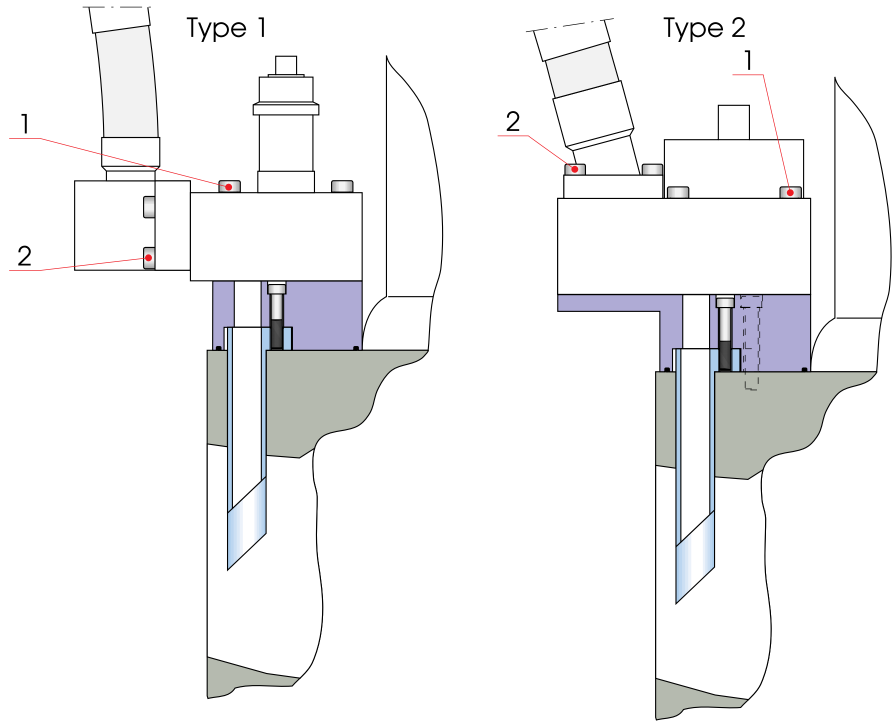
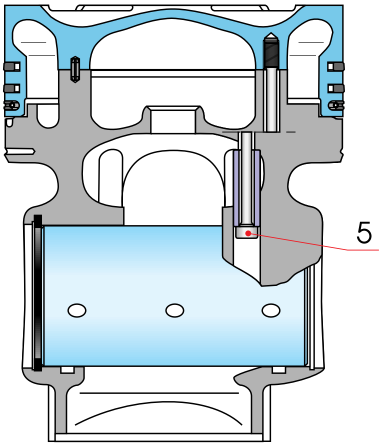


Fig 07-7

3207059720

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

E: Piston



Piston of type 1

Fig 07-8

3207959542

	Piston	Torque (Nm)
5.	Piston crown connection screws. 1. Lubricate threads and contact surfaces with Molycote Paste G-n-plus. 2. Tighten the screws crosswise. 3. Loosen the screws. 4. Pre-tighten the screws crosswise. 5. Tighten the screws crosswise further with an angle of 6. Test for the right tightness. Screw should not move when tightening by 65 Nm torque. **Note!** If the free length of the screws exceeds **166 mm** the screws must be replaced.	 80 Nm 20 Nm 90°

F: Turbocharger fastening screws

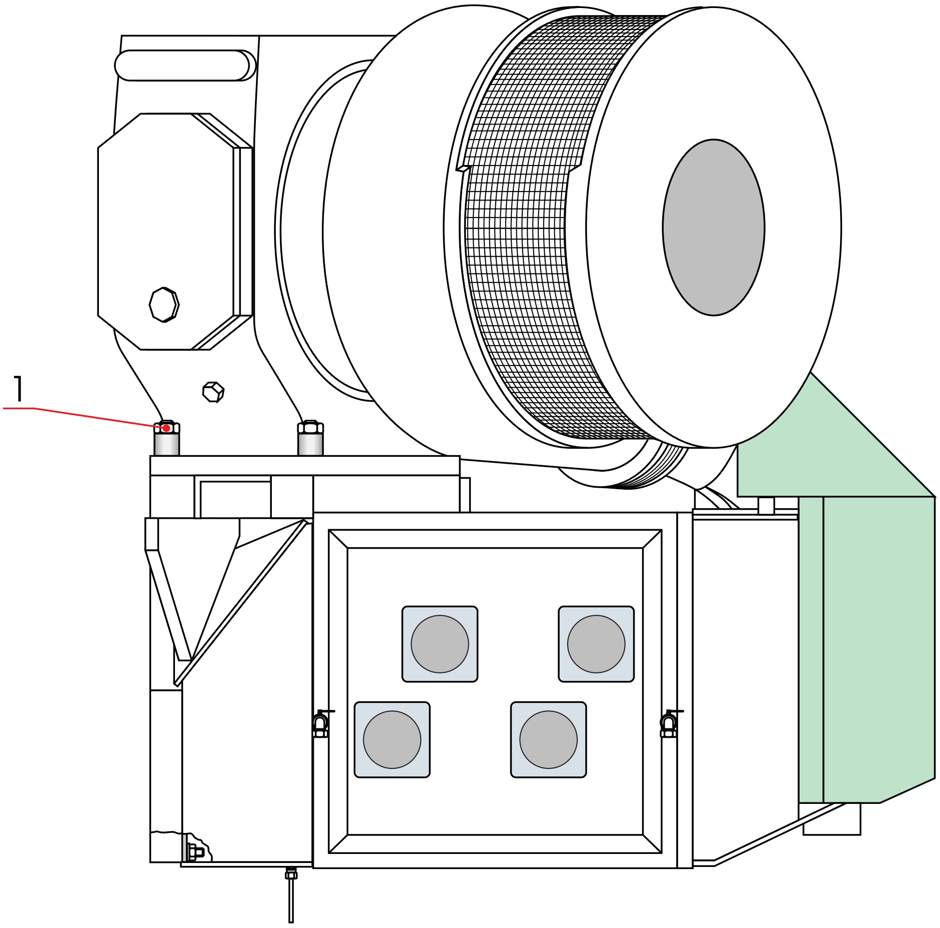


Fig 07-9

3207069720

Turbocharger type	Screw pos.1 Torque (Nm)
NA-355, M24	585±30
TPL 65, M20	540±20
HS 5800, M16	270±10

G, H: Engine driven pumps

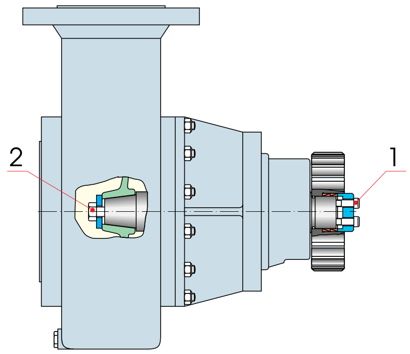


Fig 07-10

32071010337

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

G, H: Engine driven pumps, WD-125

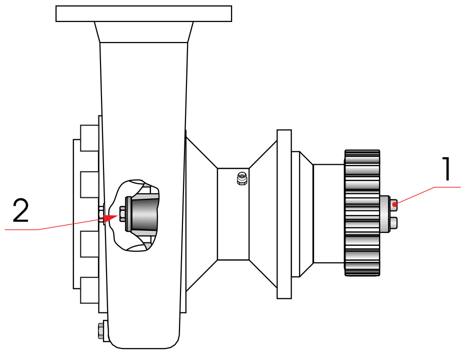


Fig 07-11

3207260251

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

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

G, H: Engine driven pumps

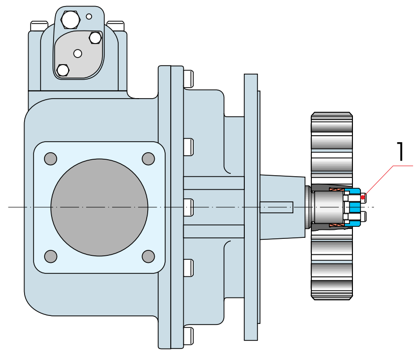


Fig 07-12 32071020337

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

I: Free end of crankshaft

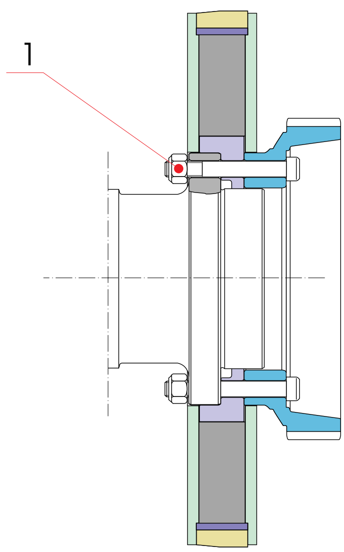


Fig 07-13 3207649045

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

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

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

07.2 Use of locking fluid

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

07.3 Hydraulically tightened connections

07.3.1 Tightening pressures for hydraulically tightened connections

Hydraulically tightened connections

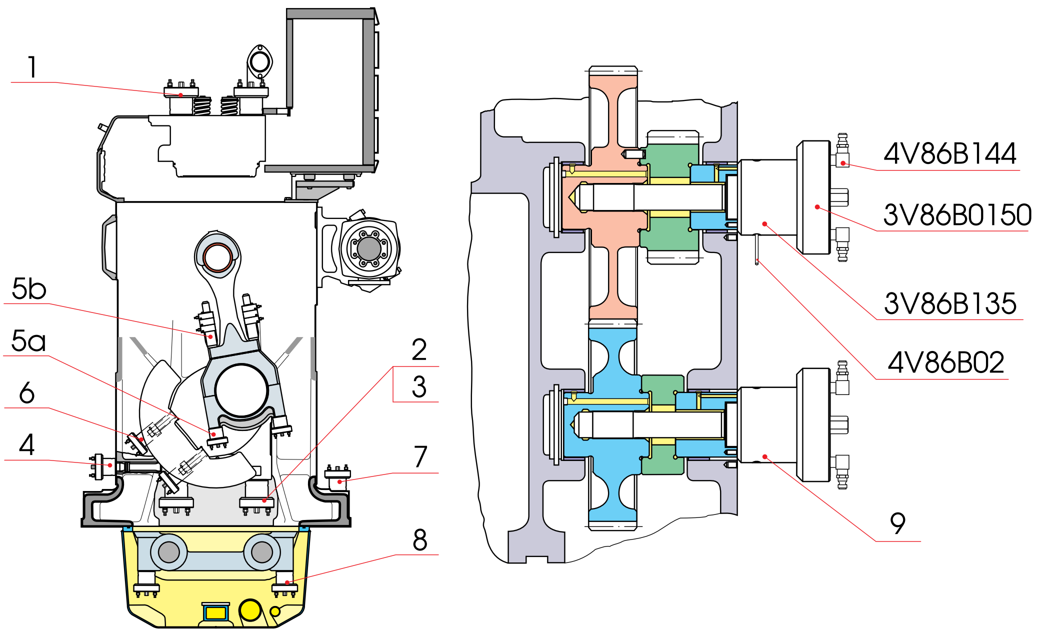


Fig 07-14

3207979542

Pos.	Screw connection	Max. hydraulic pressure (bar)		Hydraulic cylinder
		tightening	loosening	
1.	Cylinder head screws M56: - outer diameter of cylinder liner 450 mm	500	520	3V86B79
2.	Main bearing screws M56	615	635	3V86B79
3.	Thrust bearing screws M42	615	635	3V86B78
4.	Lateral screws of main bearings and thrust bearing M42	615	635	3V86B78
5.	Connecting rod screws : 5a. M30 tightening in two steps First step Second step 5b. M24 tightening in two steps First step Second step	 300 600 400 750	 620 770	 3V86B186 2V86B201
6.	Counterweight screws M42	600	620	3V86B78
7.	Engine fastening screws M42	x)		3V86B78
8.	Fastening screws M42 for balancing shaft bearing bracket	715	735	3V86B78
9.	Intermediate gears M56	660	680	3V86B0150

x) Pos. 7 see installation instructions.

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

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

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

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

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

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

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

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

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

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

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

07.3.3 Dismantling hydraulically tightened screw connections

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 scheme 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 half a revolution (180°), otherwise the nut is locked by the cylinder and impossible to loosen.

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

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

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

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

Hydraulic cylinder

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

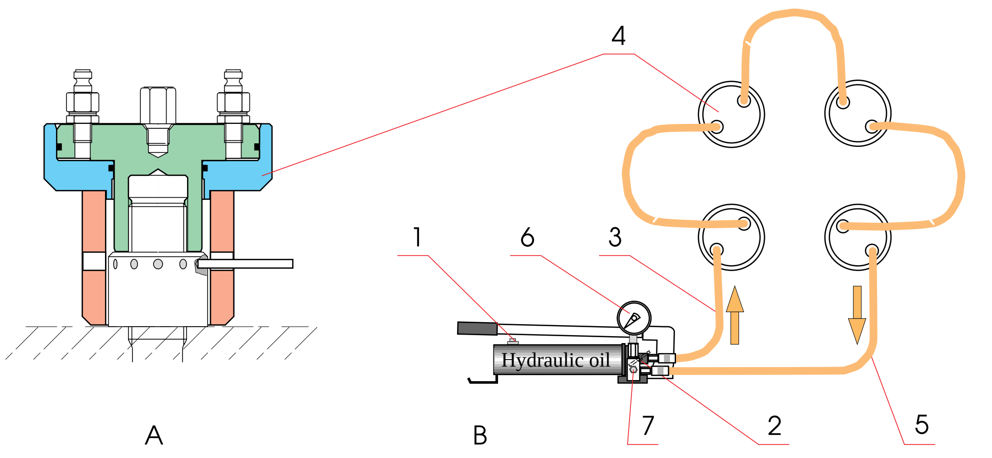


Fig 07-15 3207528935

07.3.4 Reassembling hydraulically tightened screw connections

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

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

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

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

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

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

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

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

07.3.5 Hydraulic tool for connecting rod screws

Hydraulic tool, hose connection and tool section

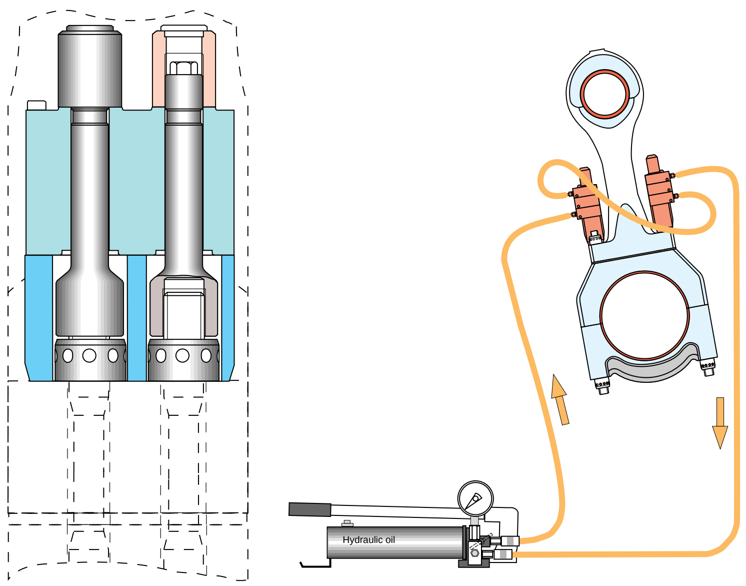


Fig 07-16 3207889542

07.4 Use of hydraulic extractor cylinder

For some power demanding operations a hydraulic extractor cylinder is used. In connection with this cylinder, the hydraulic high pressure hand pump is utilized, coupling scheme acc. to Fig 07-17.

Hydraulic extractor cylinder

1. Hydraulic cylinder
2. Expansion ring

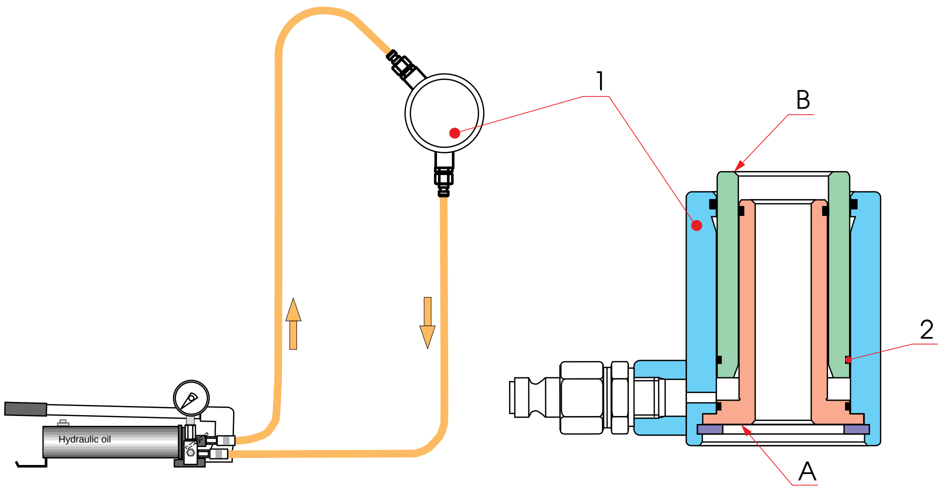


Fig 07-17 3207538935

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

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

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

Relation between pressure and force for hydraulic extractor cylinder 3V83E61

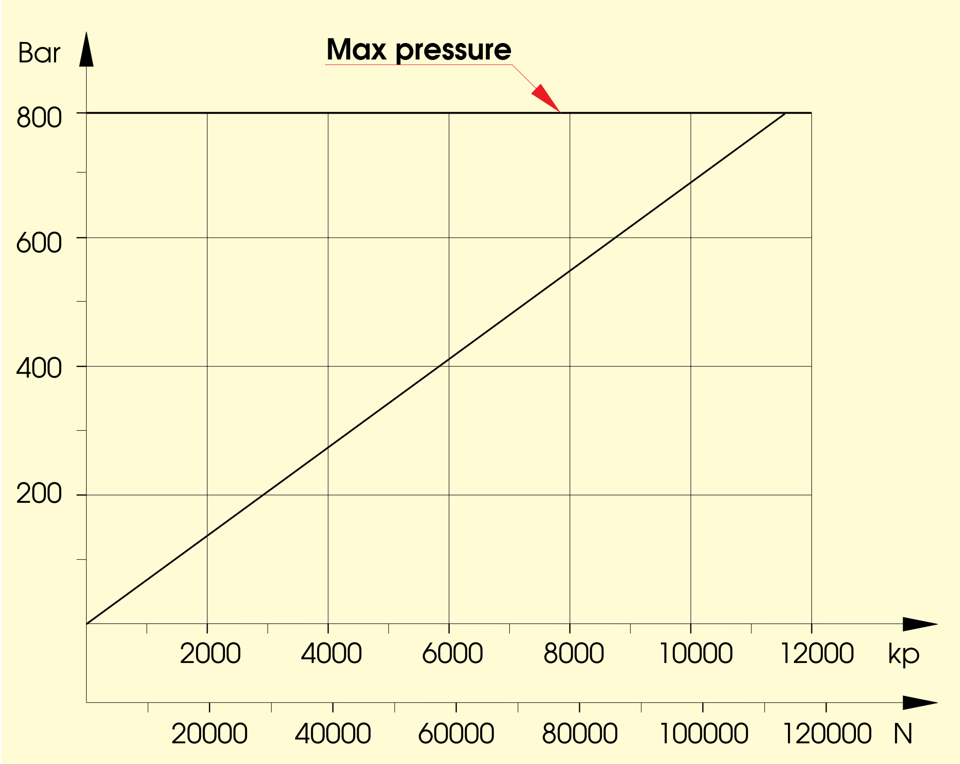


Fig 07-18 3207548935

07.5 Low pressure pump for lifting purposes in the crankcase

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

08. Trouble shooting

08.1 General

The engine should be maintained according to the schedule in chapter 04. Some possible operating troubles may though require prompt action. The engine operators should therefore aquire knowledge of this chapter for action when needed.

The contents of this text shall be used as guidelines only as this manual do not necessarily exactly describe the actual installation.

Warning! **To avoid personal and/or property injury, the local electrical installation safety precautions and chapter 23 as well as appendix 00A in this manual must be followed during all maintenance.**

08.2 Trouble shooting based on messages

As the engines mainly operates in multi-engine installations this chapter deals with two categories of error messages:

Messages in the engine automation (WECS) safety process:

- Engine shutdown (SHD)
- Load reduction (LRED)
- Alarm (ALM)
- Start blocking (STB)
- Sensor failure (SF)

Messages in the plant automation (PLC) safety process:

- Engine shutdown (SHD)
- Load reduction (LRED)
- Alarm (ALM)
- Start blocking (STB)
- Sensor failure (SF)

Shutdowns (SHD) messages by WECS			
Code	**Message**	**Reason**	**Action**
KDU0_1E001SDI	SHD, 24 V DC power failure, KDU1	Power supply failure to KDU	Check acc. to Fig 08-10 Power supply failure to KDU
KDU0_1E002SDI	SHD, 24 V DC power failure, KDU2	Power supply failure to KDU	Check acc. to Fig 08-10 Power supply failure to KDU
DCU0_1E001SDI	SHD, CAN-bus failure DCU 1	MCU unable to communicate with DCU 1 over CAN bus	DCU CAN LED blinking and power LED lit. Check the power supply for the DCU, if the power supply voltage is within the limits (24 VDC +/- 4), check the CAN according to the Fig 08-13. Replace DCU
DCU0_1E002SDI	SHD, CAN-bus failure DCU 2	MCU unable to communicate with DCU 2 over CAN bus	DCU CAN LED blinking and power LED lit. Check the power supply for the DCU, if the power supply voltage is within the limits (24 VDC +/- 4), check the CAN according to the Fig 08-13. Replace DCU
DCU0_1E003SDI	SHD, CAN-bus failure DCU 3	MCU unable to communicate with DCU 3 over CAN bus	DCU CAN LED blinking and power LED lit. Check the power supply for the DCU, if the power supply voltage is within the limits (24 VDC +/- 4), check the CAN according to the Fig 08-13. Replace DCU
CCU0_1E3nnSDI	SHD, CAN-bus failure, CCUn	CAN communication bus failure to CCU	Check acc. to Fig 08-11 CAN-bus failure CCU
SOB0_1E052SDH	SHD, Dev. betw. reference and actual speed	Internal speed controller reference value deviates from the actual speed	Check the fuel supply, too big load step
SOB0_1E050SDH	SHD, Dev. between kW-ref. and actual load *)	Too high deviation between actual load and setpoint, too high load request. Air/Fuel ratio incorrect	Please contact nearest Wärtsilä Service office
CCU0_1E0nnSDI	SHD, EMG mode, 24VDC power supply failure, CCUn	24 VDC power supply failure to CCU	Check acc. to Fig 08-9. Power supply failure to CCU
SCX0_1E055SDI	SHD, EMG mode, Degassing failure	Gas pressure in the main gas line after engine stop	Check the ventilation valve operation and the shut-off valve operation on the gas regulating unit
SOB0_1E001SDH	SHD, EMG mode, Overload	Overload 110 % of rated load	Check load demands
SOB0_1S001SDH	SHD, EMG mode, Overspeed from engine speed pickup, ST173	Measured (secondary) speed over rated speed, 115 %	Check the event list for triggering cause (grid connection status signals)
SOB0_1H001SDH	SHD, EMG mode, Overspeed from rotary encoder, ST175	Measured (primary) speed over rated speed, 115 %	Check the event list for triggering cause (grid connection status signals)
CCU0_1E2nnSDI	SHD, EMG mode, Speed / TDC ratio failure, CCUn	Speed pulses missing from rotary encoder	Check possible wiring earth faults and acc. to Fig 08-5. Rotary encoder failure

*) only in kW control

Shutdowns (SHD) messages by WECS			
Code	**Message**	**Reason**	**Action**
SOB0_1E004SDI	SHD, Engine load sensor failure, UT793	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-4 4-20 mA sensor failure MCU
SCX0_1E005SDI	SHD, Engine status from WECS, Emergency mode	Emergency mode active	Check the separately informed emergency cause (primary)
SCX0_1E004SDI	SHD, Engine status from WECS, Shutdown mode	Shutdown mode active	Check the separately informed shutdown cause (primary)
SCX0_1F000SDH	SHD, Heavy knocking	Cylinder overload, Leaking main gas valve, Poor gas quality, Injection/ignition timing error	Check main gas valve, Check encoder position, Perform cylinder balancing
SOB0_1P001SDH	SHD, High crankcase pressure, PT700	Obstraction in crankcase breathing line, Exhaust gas blow by, Bearing seizure	Check crankcase breathing line, check bearing temperatures, inspect cylinder liners
SOC0_1T100SDH	SHD, High cylinder liner temperature	Continuous light knocking, Exhaust gas blow-by, Piston seizure, High cooling water temperature	Check ignition system, check calibration of knock detection system, check main gas valve, check cooling water system, Visually inspect piston and cylinder liner
SNA0_1T100SDH	SHD, High dev. exh. gas temp. cyl./average	Cylinder exhaust gas temperature is significantly higher than engine average	See cylinder combustion failure check lists in section 08.2.1.
SNA0_1T000SDH	SHD, High exhaust gas temperature	Big load steps, Leaking main gas valve, Incorrect Air/Fuel ratio, Burned exhaust gas valves	See cylinder combustion failure check lists in section 08.2.1.
BAG0_1T000SDH	SHD, High generator bearing temperature	Low lube oil level, bearing seizure	Check lube oil level, check alignment, Visually inspect the bearing
BAG0_1T006SDH	SHD, High generator cold cooling air temp., TE758 *)	High generator cooling water temperature	Check external cooling system
BAG0_1T007SDH	SHD, High generator hot cooling air temp., TE759 *)	High generator cooling water temperature	Check external cooling system
BAG0_1T001SDH	SHD, High generator winding temperature, L1	High winding temperature, due to high reactive load, overcurrent, high harmonics, clogged filters or high ambient temperature	Check reactive loads and currents (reduce load), Clean filters and ensure that ventilation is on

*) only water cooled generators

Shutdowns (SHD) messages by WECS			
Code	**Message**	**Reason**	**Action**
BAG0_1T002SDH	SHD, High generator winding temperature, L2	High winding temperature, due to high reactive load, overcurrent, high harmonics, clogged filters or high ambient temperature	Check reactive loads and currents (reduce load), Clean filters and ensure that ventilation is on
BAG0_1T003SDH	SHD, High generator winding temperature, L3	High winding temperature, due to high reactive load, overcurrent, high harmonics, clogged filters or high ambient temperature	Check reactive loads and currents (reduce load), Clean filters and ensure that ventilation is on
SOC0_1T000SDH	SHD, High main bearing temperature	Low lube oil flow, main bearing seizure	Check lube oil pump and system, Check main bearing temperature trends, Visualy inspect the bearing
SOB0_1E055SDH	SHD, High speed dev. betw. pickup and rotary enc.	Deviation in speed measured by MCU and CCUs	Check acc. to Fig 08-6 inductive sensor failure and 4-20 mA signal from OTM to MCU. Check the Fig 08-5. Rotary encoder failure.
SNA0_1T100SDL	SHD, Low dev. exh. gas temp. cyl./average	Cylinder exhaust gas temperature is significantly lower than engine average	See cylinder combustion failure check lists in section 08.2.1.
SQA0_1P008SDL	SHD, Low lube oil pressure, inlet, PT201	Contaminated lube oil filter, Low lube oil level, Clogged cooling system, Broken pipes, Foaming	Check diff pressure over lube oil filter, Check lube oil level, Check cooling system, Check pipe system, Check lube oil sump for foaming
SQA0_1P008SDI	SHD, Lube oil pressure sensor failure, PT201	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-3 4-20 mA sensor failure
SCX0_1E059SDH	SHD, Main fuel injection duration max. time	Engine is not getting enough fuel to maintain speed and/or load	Check the gas flow and pressures and the gas regulating unit
SCX0_1E056SDH	SHD, Max idle time exceeded	The engine has been running idle for more than 5 minutes	Idle running for more than 5 minutes is not allowed. Check synchronisation circuits
SNA0_1T000SDL	SHD, Min exhaust gas temp. not reached	Minimum required combustion temperature during start not reached	If the same shutdown occurs repeatedly during a series of start attempts.
SOB0_1E054SDL	SHD, Nominal speed not reached	Expected acceleration to nominal speed not achieved, Some cylinders did not get correct air/fuel mixture	Check that the main gas pressure is close to the setpoint. If the same shutdown occurs repeatedly during a series of start attempts.
SOB0_1E058SDL	SHD, Too low engine speed at current load *)	Too high load at current speed, overload	Check speed and load demands

*) only Compset/Pumpset installations

Alarm (ALM) messages by WECS			
Code	**Message**	**Reason**	**Action**
SNA0_1T1nnDAH	ALM, Cyl. disabled due to temp. dev., cyl n	Combustion failure of cylinder. Cylinder injection is disabled	See cylinder combustion failure check lists in section 08.2.1.
SOB0_1E050AH	ALM, Dev. between kW-ref. and actual load *)	Too high deviation between actual load and setpoint, too high load request. Air/Fuel ratio incorrect	Please contact nearest Wärtsilä Service office
SCX0_1E062ALI	ALM, Failed start attempt	Start attempt failed for initial start preparations	Check function of starter motors, Check fuel supply, Check start air supply
BAG0_1L001ALI	ALM, Generator water leakage, LS756 **)	Generator cooling water circuit leakage	Visual check of cooling system to be performed
SNB0_1T004AH	ALM, High charge air temperature, TE622	High ambient temperature, High LT water temperature, CA cooler blow-by, Contaminated CA coolers	Check cooling system, Check difference between LT and CA temperature, Check CA diff pressure
SOB0_1P001AH	ALM, High crankcase pressure, PT700	Obstraction in crankcase breathing line, Exhaust gas blow by, Bearing seizure	Stop the engine. Check crankcase breathing line, check bearing temperatures, inspect cylinder liners
SNA0_1T100AH	ALM, High dev. exh. gas temp. cyl./average	Cylinder exhaust gas temperature is significantly higher than engine average	See cylinder combustion failure check lists in section 08.2.1.
SNA0_1T0nnAH	ALM, High exhaust gas temperature, cyl n	Big load steps, Leaking main gas valve, Incorrect Air/Fuel ratio, Burned exhaust gas valves	See cylinder combustion failure check lists in section 08.2.1.
BAG0_1T004AH	ALM, High gen. bearing drive end temp., TE751	Low lube oil level, bearing seizure	Check lube oil level, Check generator ventilation
BAG0_1T005AH	ALM, High gen. bearing non-drive end temp., TE752	Low lube oil level, bearing seizure	Check lube oil level, Check generator ventilation
BAG0_1T006AH	ALM, High generator cold cooling air temp., TE758 **)	High generator cooling water temperature	Check external cooling system
BAG0_1T007AH	ALM, High generator hot cooling air temp., TE759 **)	High generator cooling water temperature	Check external cooling system
BAG0_1T001AH	ALM, High generator winding temperature L1	High winding temperature, due to high reactive load, overcurrent, high harmonics, clogged filters or high ambient temperature	Check reactive loads and currents (reduce load), Clean filters and ensure that ventilation is on

*) only in kW control
**) only water cooled generators

Alarm (ALM) messages by WECS			
Code	**Message**	**Reason**	**Action**
BAG0_1T002AH	ALM, High generator winding temperature L2	High winding temperature, due to high reactive load, overcurrent, high harmonics, clogged filters or high ambient temperature	Check reactive loads and currents (reduce load), Clean filters and ensure that ventilation is on
BAG0_1T003AH	ALM, High generator winding temperature L3	High winding temperature, due to high reactive load, overcurrent, high harmonics, clogged filters or high ambient temperature	Check reactive loads and currents (reduce load), Clean filters and ensure that ventilation is on
SVH0_1T013AH	ALM, High HT water temperature, TE402	Insufficient cooling, Low cooling water flow	Check cooling system
CCU0_1T0nnAH	ALM, High internal temp. CCUn	Internal temperature of CCU too high	Check engine room ventilation
DCU0_1T001AH	ALM, High internal temperature, DCU 1, TE831	Internal temperature of DCU too high	Check engine room ventilation
DCU0_1T002AH	ALM, High internal temperature, DCU 2, TE832	Internal temperature of DCU too high	Check engine room ventilation
DCU0_1T003AH	ALM, High internal temperature, DCU 3, TE833	Internal temperature of DCU too high	Check engine room ventilation
KDU0_1T001AH	ALM, High internal temperature, KDU1	Internal temperature of KDU too high	Check engine room ventilation
KDU0_1T002AH	ALM, High internal temperature, KDU2	Internal temperature of KDU too high	Check engine room ventilation
SMU0_1T102AH	ALM, High internal temperature, SMU 1-2, TE841	Internal temperature of SMU too high	Check engine room ventilation
SMU0_1T103AH	ALM, High internal temperature, SMU 1-3, TE842	Internal temperature of SMU too high	Check engine room ventilation
SMU0_1T202AH	ALM, High internal temperature, SMU 2-2, TE843	Internal temperature of SMU too high	Check engine room ventilation
SMU0_1T302AH	ALM, High internal temperature, SMU 3-2, TE844	Internal temperature of SMU too high	Check engine room ventilation
SOC0_1T1nnAH	ALM, High liner temp., cylinder n, average	Continuous light knocking, Exhaust gas blow-by, Piston seizure, High cooling water temperature	Check ignition system, check calibration of knock detection system, check main gas valve, check cooling water system, check piston and cylinder liner
SQA0_1T003AH	ALM, High lube oil temperature, inlet, TE201	Lube oil cooler clogged, Cooling water temperature too high	Check lube oil cooler, check cooling water temperature

Alarm (ALM) messages by WECS			
Code	**Message**	**Reason**	**Action**
SZA0_1P001ALI	ALM, High main gas pressure deviation	Main gas pressure deviates from setpoint	Check calibration of gas regulating unit
SZA0_1P002ALI	ALM, High PCC gas pressure deviation *)	Pilot gas pressure deviates from setpoint	Check calibration of gas regulating unit
SCX0_1E060AH	ALM, High press. difference main gas / charge air	Too high gas pressure compared to charge air pressure	Engine parameters need to be optimized
SOC0_1T0nnAH	ALM, High temperature, main bearing n	Contaminated oil, Low lube oil flow, main bearing seizure	Regularly oil sample tests, Check lube oil pump and system, Check main bearing temperature trends
KDU0_1E101ALI	ALM, KDU CAN failure, KDU1	CAN communication bus failure to KDU	Check acc. to Fig 08-12 CAN bus failure KDU
KDU0_1E102ALI	ALM, KDU CAN failure, KDU2	CAN communication bus failure to KDU	Check acc. to Fig 08-12 CAN bus failure KDU
KDU0_1E301ALI	ALM, KDU failure, KDU1	Knock values are not updated	Check that the rotary switches are according to the engine electrical drawings
KDU0_1E302ALI	ALM, KDU failure, KDU2	Knock values are not updated	Check that the rotary switches are according to the engine electrical drawings
SCX0_1F0nnSF	ALM, Knock sensor failure, cylinder n	Self diagnostics of knock detection system indicates too low signal level	Check valve clearances of cylinder head, Check sensor acc. To Fig 08-8 Knock sensor failure
SOB0_1E057ALI	ALM, kW control trip	Too high frequency deviation from nominal grid frequency	Engine will enter speed droop control
STA0_1P005AL	ALM, Low control air pressure, PT311	Low control air pressure	Check control air supply for leakages
SNA0_1T100AL	ALM, Low dev. exh. gas temp. cyl./average	Cylinder exhaust gas temperature is significantly lower than engine average	Refer to cylinder combustion failure check lists in section 08.2.1.
SVH0_1P003AL	ALM, Low HT water pressure, PT401	Low cooling water level, Obstraction in pump or suction line, Exhaust gases in cooling system	Check cooling water level, Check cooling water lines, Check cylinder gaskets
SVH0_1T006AL	ALM, Low HT water temperature, inlet, TE401	Insufficient pre-heating before start-up, Thermostatic valve failure	Check pre-heater, Check thermostatic valve
SVL0_1P003AL	ALM, Low LT water pressure inlet, PT451	Low cooling water level, Obstraction in pump or suction line	Check cooling water level, Check cooling water lines
SQA0_1L001AL	ALM, Low lube oil level, LS204	Lube oil level below low alarm limit	Check the lube oil level

*) only dual gas line system

Alarm (ALM) messages by WECS			
Code	**Message**	**Reason**	**Action**
SQA0_1P008AL	ALM, Low lube oil pressure, inlet, PT201	Contaminated lube oil filter, Low lube oil level, Clogged cooling system, Broken pipes, Foaming	Check diff pressure over lube oil filter, Check lube oil level, Check cooling system, Check pipe system, Check lube oil sump for foaming
STA0_1P003AL	ALM, Low start air pressure, PT301	Start air pressure low	Check start air supply
SNA0_1T1nnAH	ALM, Max. temp. compensation, cyl. A1	Combustion failure of cylinder	See cylinder combustion failure check lists in section 08.2.1.
SOB0_1E001AH	ALM, Overload	Overload 105 % of rated load	Check load demands
CCU0_1E1nnAH	ALM, Speed / TDC ratio failure, CCUn	Speed pulses missing from rotary encoder (SG) or speed pickup (DF)	Check possible wiring earth faults and acc. to Fig 08-5. Rotary encoder failure DF specific speed pickup fault finding chart to be added
SOB0_1E056AL	ALM, Too lean air/fuel mixture	Wastegate setpoint is not reached or the wastegate is at either end limit of its operating range	Check the wastegate I/P converter, positioner and wastegate overall functionality. Recalibrate the wastegate.
SOA0_1G001ALI	ALM, Turning gear engaged, GS792	Turning gear engaged	N/A

Load Reductions (LR/LRED) messages by WECS			
Code	**Message**	**Reason**	**Action**
SNA0_1T000AH	LR, High exhaust gas temperature	Leaking main gas valve, Incorrect Air/Fuel ratio, Burned exhaust gas valves	See cylinder combustion failure check lists in section 08.2.1.
KDU0_1E000ALI	LR, KDU failure	Knock values are not updated	Check that the rotary switches are according to the engine electrical drawings
SCX0_1F000AH	LR, Load red. from knocking	Cylinder overload, Leaking main gas valve, Poor gas quality, Injection/ignition timing error	Check main gas valve, Check encoder position, Perform cylinder balancing
SOB0_1E051ALI	LR, Load reduction active	Load has been reduced temporarily due to separately informed cause	Check the separate load reduction cause informed
SOB0_1E056AH	LR, Too rich air/fuel mixture (load red.)	Wastegate setpoint is not reached or the wastegate is at either end limit of its operating range	Check the wastegate I/P converter, positioner and wastegate overall functionality. Recalibrate the wastegate.
SCX0_1F0nnSDH	LRED, Heavy knocking cylinder n	Cylinder overload, Leaking main gas valve, Poor gas quality, Injection/ignition timing error	Check main gas valve, Check encoder position, Perform cylinder balancing

Start Blocks (STB) messages by WECS			
Code	**Message**	**Reason**	**Action**
CCU0_1E032SBL	STB, CCU configuration fault	CCU configuration missmatch	Check that the rotary switches are according to the engine electrical drawings
CCU0_1E031SBL	STB, CCU power supply failure	CCU supply voltage is too low (below 18 VDC)	Check the CCU supply voltage acc. to Fig 08-9. Power supply failure
SCX0_1E052SBL	STB, Communication fault WECS / PLC	The MCU has not recevied project constants from the PLC (Profibus index 53 received).	Check the profibus communication (cabling and terminating resistors)
SOB0_1S002SBL	STB, Engine speed from redundant pick-up, ST173	Engine speed is not zero	Wait until the engine has stopped completely
SOB0_1H001SBL	STB, Engine speed from rotary encoder, ST175	Engine speed is not zero	Wait until the engine has stopped completely
SVH0_1T006SBL	STB, Low HT water temperature, TE401	HT water temperature too low for starting	Pre-heat the engine
SQA0_1L001SBL	STB, Low lube oil level, LS204	Lube oil level too low	Check the lube oil level
SQA0_1P008SBL	STB, Low lube oil pressure engine inlet, PT201	Pre-lubrication pressure is too low	Check the pre-lubrication pump and adjust pressure if necessary
STA0_1P003SBL	STB, Low starting air pressure, PT301	Starting air pressure is too low	Check the starting air supply
SOA0_1G001SBL	STB, Turning gear engaged, GS792	Turning gear is engaged	Disengage the turning gear

Sensor Failure (SF) messages by WECS			
Code	**Message**	**Reason**	**Action**
SVL0_1P003SF	SF, LT water pressure, inlet, PT451	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-3. 4-20 mA sensor failure
NGA0_1T001SF	SF, Air temp., TC A inlet, TE600A	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
NGA0_1T002SF	SF, Air temp., TC B inlet, TE600B	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SNB0_1P007SF	SF, Charge air pressure, CAC outlet, PT622	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-4 4-20 mA sensor failure MCU
SNB0_1T004SF	SF, Charge air temp., CAC outlet, TE622	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1 PT-100 sensor failure
STA0_1P005SF	SF, Control air pressure, PT311	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-3. 4-20 mA sensor failure
SOB0_1P001SF	SF, Crankcase pressure, PT700	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-3. 4-20 mA sensor failure or Fig 08-4 4-20 mA sensor failure MCU
SOC0_1T1nnSF	SF, Cylinder n liner temp., average	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-2. Thermocouple sensor failure
SOB0_1E004SF	SF, Engine load, UT793	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-4 4-20 mA sensor failure MCU
SOB0_1S001SF	SF, Engine speed, redundant pick-up, ST173	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-6. inductive sensor failure and 4-20 mA signal from OTM to MCU
NHA0_1T002SF	SF, Exh. gas temp., TC B outlet, TE527	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-2. Thermocouple sensor failure
NHA0_1T001SF	SF, Exh. gas temp., turbo charger A outlet, TE517	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-2. Thermocouple sensor failure
SNA0_1T0nnSF	SF, Exh. gas temp.,,cylinder n average	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-2. Thermocouple sensor failure
BAG0_1T004SF	SF, Generator bearing temp., drive end, TE751	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
BAG0_1T005SF	SF, Generator bearing temp., non-drive end, TE752	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
BAG0_1T006SF	SF, Generator cold cooling air, TE758	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
BAG0_1T007SF	SF, Generator hot cooling air, TE759	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure

Sensor Failure (SF) messages by WECS			
Code	**Message**	**Reason**	**Action**
BAG0_1T001SF	SF, Generator winding temp., L1, TE753	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
BAG0_1T002SF	SF, Generator winding temp., L2, TE754	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
BAG0_1T003SF	SF, Generator winding temp., L3, TE755	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SVH0_1P003SF	SF, HT water pressure, inlet, PT401	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-3. 4-20 mA sensor failure
SVH0_1T006SF	SF, HT water temp., inlet, TE401	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SVH0_1T013SF	SF, HT water temp., outlet, TE402	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SVL0_1T005SF	SF, LT water temp., inlet, TE451	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SVL0_1T006SF	SF, LT water temp., outlet, TE452	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SQA0_1P008SF	SF, Lube oil pressure, inlet, PT201	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-3. 4-20 mA sensor failure
SQA0_1T003SF	SF, Lube oil temp., inlet, TE201	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SQA0_1T004SF	SF, Lube oil temp., outlet, TE202	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-1. PT-100 sensor failure
SOC0_1T0nnSF	SF, Main bearing n temperature	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-2. Thermocouple sensor failure
SZA0_1P001SF	SF, Main gas pressure, PT901	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-4 4-20 mA sensor failure MCU
SZA0_1P002SF	SF, PCC gas pressure, PT911 *)	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-4 4-20 mA sensor failure MCU
STA0_1P003SF	SF, Starting air pressure, PT301	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-3. 4-20 mA sensor failure
DCU0_1T001SF	SF, Temp. in DCU1, TE831	Internal temperature measurement of I/O board broken	Replace I/O board
DCU0_1T002SF	SF, Temp. in DCU2, TE832	Internal temperature measurement of I/O board broken	Replace I/O board

*) only dual gas line system

Sensor Failure (SF) messages by WECS			
Code	**Message**	**Reason**	**Action**
DCU0_1T003SF	SF, Temp. in DCU3, TE833	Internal temperature measurement of I/O board broken	Replace I/O board
SMU0_1T102SF	SF, Temp. in SMU1-2, TE841	Internal temperature measurement of I/O board broken	Replace I/O board
SMU0_1T103SF	SF, Temp. in SMU1-3, TE842	Internal temperature measurement of I/O board broken	Replace I/O board
SMU0_1T202SF	SF, Temp. in SMU2-2, TE843	Internal temperature measurement of I/O board broken	Replace I/O board
SMU0_1T302SF	SF, Temp. in SMU3-2, TE844	Internal temperature measurement of I/O board broken	Replace I/O board
SOB0_1S002SF	SF, Turbo charger A speed, SE518	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-7. Magnetic pickup sensor failure
SOB0_1S003SF	SF, Turbo charger B speed, SE528	Sensor broken or wiring fault (broken or loose connections)	Check acc. to Fig 08-7. Magnetic pickup sensor failure
SOA0_1G001SF	SF, Turning gear engaged, GS792	Sensor broken or wiring fault (broken or loose connections)	N/A

Status/Events messages by WECS			
Code	**Message**	**Reason**	**Action**
SCX0_1E051INF	Communication restarted	Profibus communication processor is restarted	N/A
SCX0_1E006INF	Engine ready to start, from WECS	Engine ready to start, startblocks are cleared	n/a
SCX0_1E003INF	Engine status from WECS, Run mode	Run mode active	n/a
SCX0_1E002INF	Engine status from WECS, Start mode	Start mode active	n/a
SCX0_1E001INF	Engine status from WECS, Stop mode	Stop mode active	n/a
SCX0_1E058INF	External emergency stop order, from WECS	Emergency stop order active, activated by engine external system. Safety relay activated	n/a
SCX0_1E057INF	External stop order, from WECS	Stop order active, activated by engine external system	n/a
MCU0_1E101INF	MCU restarted	MCU restarted is activated when power gets below the data limit or if the processor board is manually reset	If this message occurs during normal running check the DC/DC converter (U1) input (24 VDC) and output voltages (5 VDC). Replace the DC/DC converter if the output voltage is not 5 VDC. If the DC/DC converter is ok then likely cause is the 5 VDC board failure or processor board failure of the MCU. The 5 VDC board and MCU are to be replaced if faulty.
SCX0_1E050INF	Profibus index 53 received	Acknowledges that the MCU has recevied project constants from the PLC, i.e the profibus communication is in order. This event should occur immediately after the "MCU restarted" event.	If this event is not occuring after "MCU restarted" check the profibus communication (cabling and terminating resistors).
SCX0_1E101CMD	Reset alarm & shutdown	Alarm and shutdown reset request to WECS	n/a
SCX0_1F0nnINF	Status, Light knocking, cylinder n	Normal operation	If excessive amount of events on same cylinders are observed, the knock detection might need optimization

PT-100 sensor failure

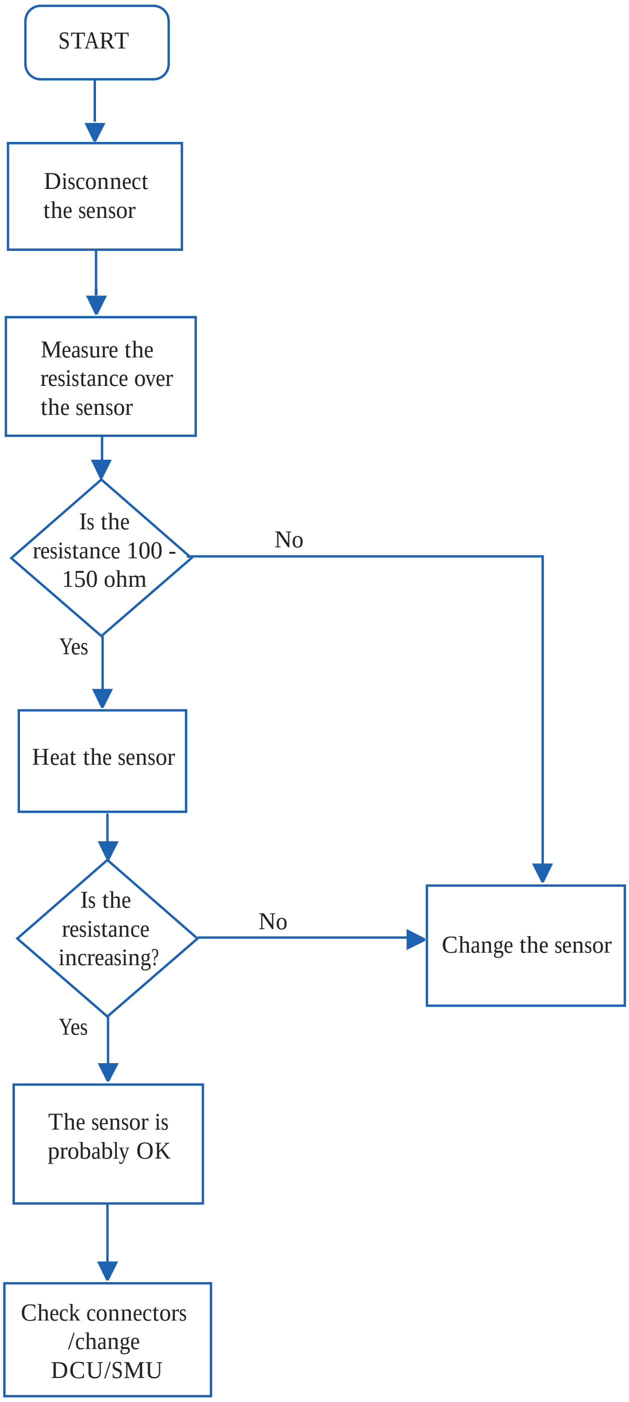


Fig 08-1

3208010342

Thermocouple sensor failure

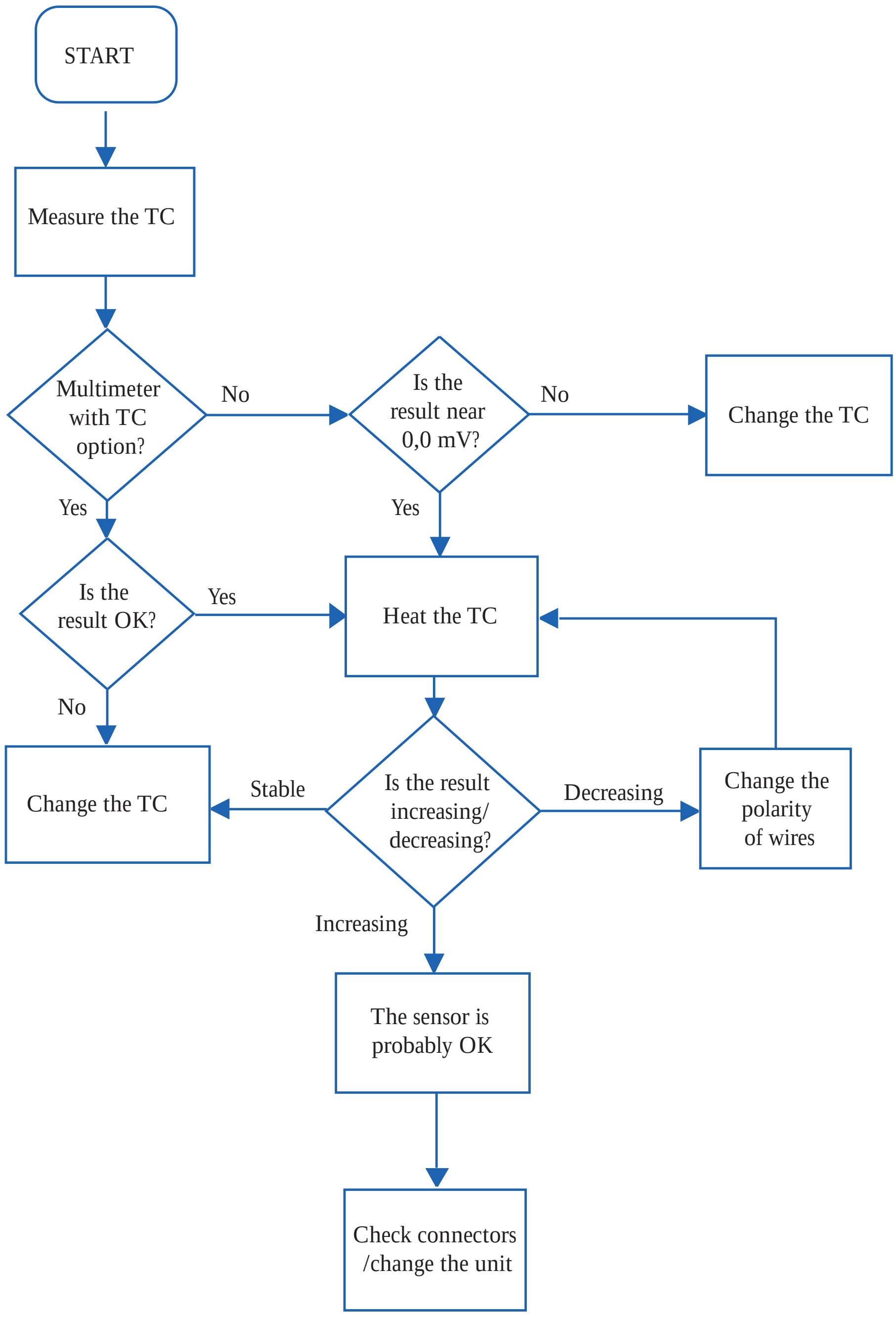


Fig 08-2

3208020342

4-20 mA signal failure DCU

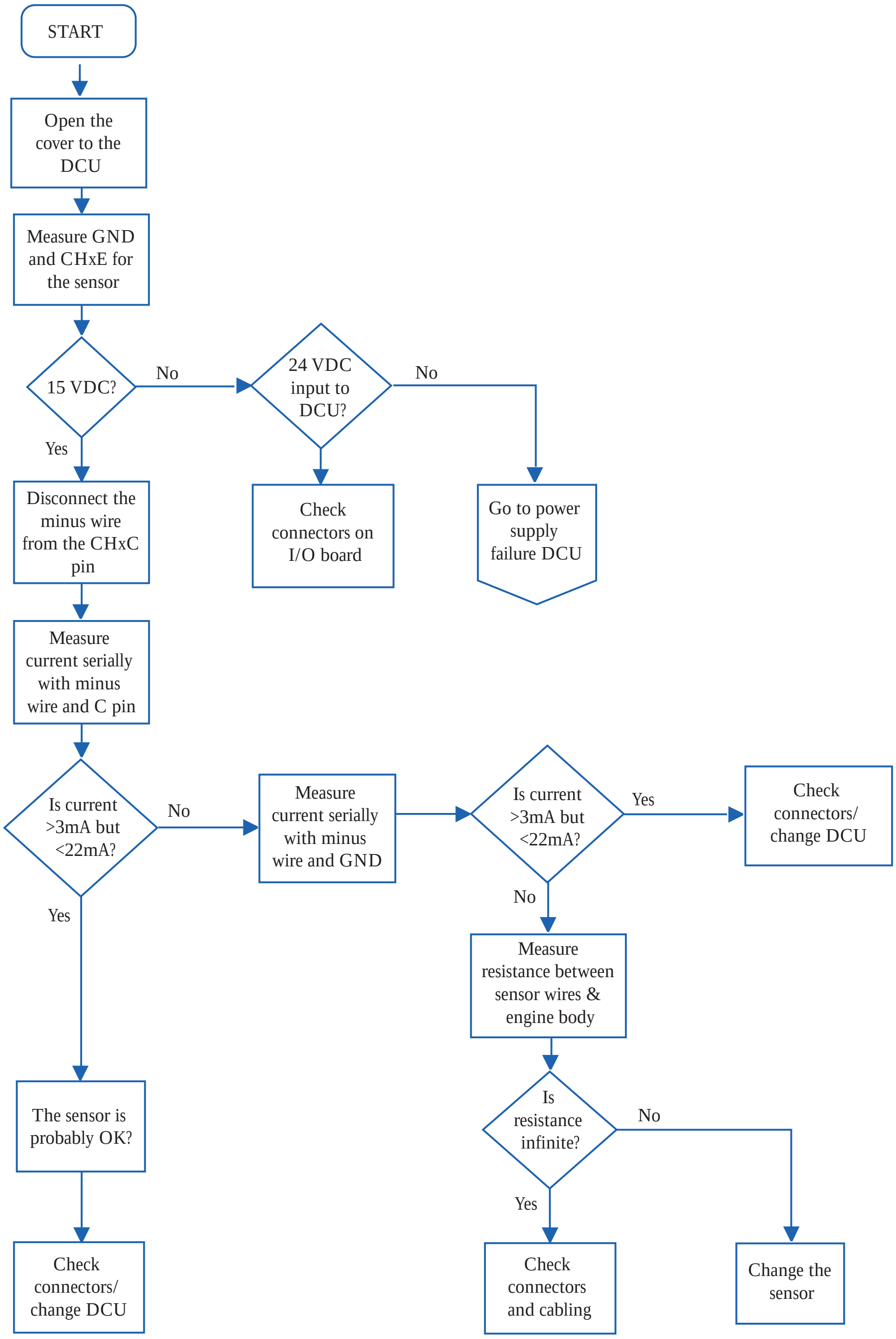


Fig 08-3

3208030342

4-20 mA sensor failure MCU

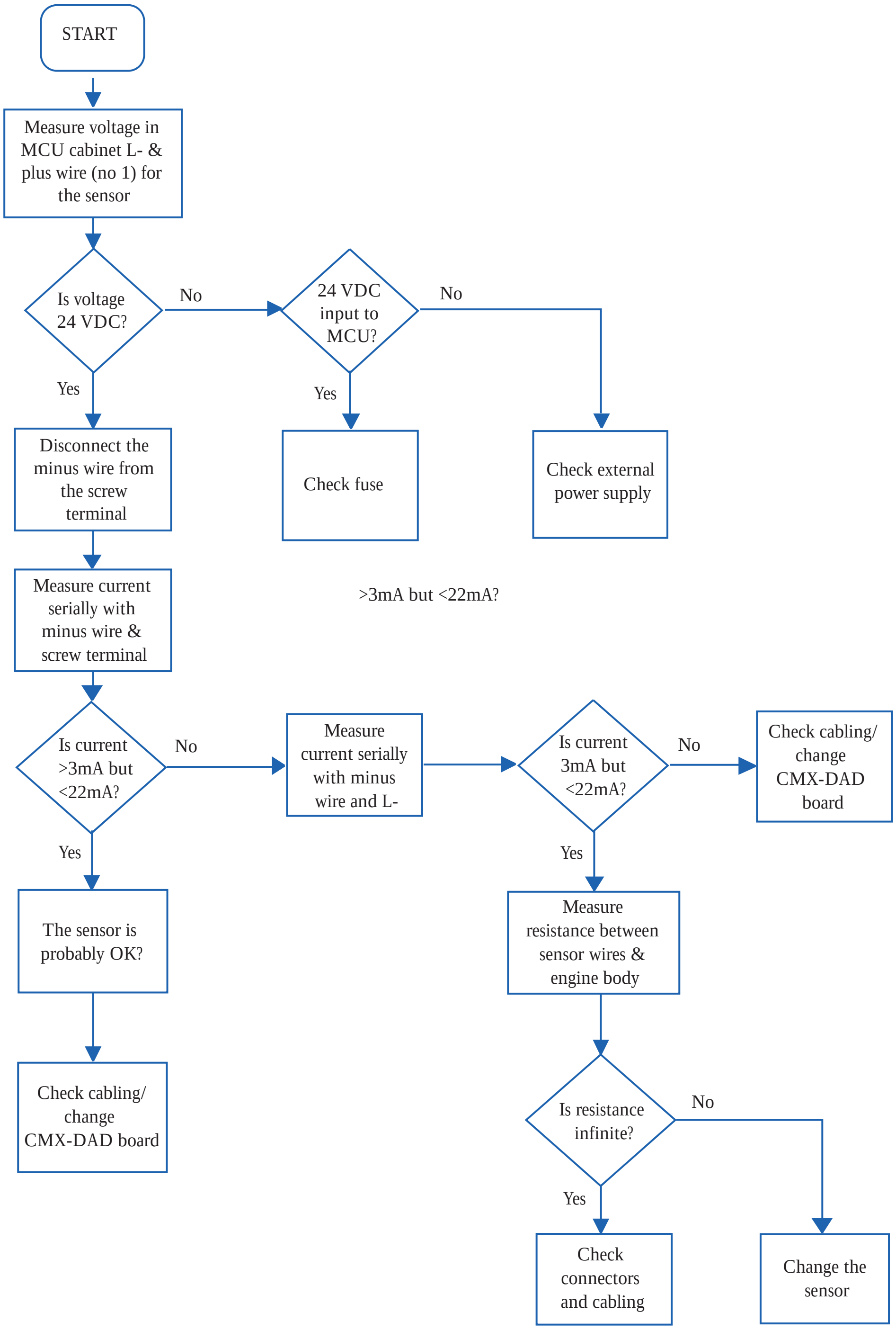


Fig 08-4

3208040342

Rotary encoder failure

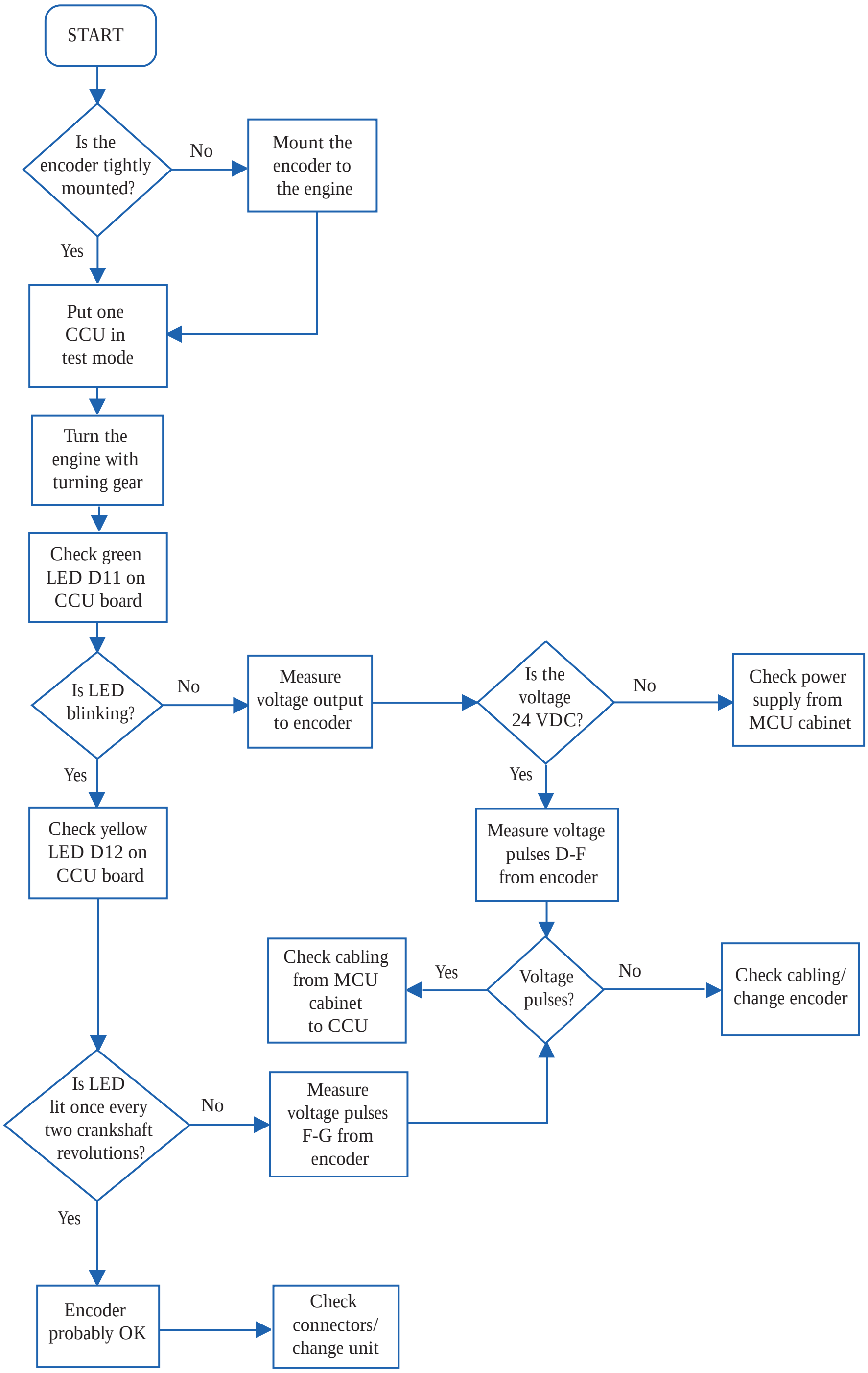


Fig 08-5

3208050342

Inductive pickup sensor failure

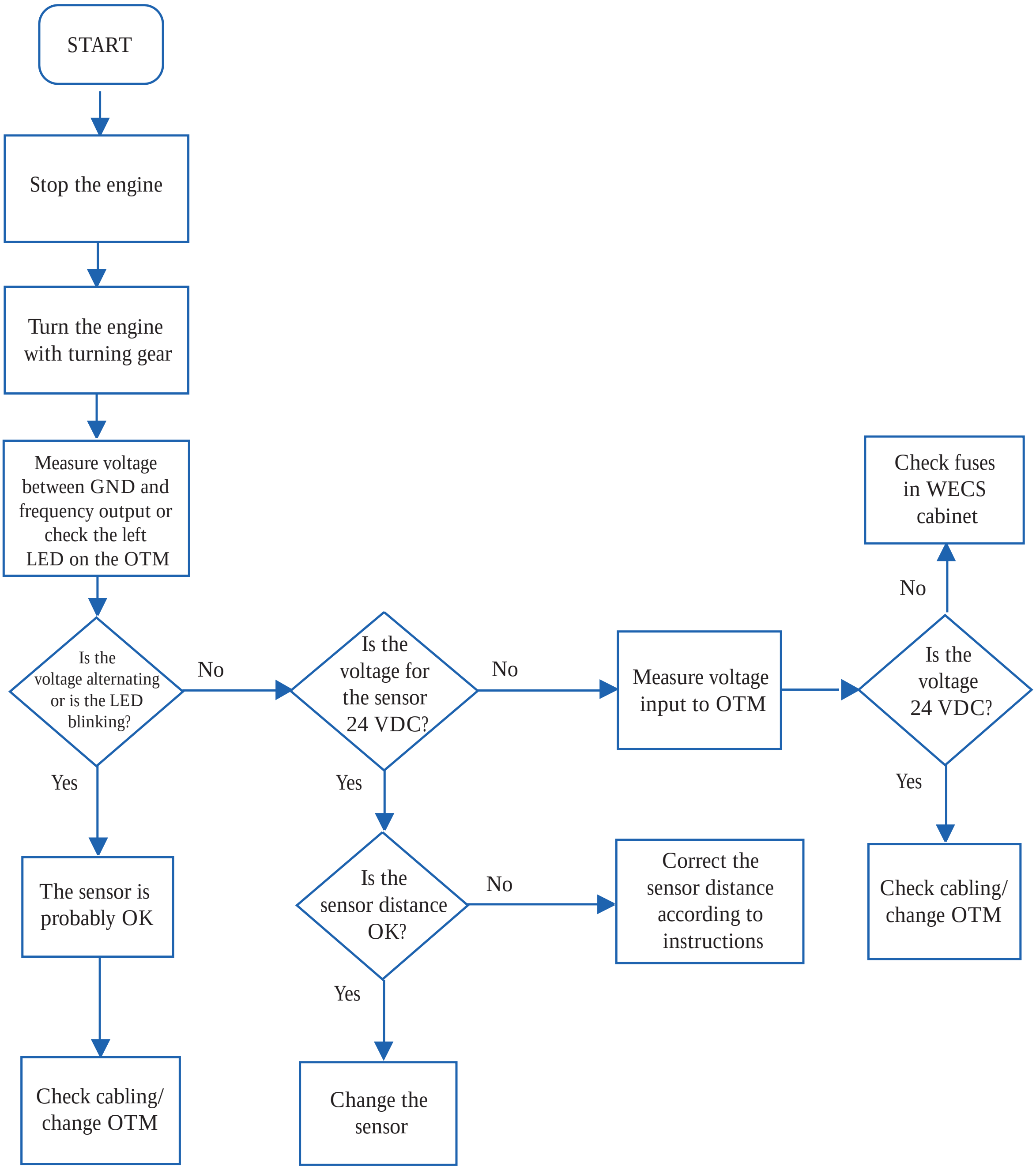


Fig 08-6

3208060342

Magnetic pickup sensor failure

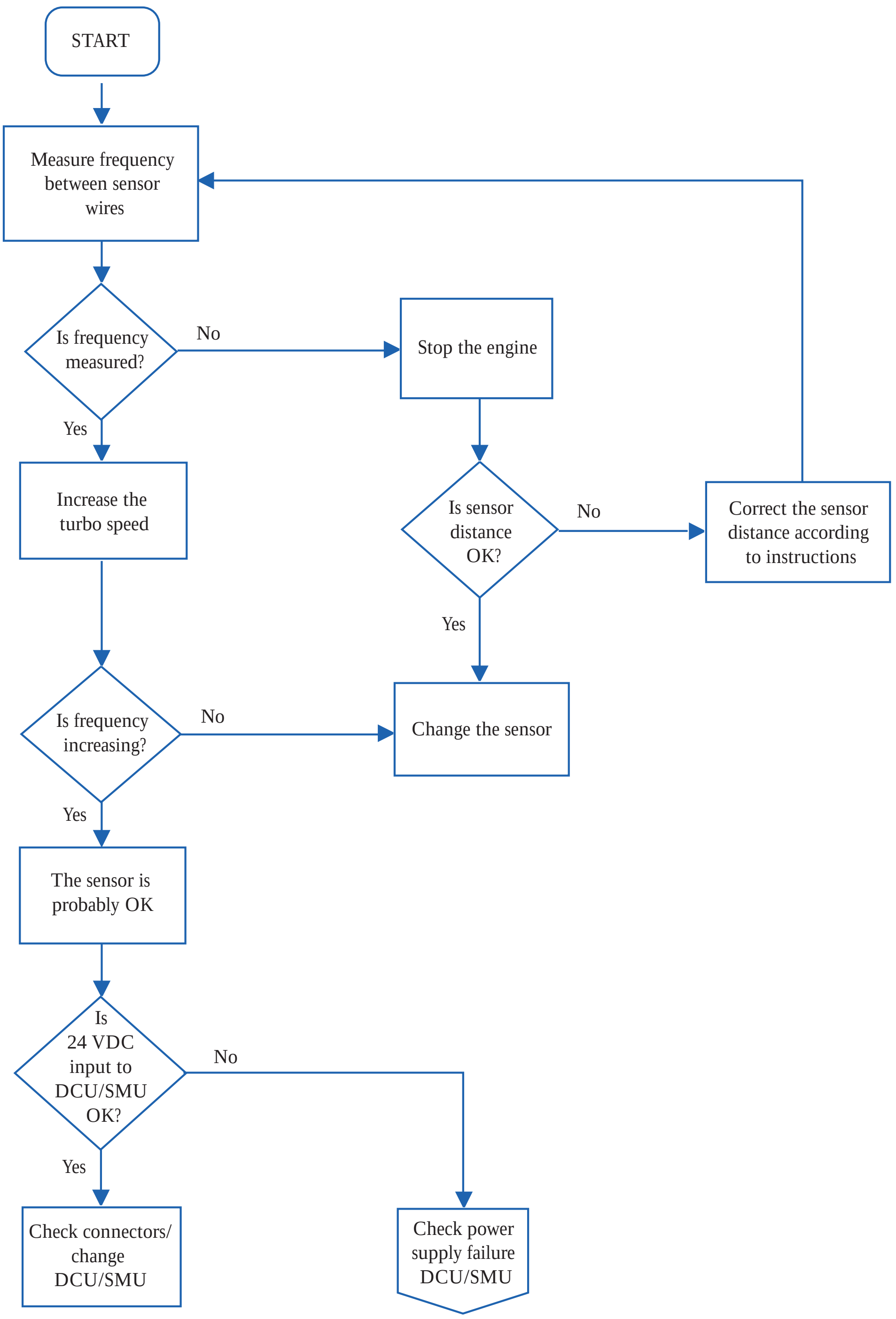


Fig 08-7

3208070342

Knock sensor failure

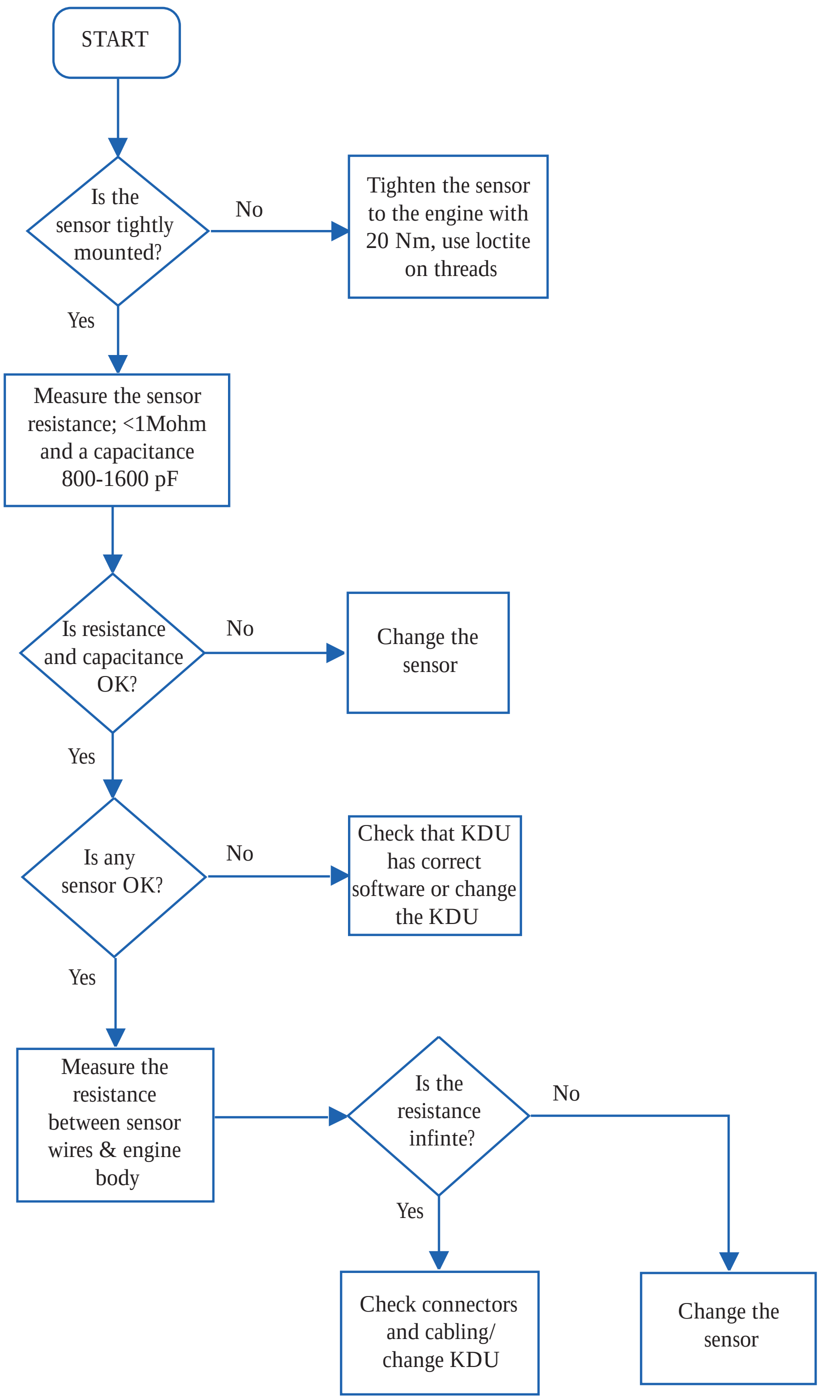


Fig 08-8 3208080342

Power supply failure CCU

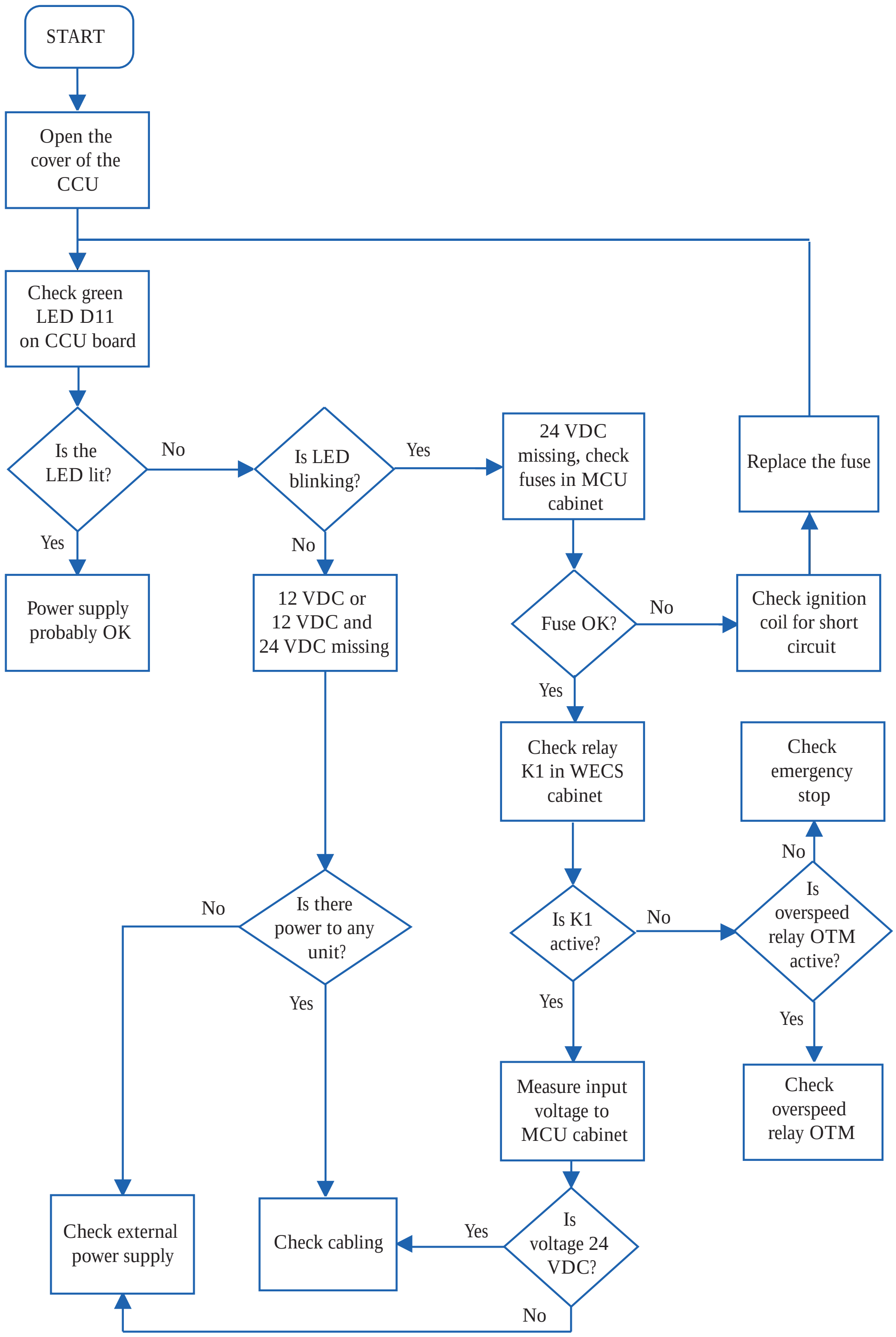


Fig 08-9

3208090342

Power supply failure KDU

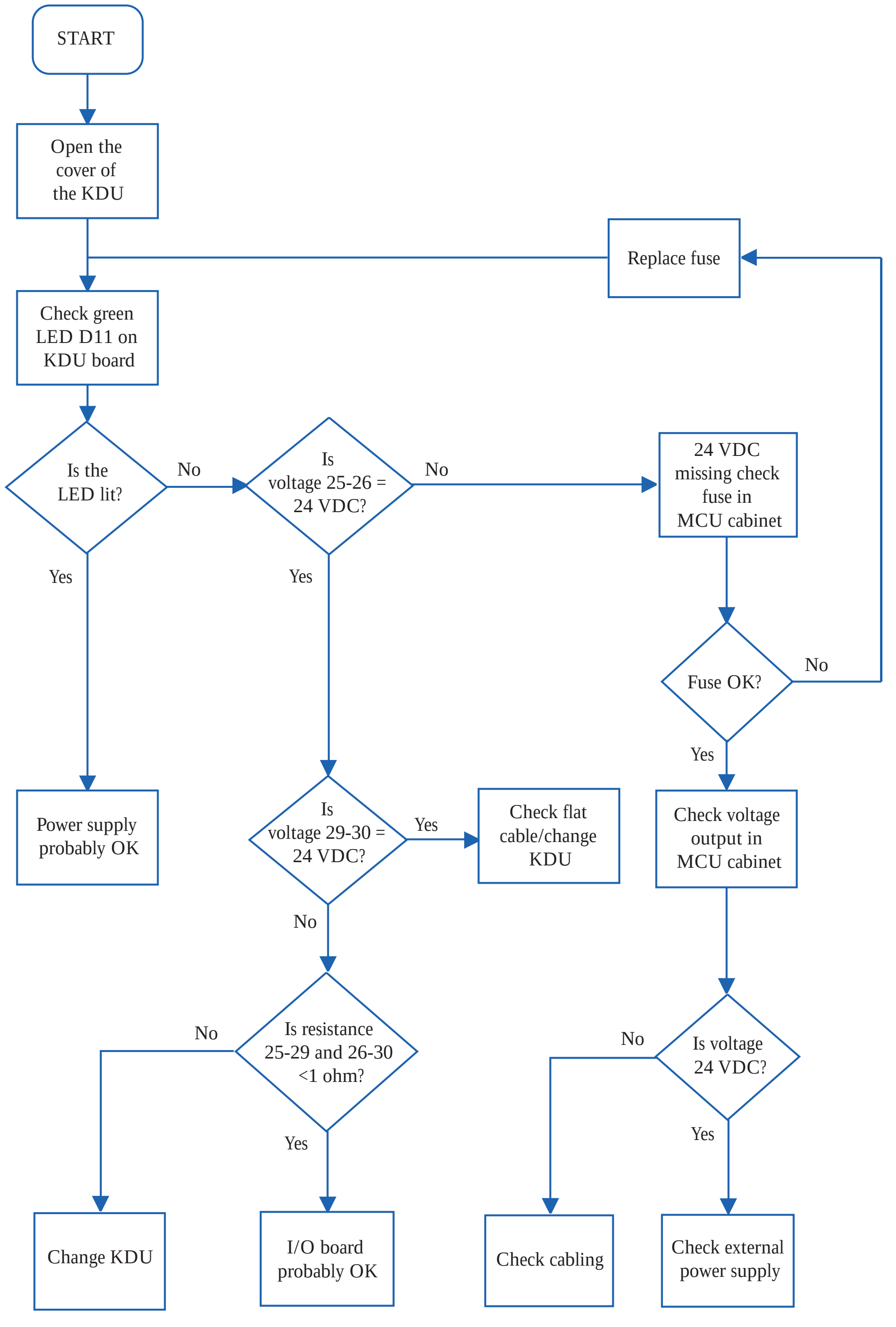


Fig 08-10 3208100342

CAN-bus failure CCU

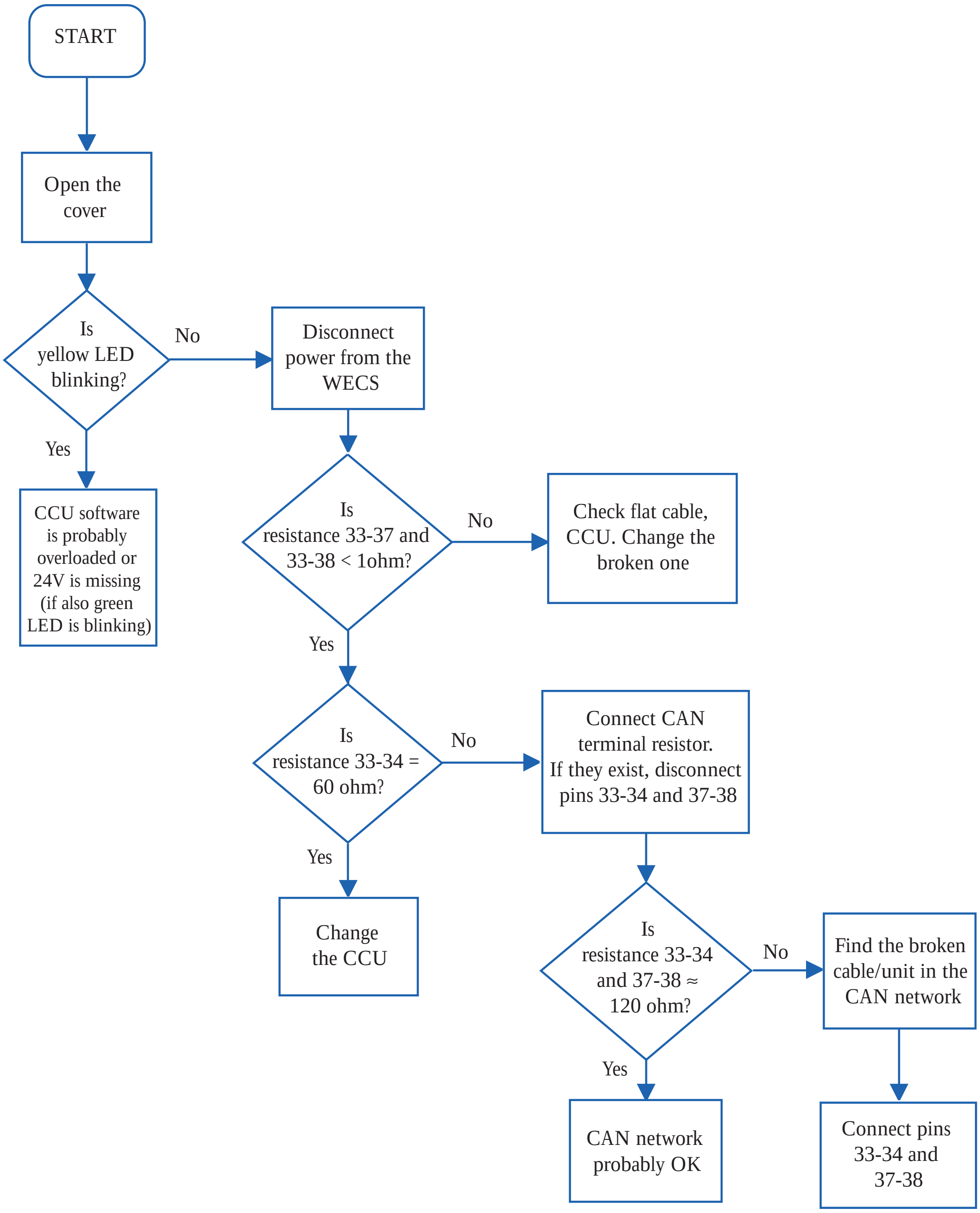


Fig 08-11

3208110342

CAN-bus failure KDU

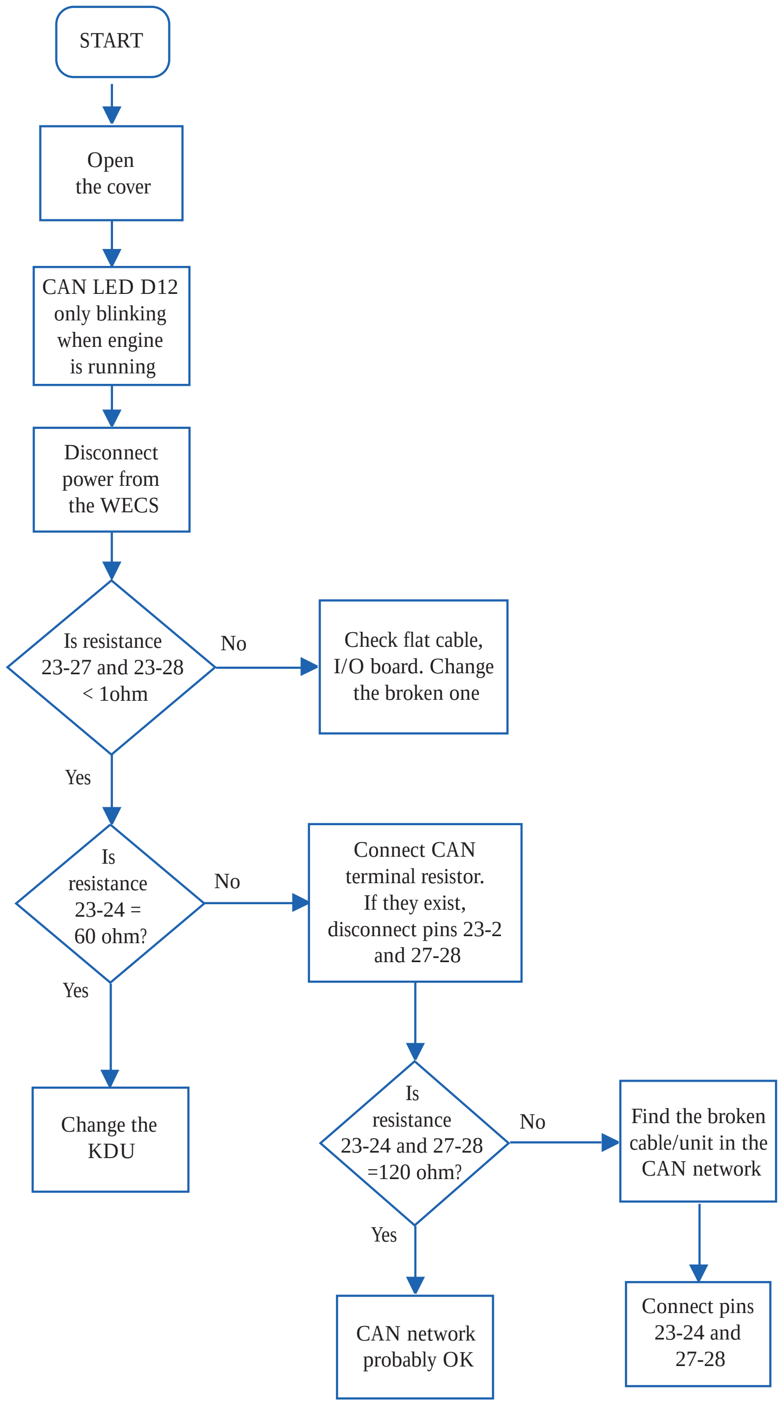


Fig 08-12 3208120342

CAN-bus failure DCU

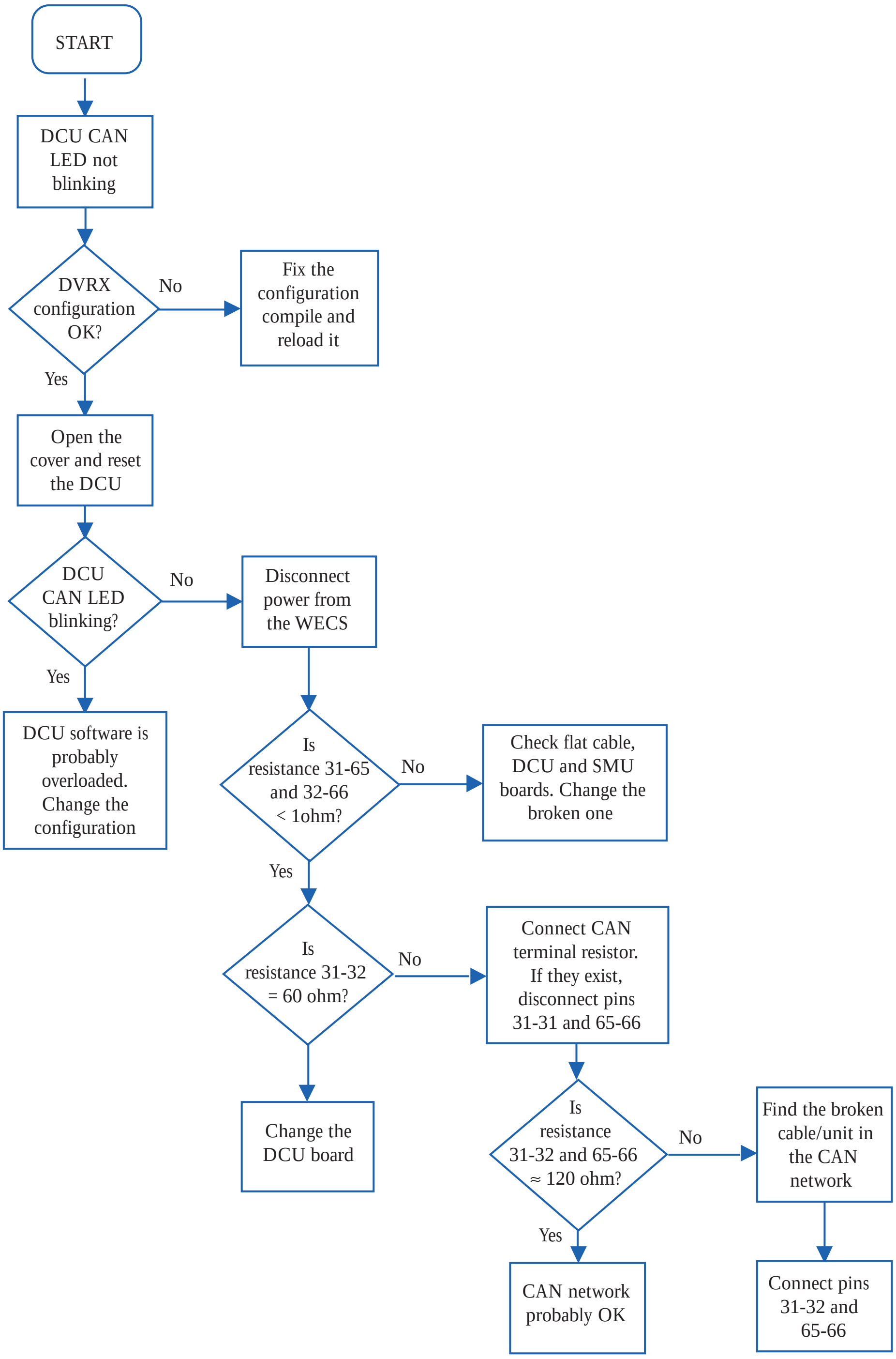


Fig 08-13

3208130342

Main/PCC gas valve and ignition test

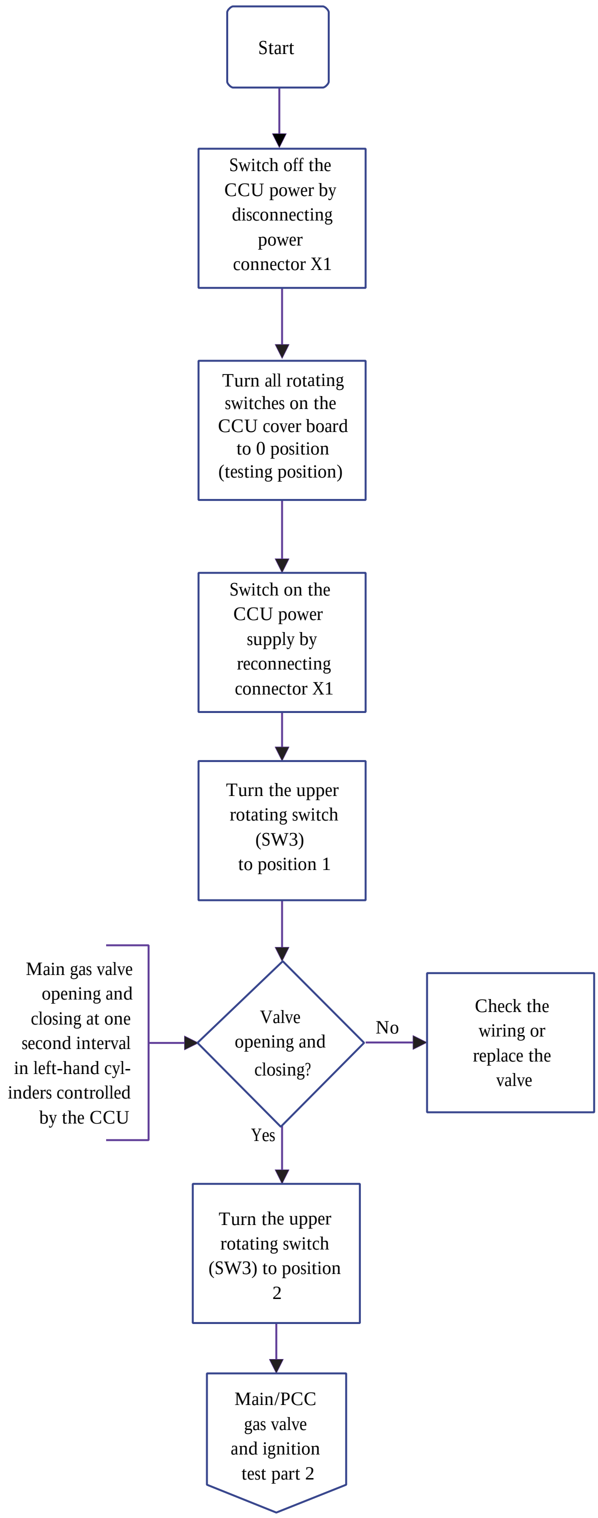


Fig 08-14

3208290404

Shutdowns, Emergency (EMG) messages by PLC			
Code	**Message**	**Reason**	**Action**
CFC0_1S020EST	EMG, Control room emergency pushbutton	Genset control panel emergency push button activated	n/a
CFC0_1K001SDI	EMG, Emerg. circuit safety relay ind.	Safety relay tripped	Check the separately informed emergency indications
CFC0_1S023EST	EMG, Engine room emergency pushbutton	Engine room panel emergency push button activated	n/a
BLN0_1F001SDI	EMG, Fire fighting alarm	Fire detection system is activated	Check the cause and follow the local regulations
ZBB0_1A001SDH	EMG, Gas alarm level 2	Gas alarm 20 % LEL reached	Check the cause for the gas leakage
CFC0_1A101SDI	EMG, WECS panel emergency pushbutton	WECS panel emergency push button activated	n/a

Shutdowns (SHD) messages by PLC			
Code	**Message**	**Reason**	**Action**
BAE0_1F87NSDI	SHD, Differential current relay tripped	Generator stator short circuit protection activated	Check the generator stator according to the generator manufacturer manuals
CFC0_1D008SDI	SHD, Engine did not stop in 20 min	After stop command given is maximum 20 minutes allowed for unloading and stopping	Check bus communication
CFC0_1D007SDI	SHD, Engine start failed	Expected acceleration to nominal speed not achieved within 50 seconds since open command given to gas regulating unit	Check engine related start failure indications, Check the last gas regulating unit valve (V018) (and V28 if PCC gas line applied)
SOB0_1F162SDI	SHD, Engine ventilation failed (Start motor)	Gas ventilation completed information not received from WECS within one minute from start command	Check start motor functionality
NHA0_1A001SDI	SHD, Exhaust gas ventilation shutdown	n/a	n/a
ZBB0_1A001SDI	SHD, Gas leak test failed	One of the shut-off valves or the ventilation valves are leaking, or the pressure switch/transmitter is broken	Check the shut-off/ventilation valves functionality, Check the pressure switch/transmitter
ZBB0_1P003SDH	SHD, High inlet gas pressure	Too high gas supply pressure to gas regulating unit	Check gas supply line
ZBB0_1P003SDL	SHD, Low inlet gas pressure	n/a	n/a
ZBB0_1V007SDI	SHD, Main gas safety shut-off valve	Too high pressure after regulating valve	Check regulating valve functionality
QEP0_1M001SDI	SHD, Prelubrication failed	n/a	n/a
SOB0_1F161SDI	SHD, Shutdown active from load red.	The engine has been overloaded longer than defined time	Check load signal to WECS (mA)
CFC0_1S007SDI	SHD, Start preparation failed	Gas leak test is passed and WECS ready for start information is not received within 2 minutes or gas leakage test failed	Check the gas regulating unit valve functionalities, Check the WECS start condition indications (WOIS Control Display)
CFC0_1A100SDI	SHD, WECS communication failure shutdown *)	Communication malfunction due to cabling problem, loose connection(s)	Check communication cabling
SCX0_1F201SDI	SHD, WECS HW shutdown signal for the PLC	WECS hardwired shutdown circuit contact activated	Check the separately informed shutdown causes

*) DF: Gas trip

Alarm (ALM) messages by PLC			
Code	**Message**	**Reason**	**Action**
CFC0_1F010ALI	ALM, AC-power failure CFC Panel	CFC panel AC-power supply failure	Check the fuse for the AC supply
SOB0_1F150ALI	ALM, Automatic derating active	Some of the derating causes are active	Check the separately informed derating cause
CFC0_1F001ALI	ALM, AVR alarm	Common alarm from the AVR or MCB tripped	Check the AVR display for error, Check all miniature circuit breakers in the AVR circuit including the generator auxiliary terminal box
CFC0_1F012ALI	ALM, DC-power failure CFC Panel	CFC panel DC-power supply failure	Check the MCBs (miniature circuit breakers) on the DC supply side
SNB0_1P003AH	ALM, Diff. pressure over charge air filter A	Charge air filter clogged	Clean the air filter
SNB0_1P004AH	ALM, Diff. pressure over charge air filter B	Charge air filter clogged	Clean the air filter
VDA0_1B001OVH	ALM, Electrical preheater 1 overheated	Electrical preheater thermo relay tripped	Check the thermo relay
VDA0_1B002OVH	ALM, Electrical preheater 2 overheated	Electrical preheater thermo relay tripped	Check the thermo relay
VDA0_1A001MFI	ALM, Electrical preheating control center fault	Electrical preheater overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
VDA0_1A001AFI	ALM, Electrical preheating Start/Stop fault	Electrical preheater activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
CFC0_1S002ALI	ALM, Engine control mode conflict betw. WECS/PLC	Control mode conflict, hardwired WECS parallell with grid information faulty	Check the hardwired parallel with grid information to WECS
NHA0_1A001ALI	ALM, Exh.vent. Emergency venting active (20 min.)	Emergency (natural) venting is activated due to ventilation failure	Check the separately informed reasons (motor control center fault, start/stop fault, valve fault, flow switch fault)
NHA0_1M001MFI	ALM, Exh.vent.fan motor control center fault	Exhaust ventilation fan motor overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
NHA0_1M001AFI	ALM, Exh.vent.fan Start/Stop command failure	Exhaust ventilation fan motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
NHA0_1Q001ALI	ALM, Exh.vent.flow switch fault	Exhaust ventilation flow switch fault, due to flow indication not received within pre-defined time since activation of exhaust ventilation or due to indication of flow even though exhaust gas ventilation not active	Check the exhaust ventilation fan operation and the flow switch functionality

Alarm (ALM) messages by PLC			
Code	**Message**	**Reason**	**Action**
NHA0_1A001VFI	ALM, Exh.vent.valve fault	Exhaust ventilation valve is not opened within pre-defined time from the command	Check the ventilation valve functionality, Check the valve open indication switch, Check the air supply
NHA0_1V001OPN	ALM, Explosion relief valve 1 open	Explosion relief valve opened	Check the explosion relief valve
NHA0_1V002OPN	ALM, Explosion relief valve 2 open	Explosion relief valve opened	Check the explosion relief valve
NHA0_1V003OPN	ALM, Explosion relief valve 3 open	Explosion relief valve opened	Check the explosion relief valve
ZBB0_1A001ALI	ALM, Gas alarm level1	Gas alarm 10 % LEL reached	Check the cause for the gas leakage
ZBB0_1V015ALI	ALM, Gas shutoff valve V015 leaking	Pressure raise detected between gas shutoff valves V015 and V018 during gas leakage test	Check the V015 gas shutoff valve for leakages
ZBB0_1V015TFI	ALM, Gas shutoff valve V015 stuck	Sufficient pressure not detected at gas shutoff valve V018 during gas leakage test	Check the V015 gas shutoff valve functionality
ZBB0_1V018ALI	ALM, Gas shutoff valve V018 leaking	Pressure lost between gas shutoff valves V015 and V018 during gas leakage test	Check the V018 gas shutoff valve for leakages
BAG0_1B001MFI	ALM, Gen anticond. heater, control center fault	Gen. anticondensation heater overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
BAG0_1B001AFI	ALM, Gen anticond. heater, Start/Stop fault	Gen. anticondensation heater activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
BAE0_1Q000MCB	ALM, Gen. breaker common alarm (MCB open)	Generator MV panel common alarm, MCB tripped	Check the wiring
BAE0_1Q000ALI	ALM, Gen. breaker position error	Breaker open and close signals active OR none of the signals active	Check the position contacts and wiring
BAE0_1E001ALI	ALM, Gen. breaker SF6 pressure low	Leakage on breaker, SF6 is leaking out	Check the SF6 pressure from local gauge. If low, contact breaker manufacturer, otherwise check wiring and contacts.
CFC0_1S012TRI	ALM, Gen. breaker tip circuit indication	Breaker trip circuit activated	Check the separately informed breaker trip cause
CFC0_1S012TRP	ALM, Gen. breaker trip (Primary)	Breaker trip circuit activated	Check the separately informed breaker trip cause

Alarm (ALM) messages by PLC			
Code	**Message**	**Reason**	**Action**
BAE0_1Q001ALI	ALM, Gen. breaker truck position error	Breaker service and isolated signals active OR none of the signals active	Check the position contacts and wiring
BAE0_1Q009ALI	ALM, Gen. earthing disconnector position error	Breaker open and close signals active OR none of the signals active	Check the position contacts and wiring
BAE0_1F000MCB	ALM, Gen. measuring MCB open	Generator junction box MCB tripped	Check the wiring
BAE0_1F51N1AOPR	ALM, Gen. Prot., Earth fault I01 trip	Earth fault protection activated	Check the prot. relay event recorder. Check the earth fault reasons
BAE0_1F51N1BOPR	ALM, Gen. Prot., Earth fault I01> trip	Earth fault protection activated	Check the prot. relay event recorder. Check the earth fault reasons
BAE0_1F51N2AOPR	ALM, Gen. Prot., Earth fault I02 trip	Earth fault protection activated	Check the prot. relay event recorder. Check the earth fault reasons
BAE0_1F51N2BOPR	ALM, Gen. Prot., Earth fault I02> trip	Earth fault protection activated	Check the prot. relay event recorder. Check the earth fault reasons
BAE0_1F59NAOPR	ALM, Gen. Prot., Earth fault U0 trip	Earth fault protection activated	Check the prot. relay event recorder. Check the earth fault reasons
BAE0_1F59NBOPR	ALM, Gen. Prot., Earth fault U0> trip	Earth fault protection activated	Check the prot. relay event recorder. Check the earth fault reasons
BAE0_1F67NOPR	ALM, Gen. Prot., Earth fault, directional I0 trip	Earth fault protection activated	Check the prot. relay event recorder. Check the earth fault reasons
BAE0_1F51AOPR	ALM, Gen. Prot., Overcurrent I trip	Activation of primary generator short-circuit protection if a fault occurs in the busbar or in the utility. Possible other reasons for activation: overloading protection of the generator and as a back-up for the differential relay in case of stator short circuits.	Check the prot. relay event recorder. Check for reasons for short-circuits
BAE0_1F81HOPR	ALM, Gen. Prot., Overfrequency f	Sudden loss of load	Check the prot. relay event recorder. Check load fluctuations and reasons for loss of load
BAE0_1F59AOPR	ALM, Gen. Prot., Overvoltage U trip	Activation due to prolonged operation with excessive over voltage or in case of AVR failures or network disturbances	Check the prot. relay event recorder. Check for reasons for overvoltages, Check the AVR
BAE0_1F59BOPR	ALM, Gen. Prot., Overvoltage U> trip	Activation due to prolonged operation with excessive over voltage or in case of AVR failures or network disturbances	Check the prot. relay event recorder. Check for reasons for overvoltages, Check the AVR

Alarm (ALM) messages by PLC			
Code	**Message**	**Reason**	**Action**
BAE0_1F32AOPR	ALM, Gen. Prot., Reverse power P- trip	Activation of protection for the prime mover in order to ensure that the generator will not act as a motor. Detection of the amount of reverse power flow in (watts) that would occur if the engine lose its input power.	Check the prot. relay event recorder. Check for reverse power flow reasons
BAE0_1F50AOPR	ALM, Gen. Prot., Shortcircuit I> trip	Activation of primary generator short-circuit protection if a fault occurs in the busbar or in the utility. Possible other reasons for activation: overloading protection of the generator and as a back-up for the differential relay in case of stator short circuits.	Check the prot. relay event recorder. Check for reasons for short-circuits
BAE0_1F49AOPR	ALM, Gen. Prot., Thermal overload	Long-term sensitive overloading protection of the generator activated	Check the prot. relay event recorder. Check load fluctuations and reasons for overloading
BAE0_1F46AOPR	ALM, Gen. Prot., Unbalance load I2 >	Unbalanced loads, unbalanced system faults, open conductors, or other unsymmetrical operating condition	Check the prot. relay event recorder. Check for possible reasons for unsymmetrical operation
BAE0_1F81LOPR	ALM, Gen. Prot., Underfrequency f <	Sudden loss of input power to the system or due to a sudden increase of load	Check the prot. relay event recorder. Check load fluctuations and reasons for loss of load
BAE0_1F40AOPR	ALM, Gen. Prot., Underreactance X trip	Detection of excitation faults	Check the prot. relay event recorder. Check the excitation system
BAE0_1F27AOPR	ALM, Gen. Prot., Undervoltage U <	Voltage below allowed limit, An under voltage condition in a power system may be a result of, a fault in the voltage regulator, short circuits, starting of a synchronous or induction motor, transformer energising etc	Check the prot. relay event recorder. Check the voltage regulator, Check causes for short circuits

Alarm (ALM) messages by PLC			
Code	**Message**	**Reason**	**Action**
BAE0_1F51VOPR	ALM, Gen. Prot., Voltage restr. Overcurrent I 7> (U)	Activation of back-up protection to disconnect the generator if a system fault has not been cleared by other protective devices after a sufficient time delay has elapsed	Check the prot. relay event recorder. Check also for overcurrent indications
BAE0_1F000ALI	ALM, Gen. protection relay fault	Generator protection relay internal fault	Check the protection relay display or use the protection relay program (VAMPSet) to identify the problem
BAN0_1Q000ALI	ALM, Ground disconnector (NP) position error	Breaker open and close signals active OR none of the signals active	Check the position contacts and wiring
ZBB0_1P002AH	ALM, High diff. pressure over gas filter	Gas regulating unit gas filter clogged	Replace or clean the gas filter
ZBB0_1P003AH	ALM, High inlet gas pressure	Too high gas supply pressure to gas regulating unit	Check gas supply line
ZBB0_1T001AH	ALM, High inlet gas temperature	Too high gas supply temperature to gas regulating unit	Check gas supply line
SVH0_1M001MFI	ALM, HT cooling water pump control center fault	HT cooling water pump motor overcurrent/shortcircu it tripped	Check the overcurrent/shortcircuit relay
SVH0_1M001AFI	ALM, HT cooling water pump Start/Stop fault	HT cooling water pump motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
ZBB0_1P003AL	ALM, Low inlet gas pressure	Low high gas supply pressure to gas regulating unit	Check gas supply line
ZBB0_1T001AL	ALM, Low inlet gas temperature	Low high gas supply temperature to gas regulating unit	Check gas supply line
VEA0_1L001AL	ALM, Low level in HT expansion tank	Low water level in HT expansion tank	Check the level in the HT expansion level
VEA012L001AL	ALM, Low level in LT expansion tank	Low water level in LT expansion tank	Check the level in the LT expansion level
SVL0_1M001MFI	ALM, LT cooling water pump control center fault	LT cooling water pump motor overcurrent/shortcircu it tripped	Check the overcurrent/shortcircuit relay
SVL0_1M001AFI	ALM, LT cooling water pump Start/Stop fault	LT cooling water pump motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands

Alarm (ALM) messages by PLC			
Code	**Message**	**Reason**	**Action**
SQA0_1P005AH	ALM, Lub.oil filter diff. pressure	Lubrication oil filter clogged	Check and clean the lubrication filter
CFC0_1S021ALI	ALM, Power Monitor Unit fault	Generator power monitoring unit internal fault	Check the power monitoring unit display or use the power monitoring unit program (VAMPSet) to identify the problem
QEP0_1M001MFI	ALM, Prelube motor control center fault	Prelube motor overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
QEP0_1M001AFI	ALM, Prelube pump Start/Stop fault	Prelube motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
VCA0_1M001MFI	ALM, Radiator group 1 motor control center fault	Radiator motor overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
VCA0_1M001AFI	ALM, Radiator group 1 Start/Stop fault	Radiator motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
VCA0_1M002MFI	ALM, Radiator group 2 motor control center fault	Radiator motor overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
VCA0_1M002AFI	ALM, Radiator group 2 Start/Stop fault	Radiator motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
VCA0_1M003MFI	ALM, Radiator group 3 motor control center fault	Radiator motor overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
VCA0_1M003AFI	ALM, Radiator group 3 Start/Stop fault	Radiator motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
VCA0_1M004MFI	ALM, Radiator group 4 motor control center fault	Radiator motor overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
VCA0_1M004AFI	ALM, Radiator group 4 Start/Stop fault	Radiator motor activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
SOA0_1G001MFI	ALM, Turning gear fault from PLC	Turning gear module fault	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
VDA0_1M001MFI	ALM, Water preheater 1 control center fault	Water preheater overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
VDA0_1M001AFI	ALM, Water preheater 1 Start/Stop fault	Water preheater activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands

Alarm (ALM) messages by PLC			
Code	**Message**	**Reason**	**Action**
VDA0_1M002MFI	ALM, Water preheater 2 control center fault	Water preheater overcurrent/shortcircuit tripped	Check the overcurrent/shortcircuit relay
VDA0_1M002AFI	ALM, Water preheater 2 Start/Stop fault	Water preheater activation is not according to given command	Check the functionality of the main contactor, Check the wiring for running information and start/stop commands
CFC0_1A100ALI	ALM, WECS communication failure	The PLC is not able to establish communication to WECS	Check WECS power supply, Check the profibus communication (cabling and terminating resistors)

Derating (DER) messages by PLC			
Code	**Message**	**Reason**	**Action**
SOB0_1F157INF	DER, Derating active	Some of the derating causes are active	Check the separately informed derating cause
SOB0_1F152INF	DER, Pex, Exhaust gas back pressure	Derating high Exhaust Gas back pressure due to clogged heat recovery boiler or back end cleaning devices	Check the heat recovery boiler or back end cleaning devices
SOB0_1F159INF	DER, Pgas, Gas feed pressure	Derating, due to low gas feed pressure	Check the gas supply line pressure
SOB0_1F156INF	DER, Tamb, Air inlet temperature	Derating, high air inlet temperature due to high ambient temperature	n/a
SOB0_1F154INF	DER, Tcw, Charge air coolant temperature	Derating, high charge air coolant (LT) temp due to; High ambient temperature, external cooling system problems	Check cooling system
SOB0_1F155INF	DER, Tht, HT water temperature	Derating, low HT water temperature	Check the pre-heating of the engine
SOB0_1F153INF	DER, Trec, Charge air temp in receiver	Derating, high charge air temp in receiver due to; High ambient temperature, High LT water temperature, CA cooler blow-by, Contaminated CA coolers	Check cooling system, Check difference between LT and CA temperature, Check CA diff pressure

Sensor Failure (SF) messages by PLC			
Code	**Message**	**Reason**	**Action**
SNB0_1P003SF	SF, Diff. pressure over charge air filter A	Sensor broken or wiring fault (broken or loose connections)	Check the sensor mA level at the PLC input card, if the mA level (4-20mA) is ok to the card, replace the PLC input card. If the mA level is not within the levels check the cabling to the sensor and the sensor itself
SNB0_1P004SF	SF, Diff. pressure over charge air filter B	Sensor broken or wiring fault (broken or loose connections)	Check the sensor mA level at the PLC input card, if the mA level (4-20mA) is ok to the card, replace the PLC input card. If the mA level is not within the levels check the cabling to the sensor and the sensor itself
ZBB0_1P002SF	SF, Diff. pressure over gasfilter	Sensor broken or wiring fault (broken or loose connections)	Check the sensor mA level at the PLC input card, if the mA level (4-20mA) is ok to the card, replace the PLC input card. If the mA level is not within the levels check the cabling to the sensor and the sensor itself
ZBB0_1Q001SF	SF, Gas flow	Sensor broken or wiring fault (broken or loose connections)	Check the sensor mA level at the PLC input card, if the mA level (4-20mA) is ok to the card, replace the PLC input card. If the mA level is not within the levels check the cabling to the sensor and the sensor itself
VCA0_1T002SF	SF, HT water temperature after radiator	Sensor broken or wiring fault (broken or loose connections)	Check the resistance level at the panel terminals and compare to the actual temperature. If the resistance is within the actual temperature/ resistance levels replace the PT100 card. If the resistance is not within the levels, check the cabling and connections. If the cabling and connections are ok, replace the sensor.
ZBB0_1P003SF	SF, Inlet gas pressure	Sensor broken or wiring fault (broken or loose connections)	Check the sensor mA level at the PLC input card, if the mA level (4-20mA) is ok to the card, replace the PLC input card. If the mA level is not within the levels check the cabling to the sensor and the sensor itself
ZBB0_1T001SF	SF, Inlet gas temperature	Sensor broken or wiring fault (broken or loose connections)	Check the resistance level at the panel terminals and compare to the actual temperature. If the resistance is within the actual temperature/ resistance levels replace the PT100 card. If the resistance is not within the levels, check the cabling and connections. If the cabling and connections are ok, replace the sensor.
VCA0_1T001SF	SF, LT water temperature after radiator	Sensor broken or wiring fault (broken or loose connections)	Check the resistance level at the panel terminals and compare to the actual temperature. If the resistance is within the actual temperature/ resistance levels replace the PT100 card. If the resistance is not within the levels, check the cabling and connections. If the cabling and connections are ok, replace the sensor.

Start Blocks (SB) messages by PLC			
Code	**Message**	**Reason**	**Action**
CFC0_1S012SBL	STB, Breaker trip indication	Breaker trip circuit activated	Check the separately informed breaker trip cause
BAE0_1Q001SBL	STB, Breaker truck in isolated position	Breaker truck is not in service position	Check the breaker truck position
BAE0_1Q009SBL	STB, Earthing disconnector closed	Breaker earthing disconnector closed	Check the earthing disconnector position
CFC0_1S007SBL	STB, Engine running	Engine is running	n/a
NHA0_1A001SBL	STB, Exhaust gas ventilation start block	Exhaust gas ventilation sequence is active	Wait until the gas ventilation sequence is finished
QEP0_1M001SBL	STB, Prelubrication not performed	n/a	n/a
CFC0_1S011SBL	STB, Shutdown indication active	Some shutdown cause active	Check the separately informed shutdown causes
CFC0_1S008SBL	STB, Stop command active	Stop command active	Check the stop command circuit(s)
CFC0_1A100SBL	STB, WECS communication failure	The PLC is not able to establish communication to WECS	Check WECS power supply, Check the profibus communication (cabling and terminating resistors)

Status/Events messages by PLC			
Code	**Message**	**Reason**	**Action**
CFC0_1S005ACK	AVR excitation on	Status	n/a
CFC0_1S010INF	Breaker control, open command	Status	n/a
CFC0_1S010OPC	Breaker open command	Status	n/a
CFC0_1S012RST	Breaker trip reset	Status	n/a
CFC0_1S030DIS	Disable loadsharing	Status	n/a
CFC0_1S030ENB	Enable loadsharing	Status	n/a
CFC0_1S002SEL	Engine control, speed (droop)	Status	n/a
CFC0_1S007INF	Engine control, start command	Status	n/a
CFC0_1S008INF	Engine control, stop command	Status	n/a
CFC0_1S002DRO	Engine droop control	Status	n/a
CFC0_1S002KWO	Engine kW control	Status	n/a
CFC0_1S007STO	Engine start command	Status	n/a
CFC0_1S008SPO	Engine stop command	Status	n/a
NHA0_1A001RNI	Exhaust gas vent. fan running	Status, Exhaust gas ventilation fan running	n/a
NHA0_1Q001INF	Flow switch position	Status, Exhaust gas ventilation fan flow indicator	n/a
PCC0_1M001RNI	Fuel feeder running	Status	n/a
ZBB0_1P006INF	Gas leak test pressure status, P06	Status, Gas leak test pressure sensor pressurized	n/a
ZBB0_1V015INF	Gas shutoff valve status, V015	Status, Gas shutoff valve open	n/a
ZBB0_1V018INF	Gas shutoff valve status, V018	Status, Gas shutoff valve open	n/a
ZBB0_1V014INF	Gas ventilation valve status, V014	Status, Gas ventilation valve open	n/a
ZBB0_1V016INF	Gas ventilation valve status, V016	Status, Gas ventilation valve open	n/a
ZBB0_1V019INF	Gas ventilation valve status, V019	Status, Gas ventilation valve open	n/a
BAE0_1Q000CLO	Gen. breaker closed	Status	n/a
BAE0_1Q000OPN	Gen. breaker open	Status	n/a
BAE0_1Q001OKP	Gen. breaker truck in isolated position	Status	n/a

Status/Events messages by PLC			
Code	**Message**	**Reason**	**Action**
BAE0_1Q001NOP	Gen. breaker truck in service position	Status	n/a
BAE0_1Q009CLO	Gen. earthing disconnector closed	Status	n/a
BAE0_1Q009OPN	Gen. earthing disconnector open	Status	n/a
CFC0_1S014ACK	Gen. voltage supervision	Status	n/a
CFC0_1S001SEL	Generating set control, auto mode from M1 panel	Status	n/a
CFC0_1S001INF	Generating set control, manual mode from WOIS	n/a	n/a
CFC0_1S003SEL	Generator control, voltage (droop)	Status	n/a
CFC0_1S003DRO	Generator droop control	Status	n/a
CFC0_1S003PFO	Generator P.F. Control	Status	n/a
BAN0_1Q000CLO	Ground disconnector (NP) closed	Status	n/a
BAN0_1Q000OPN	Ground disconnector (NP) open	Status	n/a
SVH0_1M001RNI	HT-water cooling pump running	Status	n/a
SOB0_1E204INF	Idle running	Status, Sequence	n/a
CFC0_1S030INF	Load sharing selected	Status	n/a
SOB0_1E207INF	Loading	Status, Sequence	n/a
SVL0_1M001RNI	LT-water cooling pump running	Status	n/a
SOB0_1E208INF	Normal operation	Status, Sequence	n/a
CFC0_1S034ACK	Parallel with grid	Status	n/a
VDA0_1A001RNI	Preheating on	Status	n/a
VDA0_1M001RNI	Preheating pump 1 running	Status	n/a
VDA0_1M002RNI	Preheating pump 2 running	Status	n/a
QEP0_1M001RNI	Prelubrication pump running	Status	n/a
VCA0_1M001RNI	Radiator group 1 running	Status	n/a
VCA0_1M002RNI	Radiator group 2 running	Status	n/a
VCA0_1M003RNI	Radiator group 3 running	Status	n/a

Status/Events messages by PLC			
Code	**Message**	**Reason**	**Action**
VCA0_1M004RNI	Radiator group 4 running	Status	n/a
SOB0_1E120SEL	Read tuning data	Status	n/a
SNA0_1T000SEL	Reset Temperature adjust	Status	n/a
CFC0_1S001AUO	Set automatic control	Status	n/a
CFC0_1S001MAO	Set manual control	Status	n/a
SOB0_1E213INF	Shutdown mode, waiting for reset	Status, Sequence	n/a
CFC0_1S011RST	Shutdown reset	Status	n/a
SOB0_1E202INF	Start preparation	Status, Sequence	n/a
SOB0_1E203INF	Starting	Status, Sequence	n/a
SOB0_1E201INF	Stop mode	Status, Sequence	n/a
SOB0_1E206INF	Synchronising	Status, Sequence	n/a
CFC0_1S006CLC	Synchronising command	Status	n/a
CFC0_1S013ACK	Synchronising on	Status	n/a
CFC0_1S006SEL	Synchronising requested	Status	n/a
CFC0_1S013SEL	Synchronising select	Status	n/a
SOB0_1E209INF	Unloading	Status, Sequence	n/a
NHA0_1A001CLI	Valve in closed position	Status, Exhaust gas ventilation fan valve closed	n/a
NHA0_1A001OPI	Valve in open position	Status, Exhaust gas ventilation fan valve open	n/a
NHA0_1A001REQ	Ventilation request from WOIS	Status	n/a

08.2.1 Cylinder combustion failure check lists

LR, High exhaust gas temperature

Cause	Check
Leaking main gas valve	A leaking Main gas valve can cause this. Swap the malfunctioning gas valve to another cylinder in order to see if the fault is moving.
Incorrect (too rich) Air/Fuel ratio	If the air/fuel ratio is too rich, normally all cylinders have increased exhaust gas temperatures. The problem can be due to incorrect wastegate adjustment or that the wastegate is fully closed. Check wastegate calibration and functionality. If the wastegate is fully closed, air flow to and from the engine might be restricted Too high pressure drop over: - Intake air filters - Charge Air-coolers - Turbo charger nozzle rings Exhaust system after engine. For instance exhaust boilers, catalytic converters a.s.o.
Exhaust gas valves	Exhaust gas valve. To check condition of valves perform a "Cylinder tightness test" of the cylinder (see chapter 12 A) Reasons for leakage might be: - Valve jamming when open - "Negative" valve clearance - Valve/seat sealing surface blow by (burned)

SHD, High exhaust gas temperature

Cause	Check
Big load step	If a too big load step is attempted the exhaust gas temperatures will increase rapidly.
Leaking main gas valve	A leaking Main gas valve can cause this. Swap the malfunctioning gas valve to another cylinder in order to see if the fault is moving.
Incorrect (too rich) Air/Fuel ratio	If the air/fuel ratio is too rich, normally all cylinders have increased exhaust gas temperatures. The problem can be due to incorrect wastegate adjustment or that the wastegate is fully closed. Check wastegate calibration and functionality. If the wastegate is fully closed, air flow to and from the engine might be restricted Too high pressure drop over: - Intake air filters - Charge Air-coolers - Turbo charger nozzle rings Exhaust system after engine. For instance exhaust boilers, catalytic converters a.s.o.
Exhaust gas valves	Exhaust gas valve. To check condition of valves perform a "Cylinder tightness test" of the cylinder (see chapter 12 A) Reasons for leakage might be: - Valve jamming when open - "Negative" valve clearance - Valve/seat sealing surface blow by (burned)

ALM, High exhaust gas temperature, cyl. n

Cause	Check
Big load step	If a too big load step is attempted the exhaust gas temperatures will increase rapidly.
Leaking main gas valve	A leaking Main gas valve can cause this. Swap the malfunctioning gas valve to another cylinder in order to see if the fault is moving.
Incorrect (too rich) Air/Fuel ratio	If the air/fuel ratio is too rich, normally all cylinders have increased exhaust gas temperatures. The problem can be due to incorrect wastegate adjustment or that the wastegate is fully closed. Check wastegate calibration and functionality. If the wastegate is fully closed, air flow to and from the engine might be restricted Too high pressure drop over: - Intake air filters - Charge Air-coolers - Turbo charger nozzle rings Exhaust system after engine. For instance exhaust boilers, catalytic converters a.s.o.
Exhaust gas valves	Exhaust gas valve. To check condition of valves perform a "Cylinder tightness test" of the cylinder (see chapter 12 A) Reasons for leakage might be: - Valve jamming when open - "Negative" valve clearance - Valve/seat sealing surface blow by (burned)

SHD, High dev. exh. gas temp. cyl./average

Cylinder exhaust gas temperature is significantly higher than engine average

Cause	Check
Big load step	If a too big load step is attempted the exhaust gas temperatures will increase rapidly.
Leaking main gas valve	A leaking Main gas valve can cause this. Swap the malfunctioning gas valve to another cylinder in order to see if the fault is moving.
Incorrect (too rich) Air/Fuel ratio	If the air/fuel ratio is too rich, normally all cylinders have increased exhaust gas temperatures. The problem can be due to incorrect wastegate adjustment or that the wastegate is fully closed. Check wastegate calibration and functionality. If the wastegate is fully closed, air flow to and from the engine might be restricted Too high pressure drop over: - Intake air filters - Charge Air-coolers - Turbo charger nozzle rings Exhaust system after engine. For instance exhaust boilers, catalytic converters a.s.o.
Exhaust gas valves	Exhaust gas valve. To check condition of valves perform a "Cylinder tightness test" of the cylinder (see chapter 12 A) Reasons for leakage might be: - Valve jamming when open - "Negative" valve clearance - Valve/seat sealing surface blow by (burned)

ALM, High dev. exh. gas temp. cyl./average

Cylinder exhaust gas temperature is significantly higher than engine average

Cause	Check
Big load step	If a too big load step is attempted the exhaust gas temperatures will increase rapidly.
Leaking main gas valve	A leaking Main gas valve can cause this. Swap the malfunctioning gas valve to another cylinder in order to see if the fault is moving.
Incorrect (too rich) Air/Fuel ratio	If the air/fuel ratio is too rich, normally all cylinders have increased exhaust gas temperatures. The problem can be due to incorrect wastegate adjustment or that the wastegate is fully closed. Check wastegate calibration and functionality. If the wastegate is fully closed, air flow to and from the engine might be restricted Too high pressure drop over: - Intake air filters - Charge Air-coolers - Turbo charger nozzle rings Exhaust system after engine. For instance exhaust boilers, catalytic converters a.s.o.
Exhaust gas valves	Exhaust gas valve. To check condition of valves perform a "Cylinder tightness test" of the cylinder (see chapter 12 A) Reasons for leakage might be: - Valve jamming when open - "Negative" valve clearance - Valve/seat sealing surface blow by (burned)

ALM or SHD, Low dev. exh. gas temp. cyl./average

Cause	Check
Spark plug malfunction	Replace spark plug.
Non return valve, spare part code no 124 009 malfunction	Recondition or renew the non-return valve, see chapter 16.
PCC valve malfunction	Perform "Main/PCC gas valve and ignition test" according to Fig 08-14.
Exhaust gas temperature sensor malfunction	If the exhaust gas temp sensor(s) is mounted on the cylinder head (part no 506-068) follow step 1. If the sensor is mounted in the exhaust manifold after the cylinder head (part no 506-985), follow step 2. 1. With engine stopped, disconnect one sensor in the connection box (part no 506-058) at the time and check reading of temperature (see WECS drawings). If there is a significant difference between the readings, the one that has the lower reading might be broken. Leave this sensor disconnected and do a test run of the engine. 2. When engine stopped check the reading of exhaust temp sensor. If the temperature is significantly lower than the other cylinders the sensor might be broken. Replace sensor.
CCU functionality, wiring.	Visually check the wiring in the CCU box, check for loose connections and damaged wire insulation. Switch processor board (top card) with another CCU and set the dial switches according to WECS drawings.
Main gas valve malfunction.	If the installed Main gas valve is equipped with a connector, check the connector pins for wear. Perform "Main/PCC gas valve and ignition test" according to Fig 08-14. If the valve solenoid is functional (sound can be heard when opening), the valve is probably OK.
Ignition system, coil, trigger module and spark plug extension	Clean the spark plug extension with a dry piece of cloth. Perform "Main/PCC gas valve and ignition test" according to Fig 08-14. (to check if sparks are created).

In uncertain cases, a suspect component can be checked by temporary mounting it on a properly working cylinder. The faulty component can hereby be identified as the failure moves to the new cylinder.

ALM, Max. temp. compensation, cyl. n

Cause	Check
Cylinder gas duration has reached maximum offset value. The cylinder need much more or much less main gas valve duration than average to maintain exhaust gas temperature.	This alarm has many possible causes. To be able to find the reason the exhaust gas temperature trends has to be monitored. If the exhaust gas temperature tends to fall below average please refer to ALM, Low dev. exh. gas temp. cyl./average If the trend is showing a rising exhaust gas temperature please refer to ALM, High dev. exh. gas temp. cyl./average

ALM, Cyl. disabled due to temp. dev., cyl. n (Optional)

Cause	Check
The cylinder combustion has failed and the fuel injection to the cylinder is disabled.	This alarm has many possible causes. To be able to find the reason the exhaust gas temperature trends has to be monitored. If the exhaust gas temperature tends to fall below average please refer to ALM, Low dev. exh. gas temp. cyl./average If the trend is showing a rising exhaust gas temperature please refer to ALM, High dev. exh. gas temp. cyl./average

08.3 Trouble shooting for air starter

Pos.	Trouble	
1.	**Starting motor does not run**	
a)	No air supply.	Check for blockage or damage to air supply lines or tank.
b)	Damaged turbine assembly.	Inspect turbine assembly and power train and repair or replace if necessary.
c)	Foreign material in starting motor and/or piping.	Remove motor assembly and/or piping and remove blockage.
d)	Blocked exhaust system.	Remove housing exhaust cover and check for blockage.
e)	Defective control valve or relay valve.	Replace control valve or relay valve.
2.	**Loss of power**	
a)	Low air pressure to starter.	Check air supply.
b)	Restricted air supply line.	Check for blockage or damage to air lines.
c)	Relay valve malfunctioning.	Clean or replace lines or relay valve. Lube relay valve.
d)	Exhaust flow restricted.	Check for blocked or damaged piping. Clean or replace piping. Check for dirt or foreign material and clean or remove. Check for ice build-up. Melt ice and reduce moisture build-up to starter.
e)	Damaged turbine assembly.	Replace turbine assembly.

3.	**Starter drive does not engage**	
a)	No pressure to drive housing port.	Check air supply.
b)	Internal drive housing ports blocked.	Remove blockage.
c)	Fluid in drive unit components.	Remove fluid.
d)	Damaged or worn piston assembly, O-ring or seals.	Replace damaged or worn parts.
e)	O-rings and seals dry.	Re-lube O-rings and seals.
4.	**Starting motor runs, pinion engages, but does not rotate flywheel**	
a)	Damaged or broken drive train.	Disassemble drive train and replace worn or damaged parts.
b)	Damaged starter valve.	Disassemble starter valve and replace worn or damaged parts.
5.	**Excessive butt engagement**	
a)	Damaged drive pinion or flywheel.	Inspect drive pinion and flywheel and replace if necessary.
b)	Damaged starter drive or components	Inspect drive components and replace worn or damaged parts.
c)	Low air pressure.	Check air supply.
d)	Wrong drive pinion.	Replace with proper drive pinion.
6.	**Oil blowing out of starter exhaust**	
a)	Oil in air supply line.	Inspect air line and remove source of oil.
b)	Splash deflector retaining screw or pipe plug missing.	Install splash deflector retaining screw or pipe plug.
c)	Worn or damaged rotor seals or static O-rings.	Replace static seals on outside of motor or send motor to manufacturer to be rebuilt.
7.	**Oil leaking from gear case**	
a)	Worn or damaged O-rings.	Replace O-rings.
b)	Loose joints.	Make sure that joints fit properly and that starter assembly cap screws are tightened to 60 ft.-lb (81 Nm). Make sure that all seals and O-rings fit and seal properly at their perimeters. If they do not, replace with new seals and O-rings.
c)	Excessive high-speed operation.	Operate according to recommendations.
d)	High number of start cycles.	Replace worn components.
e)	Loose or leaking pipe plugs.	Tighten or replace pipe plugs.
f)	Splash deflector retaining loose or pipe plug missing.	Tighten splash deflector retaining screw or replace pipe plug.

09. Specific Installation Data

09.1 General

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

10. Engine Block with Bearings, Cylinder and Oil Sump

10.1 Description

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

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

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

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

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

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

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

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

10.2 Main bearings

10.2.1 Dismantling of the main bearing

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

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

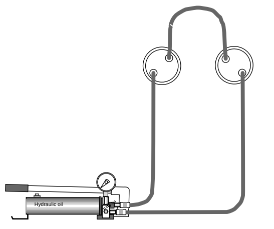
3 **Lift the distance sleeve** 3V86B46 into position on the side screw. One or two nuts can be loosened simultaneously.

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

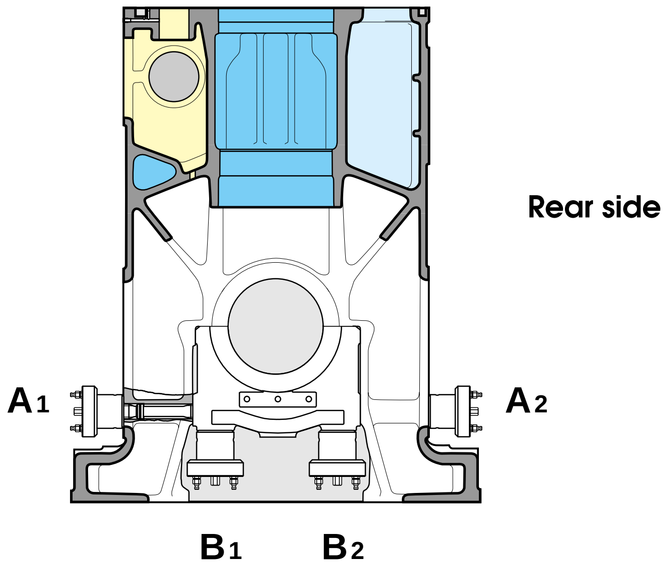
5 **Loosen the nuts of the main bearing screws** on the bearing in question as shown in Fig 10-1 (B).

Use of hydraulic cylinders

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



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



<table>
<tr><th colspan="5">Hydraulic cylinder combination</th></tr>
<tr><td colspan="2">Screw</td><td>A1 A2</td><td colspan="2">B1 B2</td></tr>
<tr><td colspan="2">Hydraulic tool</td><td>Main bearing and thrust bearing screws</td><td>Main bearing screws</td><td>Main bearing screws</td></tr>
<tr><td colspan="2">Cylinder</td><td>3V86B78</td><td>3V86B79</td><td>3V86B78</td></tr>
<tr><td colspan="2">Sleeve</td><td>3V86B46</td><td>3V86B39</td><td>3V86B46</td></tr>
<tr><td colspan="2">Pin</td><td>4V86B11</td><td>4V86B02</td><td>4V86B11</td></tr>
<tr><td colspan="2">Action/Screw</td><td colspan="2">Comments</td><td>Hydraulic pressure</td></tr>
<tr><td rowspan="2">Loosening</td><td>A1 A2</td><td colspan="2">One by one in order according to free choice.
Two nuts per side can be loosened simultaneously.</td><td>615...635 bar</td></tr>
<tr><td>B1 B2</td><td colspan="2">Always loosened simultaneously.</td><td>615...635 bar</td></tr>
<tr><td rowspan="4">Tightening</td><td>B1 B2</td><td colspan="2">Simultaneously handtight with pin 4V86B02 (B11) only.</td><td></td></tr>
<tr><td>A2</td><td colspan="2">A2 bolt tensioned first with 200 bar hydraulic pressure
and the nut turned with pin to contact.</td><td>200 bar</td></tr>
<tr><td>B1 B2</td><td colspan="2">Tightened simultaneously with full hydraulic pressure.</td><td>615 bar</td></tr>
<tr><td>A1A2</td><td colspan="2">Tightened one by one in order according to free choice
with full hydraulic pressure.</td><td>615 bar</td></tr>
</table>

Fig 10-1 3210519045

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

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

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

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

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

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

12 **Remove the lower bearing shell.**

13 **Insert the turning tool** 4V85B16 into the main bearing journal radial oil hole.

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

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

Hydraulic jack

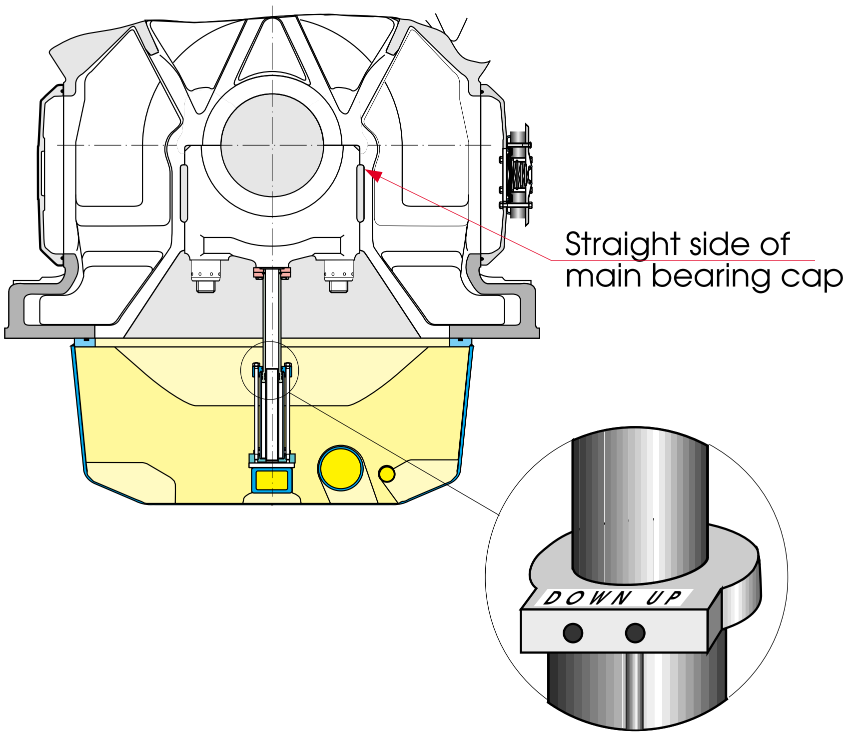


Fig 10-2 3210528932

10.2.2 Inspection of main bearings and journals

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

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

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

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

Mark the new bearings with the bearing numbers.

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

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

10.2.3 Assembling of main bearing

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

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

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

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

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

5 Insert the turning tool 4V85B16 into the main bearing journal radial oil hole and turn the crankshaft carefully until the bearing shell has turned into position. Take care that the bearing shell lug slides into the oil groove without being damaged.

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

---

6 Remove the turning tool.

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

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

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

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

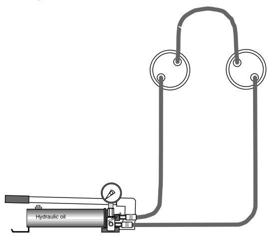
11 Tighten the nuts by hand.

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

13 Screw on the hydraulic tool 3V86B78.

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

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



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

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

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

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

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

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

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

10.3 Flywheel/thrust bearing

10.3.1 Dismantling of flywheel/thrust bearing

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

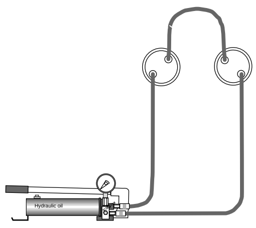
2 **Loosen the nuts** of the side screws on the flywheel/thrust bearing and the adjacent main bearing, Fig 10-1 (A).

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

Thrust bearing

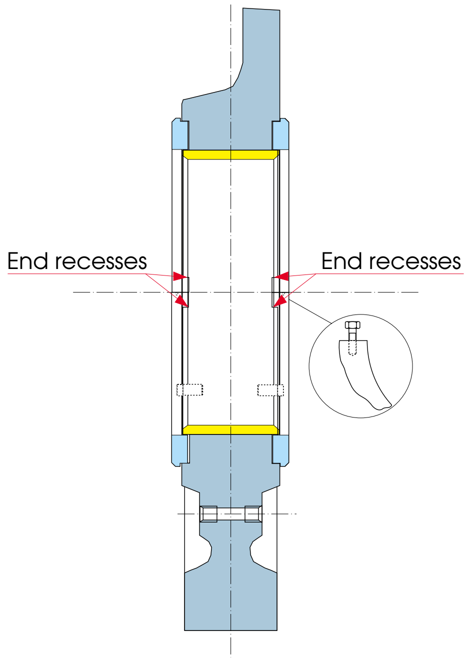


Fig 10-3 3210568935

10.3.2 Assembling of flywheel/thrust bearing

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

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

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

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

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

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

6 Remove the turning tool.

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

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

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

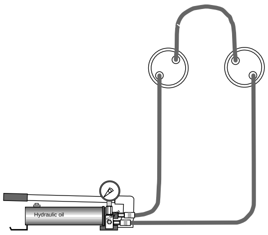
10 Connect the hoses of the hydraulic pump 1V86A18 to the hydraulic jack, the supplying hose set to the side marked UP, see Fig 10-2.

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

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

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

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



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

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

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

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

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

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

10.4 Camshaft bearings

10.4.1 Inspection of the camshaft bearing bush

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

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

2 **Remove the end cover (6),** see chapter 14, Fig 14-2.

3 **Loosen the rocker arm bracket fastening nuts,** see Fig 14-1, pos. 1, on the cylinders where the camshaft is to be replaced according to step 5, below.

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

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

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

10.4.2 Removing of camshaft bearing bush

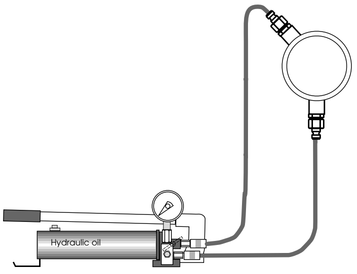
1 **Remove the camshaft cover,** guide block and camshaft piece from the two cylinders adjacent to the bearing concerned. If it is the question of an end bearing, the respective camshaft end piece has to be removed.

2 **Remove the camshaft bearing journal.**

3 **Assemble the removing device** 32.83E05 according to Fig 10-4. Notice the difference in tool assembly for the bearing next to the free end of the engine. When it is a question of an end bearing, insert the guide sleeve 2V83H149, the thicker part being directed towards the middle of the engine.

4 **Tighten the hydraulic tool** 3V83E61 by tensioning the pull screw 4V83G45.

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



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

6 **Pump pressure to the hydraulic tool** to withdraw the bearing bush. The pressure must not exceed the value stated in chapter 07, Fig 07-14. If the bearing bush does not move when this pressure is achieved, a light knock on the end flange 3V83H150 can be necessary.

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

Removing of camshaft bearing bush

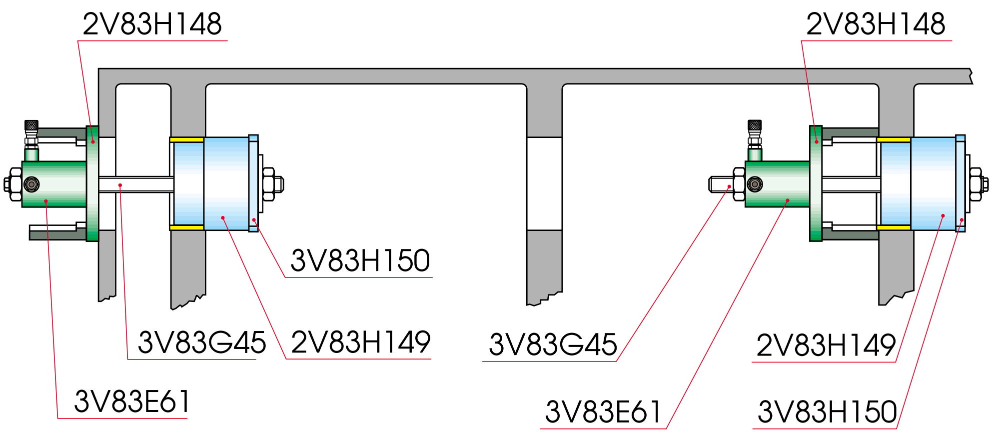


Fig 10-4 321053A9501

10.4.3 Mounting of camshaft bearing bush

1 **Lightly lubricate the new bearing bush** with clean engine oil on the outer surface and put it on the guide sleeve 2V83H149. The notch on the bearing bush side should be positioned downwards, i.e. the oil groove upwards.

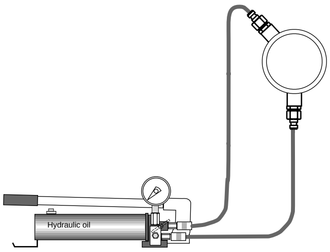
2 **Assemble the mounting device** 32.83E05 according to Fig 10-5. Notice the difference in tool assembly for the bearing next to the free end of the engine. When it is a question of an end bearing, insert the guide sleeve 2V83H149, the thinner part being directed towards the middle of the engine.

3 **Tighten the hydraulic tool** 3V83E61 by tensioning the pull screw 4V83G45 lightly.

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

5 **Pump pressure to the hydraulic tool** to mount the bearing bush. The pressure must not exceed the value stated in chapter 07, Fig 07-14.

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



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

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

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

Mounting of camshaft bearing bush

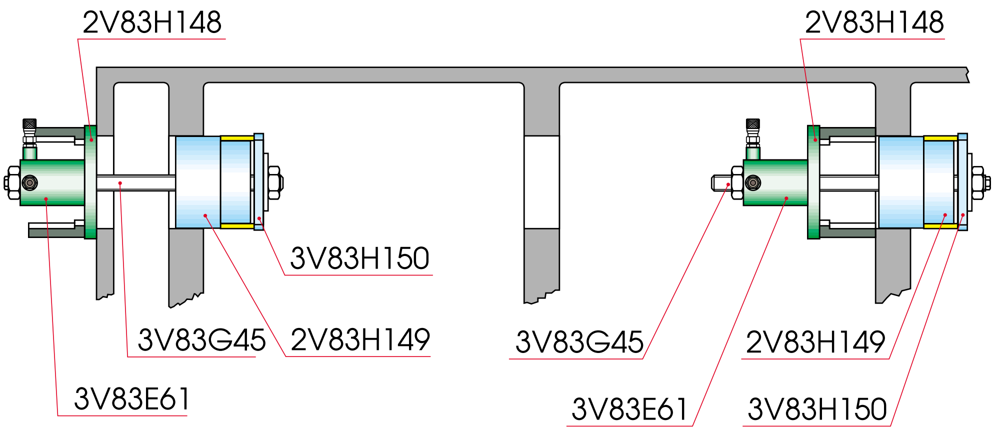


Fig 10-5 321053B9501

10.5 Cylinder liner

10.5.1 Maintenance of cylinder liner

a) **Honing of cylinder liner bore**

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

- The honing is to be carried out by means of “Plateau honing”.
- Only ceramic hones with a coarseness of 80 and 400 should be used. The hones with a coarseness of 80 should be used for about 20 strokes or until the polished areas in the cylinder liner are over scraping. The hones with a coarseness of 400 should be used for about 30 strokes to give the correct surface finish.
- The pitch angle of the honing lines in the cross hatch pattern should be about 30°, which is achieved by combining for example 40 strokes/min with a rotational speed of 100 RPM.

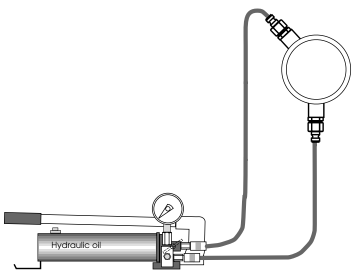
- As coolant a honing oil is preferred, but a light fuel oil 2-15 cSt could also be used.
- After honing, the liner bore must be carefully cleaned by using a suitable brush, water (preferably hot) and soap or cleaning fluid, alternatively, light fuel oil. Then dry with a cloth and lubricate with engine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

The honing equipment is delivered with the engine.

b) **Check the inner diameter of the cylinder liner,** use form No. 3210V001.

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

10.5.2 Removing cylinder liner



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

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

2 **Loosen the screw (2)** and remove the holder (1), see Fig 10-6.

3 **Assemble the lifting tool** 3V83G94, extractor 3V83H171 and the hydraulic tool 3V83E61 according to Fig 10-6.

4 **Tighten the hydraulic tool** by tensioning the nut of the pull screw 2V83G46 lightly.

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

6 **Pump pressure to the hydraulic tool** to withdraw the cylinder liner. The pressure must not exceed the value stated in chapter 07, Fig 07-14.

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

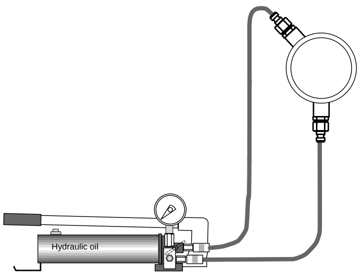
8 **Use the part of the removing device** intended for this purpose to lift the cylinder liner, see Fig 10-6.

10.5.3 Mounting of cylinder liner

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

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

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



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

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

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

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

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

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

Removing and lifting of cylinder liner

1. Holder
2. Screw
3. Mark

3V83E61 Hydraulic tool
3V83G94 Lifting tool
3V83H171 Extractor

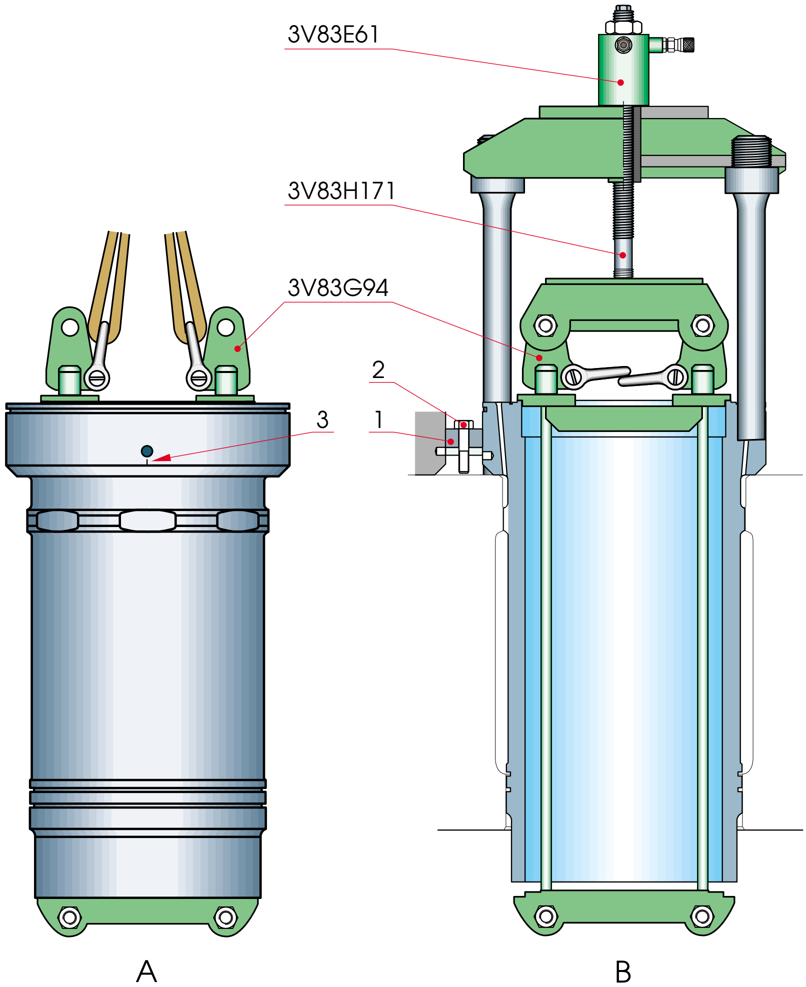


Fig 10-6

3210579543

11B. Piston Overhaul

11B.1 General

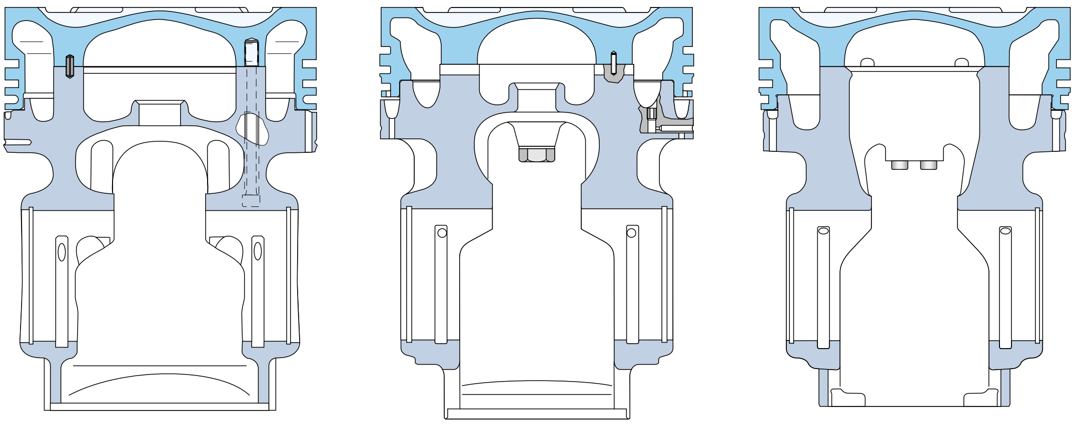
All the engines mentioned in the table below are fitted with composite type pistons.

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

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

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

Pistons



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

Fig 11B-1 321180200112

11B.2 Pistons

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

11B.3 Piston crown

11B.3.1 Visual inspection

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

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

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

11B.3.2 Crack detection test

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

- No cracks are allowed.

11B.3.3 Measurements

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

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

11B.3.4 Reconditioning

Please contact Wärtsilä for reconditioning of piston crowns.

No repair welding is allowed.

11B.4 Piston skirt

11B.4.1 Visual inspection

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

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

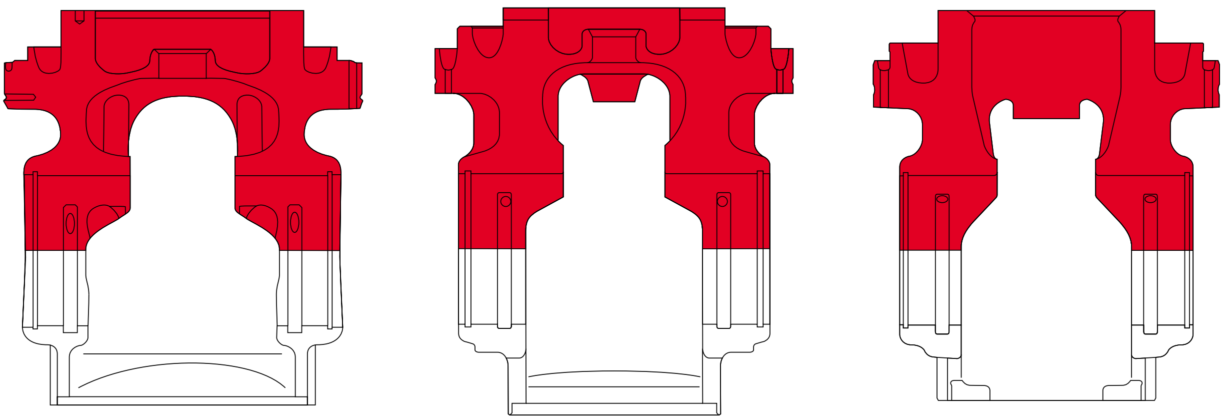
11B.4.2 Support surfaces

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

11B.4.3 Crack detection test

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

Piston skirt



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

Fig 11B-2 321180200112

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

11B.4.4 Measuring of piston crown and piston skirt

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

11B.4.5 Assembling of pistons (All types)

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

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

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

11. Crank Mechanism: Crankshaft, Connecting Rod, Piston

11.1 Counterbalancing of crankshaft

11.1.1 General

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

11.1.2 Counterbalancing of 18-cylinder V-engines

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

Supplementary weight for 18V34

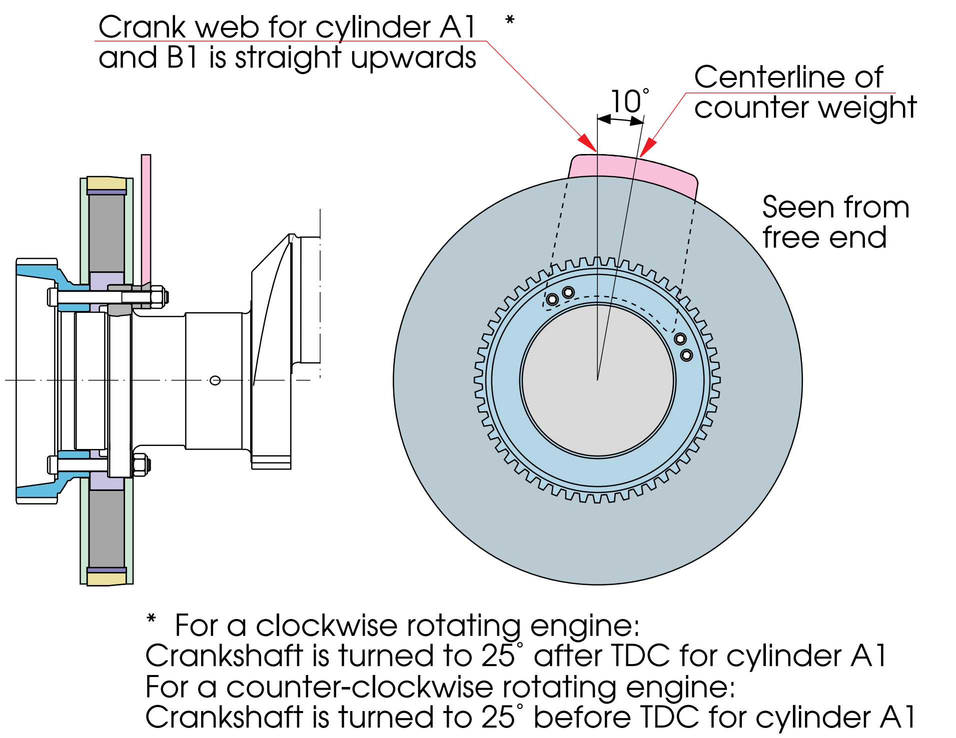


Fig 11-1 3211559045

11.2 Crankshaft

11.2.1 Description of crankshaft

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

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

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

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

11.2.2 Crankshaft alignment

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

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

By using a dial indicator:

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

2 **Set indicator at zero.**

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

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

By using a electronic deflection indicator:

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

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

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

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

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

Dial indicator position and reading

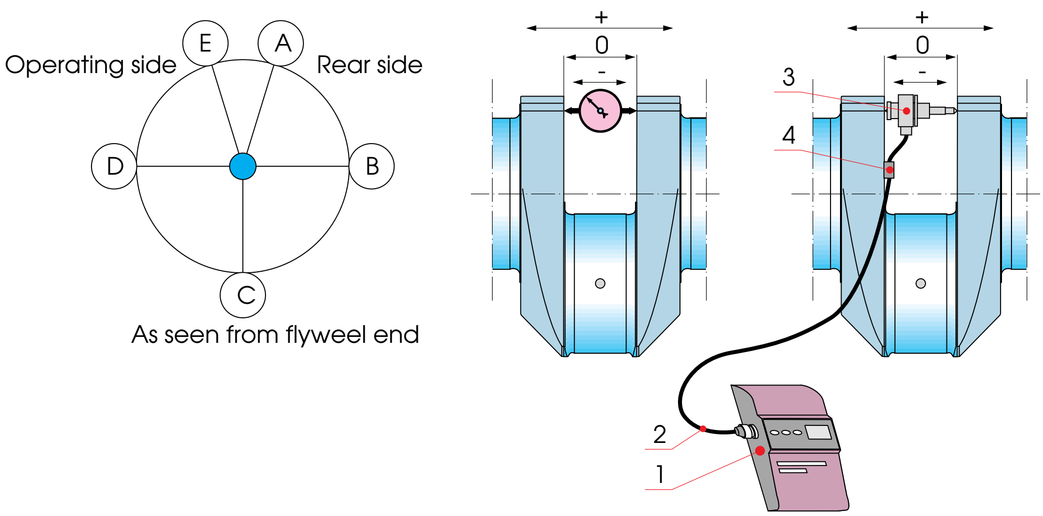


Fig 11-2 3211799901

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

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

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

For both methods:

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

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

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

11.2.3 Measurement of thrust bearing axial clearance

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

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

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

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

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

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

11.2.4 Cleaning of oil lock at crankshaft seal

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

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

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

Oil lock at crankshaft seal

1. Plug

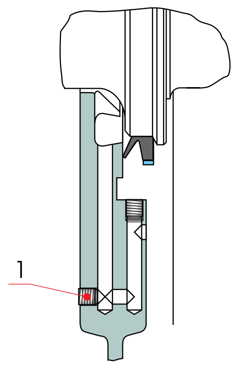


Fig 11-3 3211659601

11.3 Connecting rod and piston

11.3.1 Description of connecting rod and piston

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

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

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

Note! Always handle the pistons with care.

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

Connecting rod parts

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

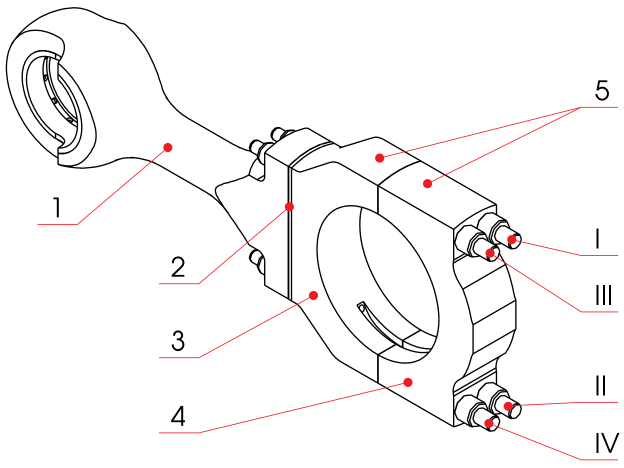


Fig 11-4 3211649544

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

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

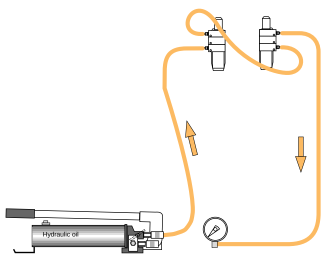
2 **Remove the anti-polishing ring.** Use the tool 836017 if necessary. By cranking the engine, the piston pushes out the anti-polishing ring.

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

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

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

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



DISMANTLING
1. Lift the distance sleeve.
2. Lift the hydraulic cylinder and screws in a one package in pos.
3. Connect hoses, open valve.
4. Tighten the tool assembly, until the piston and cylinder is on the same level, open the nuts by 180°.
5. Close the valve, pump to required pressure. Open the nuts about half a turn.
6. Open the valve slowly and remove the tool.

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

7 **Lift the hydraulic cylinders** into position and mount the strap nuts, see Fig 11-9.

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

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

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

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

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

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

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

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

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

Table 1.

Tool code	Tools marked with following numbers	
	34SG	32DF
835000	2V83F192	1V83F221
835041	3V83F158	3V83F105
835088	3V83F204	3V83F178
835092	2V11T2004	-
836017	2V83G108	2V83G370
843000	1V84D0043	1V48D0011

11.3.2.1 Use of limiter tool 835088

1 **Mount the limiter 835088** (see table 1) in the lower part of cylinder liner and tighten the screw, see Fig 11-8.

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

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

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

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

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

Extension for connecting rod

2. Screw
1V83F190 Extension for conn. rod
9. Glide
10. Upper part
11. Support arm
12. Shaft
13. Pin
835 000 Lifting tool for piston

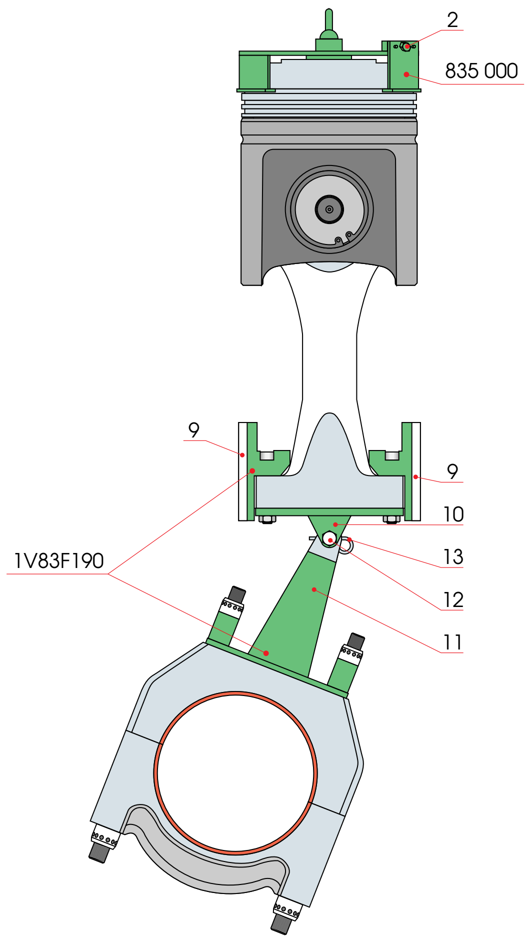


Fig 11-5

3211739701

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

8 **Mount the lifting tool 825000** (see table 1) for the piston in the upper piston ring groove. Tighten the screw (2).

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

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

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

11.3.2.2 Use of hydraulic limiter tool 835092

1 **Mount the limiter 835092** (see table 1) in the lower part of cylinder liner and tighten the screws.

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

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

4 **Mount the glides (9),** see Fig 11-7 into position and tightenthe nuts.

5 **Connect the hydraulic hose** between the hydraulic pump 4V86A33 and the limiter 835092.

6 **Close the release valve** and pump the piston upwards until the piston rings can be removed.

7 **Mount the lifting tool 835000** for the piston in the upper piston ring groove. Tighten the screw (2).

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

Hydraulic limiter tool 835092

15.Screw
16.Hydraulic adapter

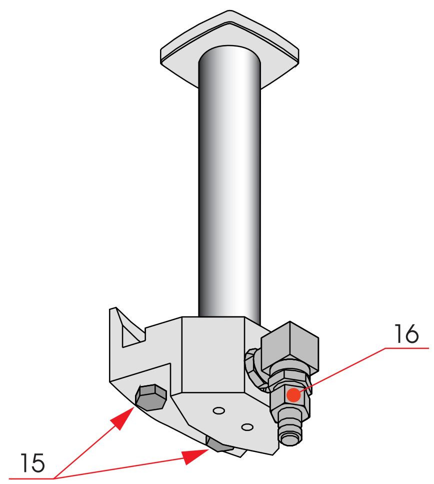


Fig 11-6 3211820409

Protecting glide

9. Glide

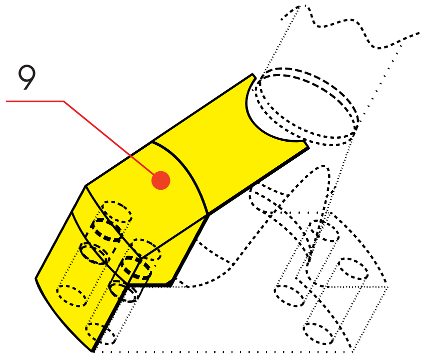


Fig 11-7 3211830409

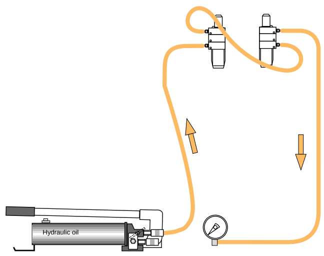
11.3.3 Changing of big end bearings

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

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

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

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



DISMANTLING
1. Lift the distance sleeve.
2. Lift the hydraulic cylinder and screws in a one package in pos.
3. Connect hoses, open valve.
4. Tighten the tool assembly, until the piston and cylinder is on the same level, open the nuts by 180˚.
5. Close the valve, pump to required pressure.
Open the nuts about half a turn.
6. Open the valve slowly and remove the tool.

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

5 **Lift the hydraulic cylinders** into position and mount the strap nuts, see Fig 11-9.

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

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

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

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

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

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

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

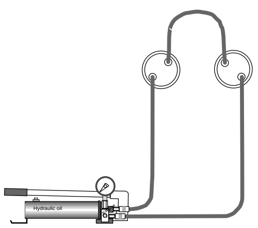
Note! **When using the stud remover 4V80D30 only the inner hexagon 27 key grip should be used when the stud is removed or tightened to torque. The outer left hand hexagon 24 screw is only for locking the tool onto the stud and will break if used to loosen the bolt.**

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

12 **Mount the limiter 835088** (se table 1) in the lower part of cylinder liner and tighten the screw, see Fig 11-8.

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

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



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

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

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

Removing and mounting of V-engine big end lower halves

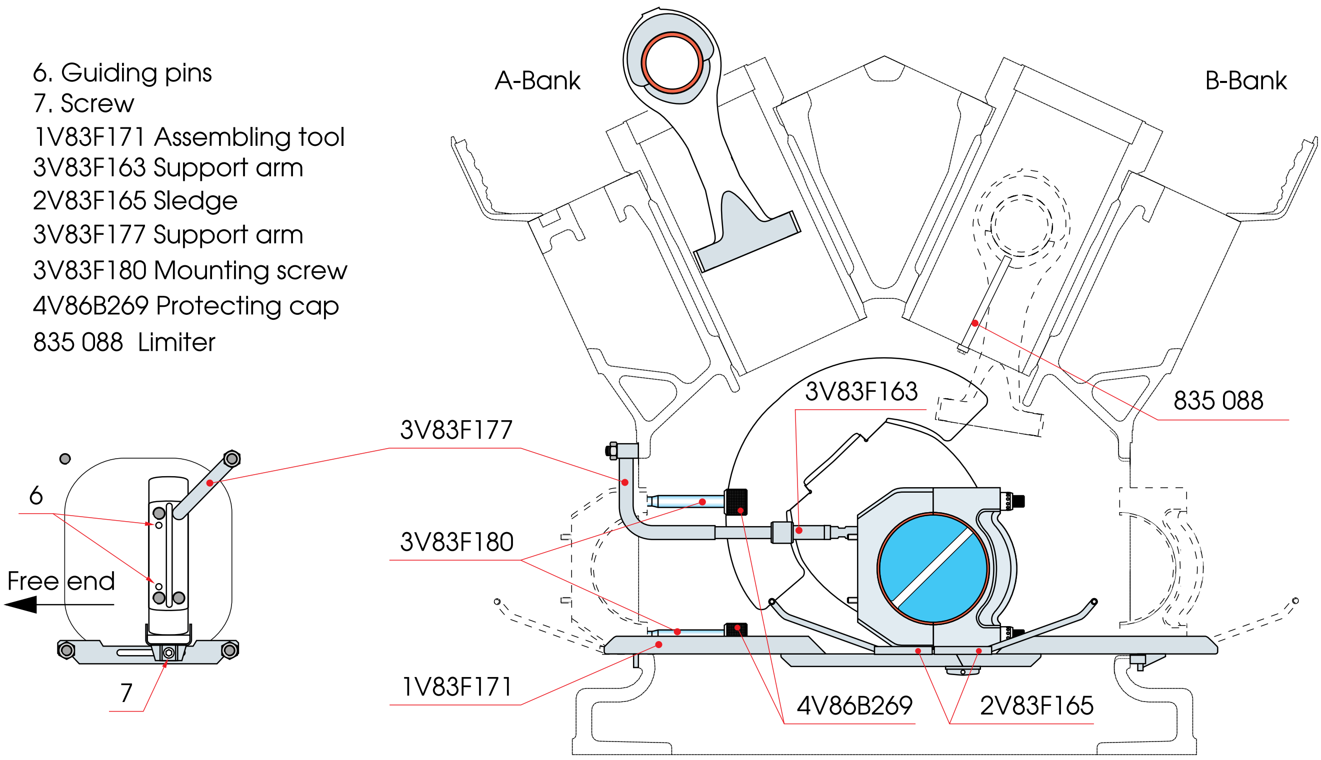


Fig 11-8 3211749701

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

Note! **Loosen crosswise.**

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

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

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

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

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

20 **Mount the assembly rail 2V83F171** through the crank case openings on the lower crank case cover studs and tighten the nuts, see Fig 11-8.

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

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

23 **Mount the support arm 3V83F163** on the upper threads (M24) of the big end and support arm 3V83F177 on the upper crank case stud, see Fig 11-8. Tighten the nut.

Piston and connecting rod assembly

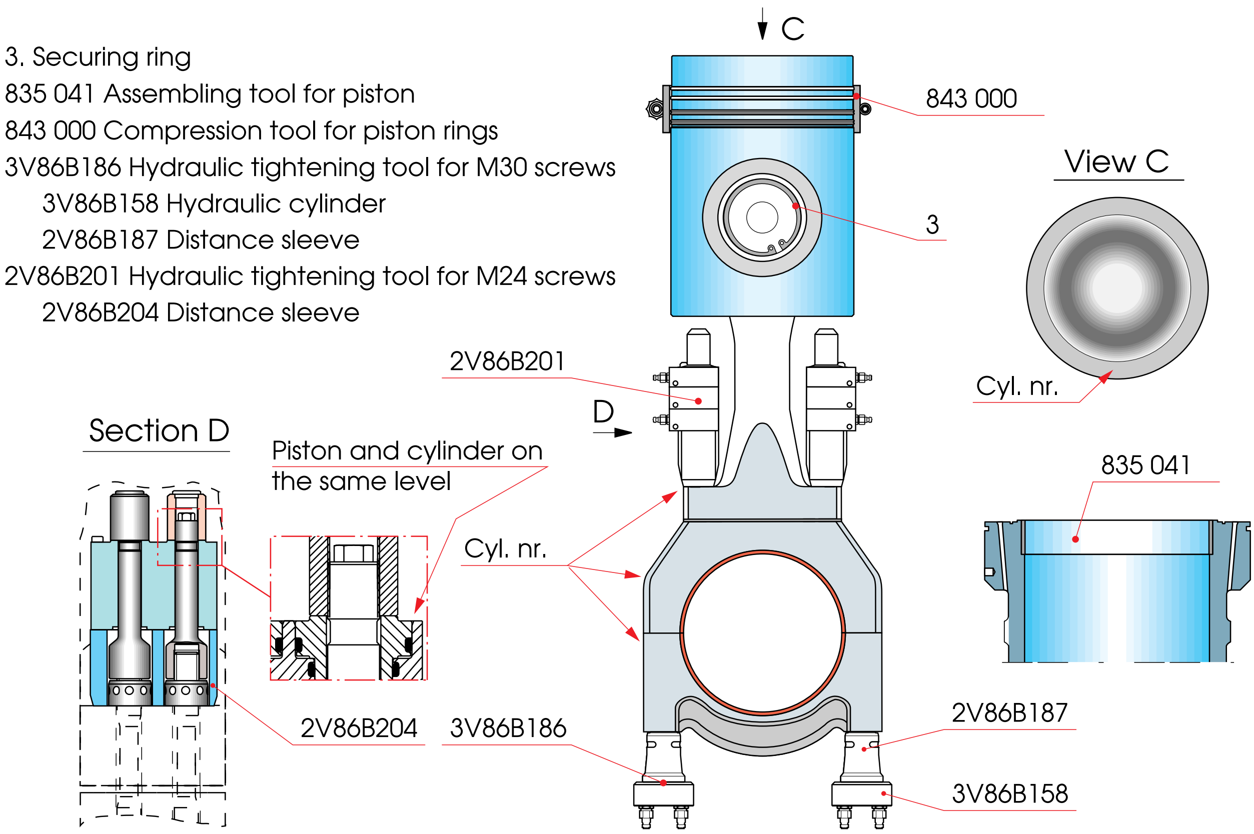


Fig 11-9 321162200045

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

25 **Unscrew the nuts** on the mounting screws and pull apart the halves.

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

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

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

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

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

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

11.3.4 Maintenance of piston, rings and connecting rod bearings

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

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

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

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

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

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

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

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

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

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

Mark new bearings with the bearing number.

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

11.3.5 Assembling and mounting of piston and connecting rod

1 Lubricate the gudgeon pin, and mount it from the same side from where it was removed, with the end marked with the drawing number in the same direction. The cylinder number is stamped on the piston crown and connecting rod, Fig 11-9. When changing the piston, mark the new piston with the same cylinder number in the same place as on the replaced one.

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

2 Mount the securing ring (3).

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

3 Mount the assembling tool through the crank case openings on the crankcase cover lower studs and tighten the nuts, see Fig 11-8. Mount the sledges 2V83F165 on the rail.

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

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

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

5 **Clean the big end upper half carefully.** Spread a thin oil film (engine oil) on the back side of the upper and lower halves. Mount the shell, so that the lug guides in its groove.

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

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

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

8 **Lift the upper big end half** on the sledge. Spread a thin oil film (engine oil) on the running surface. Lubricate end faces with grease.

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

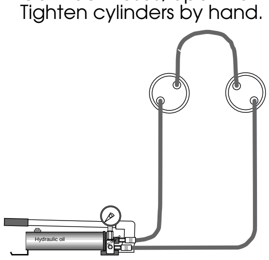
10 **Mount the support arm 3V83F177** on the upper crank case stud, see Fig 11-8. Tighten the nut.

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

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

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

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.

13 **Lift the big end lower half** on the sledge. Spread a thin oil film (engine oil) on the running surface. Lubricate end faces with grease.

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

15 **Mount the protecting cap 4V86B269** and tighten by hand.

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

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

18 **Remove the assembling tool.**

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

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

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

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

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

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

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

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

25 **Mount the lifting tool 835000** (see table 1) for the piston in the upper piston ring groove. Tighten the screw (2), see Fig 11-5.

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

11.3.5.1 Mounting by using the limiter tool 835088

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

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

3 **Mount the limiter 835088** in the lower part of cylinder liner and tighten the screw, see Fig 11-8.

4 **Place the mounting tool 835041** into the cylinder liner.

5 **Lubricate the piston.**

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

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

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

9 **Lubricate the piston** and place the clamp device for piston rings, 843000 (see table 1), around the piston, checking that the piston rings slide into their grooves.

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

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

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

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

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

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

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

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

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

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

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

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

11.3.5.2 Mounting by using the hydraulic limiter tool 835092

1 **Mount the glides (9) into the position and tighten the nuts.**

2 **Mount the limiter 835092** (see table 1) in the lower part of the cylinder liner and tighten the screws.

3 **Connect the hydraulic hose.**

4 **Raise the flange of the limiter to the highest position.**

5 **Place the mounting tool 835041** (see table 1) into the cylinder liner.

6 **Lubricate the piston.**

7 **Lower the piston/connecting rod upper part** carefully into the cylinder liner until the piston is supported by the flange of the limiter.

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

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

10 **Lubricate the piston** and place the clamp device for piston rings, 843000 (see table 1), around the piston, checking that the piston rings slide into their grooves.

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

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

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

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

14 **Lower the piston/connecting rod upper part** by carefully opening the release valve of the hydraulic pump. A few strokes with a non-recoiling hammer on the top of the piston will help if the piston movement downwards will stop.

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

Note! **The piston should move freely in the liner when the instructions above are followed. If the piston movement downwards stop, the rotating of the crankshaft must immediately stop, as there is a great risk of damaging the piston rings.**

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

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

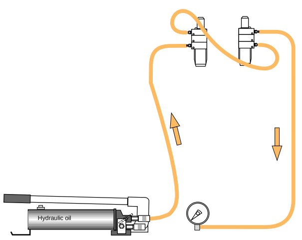
17 **Place the upper part of the connecting rod** and the big end. **Note! Remove the limiter.**

11.3.5.3 Hydraulic tightening of M24 screws

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

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

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



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

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

4 **Lift the hydraulic cylinders** into position and mount the strap nuts, see Fig 11-9.

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

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

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

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

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

Note! **Check that all tools are removed from crankcase.**

12.A. Testing of cylinder tightness

12.A.1 Testing

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

1 **Turn the piston to TDC** (all valves closed) for the cylinder concerned.

12.A.1.1 Connecting of the tool for Wärtsilä 20/32 and Vasa 32

1 **Connect the tool** (848020, Wärtsilä 20), (800064, Wärtsilä 32), (848020, Vasa 32) to the open indicator valve. Continue with section 12.A.1.4.

12.A.1.2 Connecting of the tool for Wärtsilä 34SG

1 **Remove the cover plate ,** ignition coil and the spark plug extension and other necessary components. See section 12.2.

2 **Remove the spark plug,** mount the distance sleeve 3V84H85 (848052) with seal ring and tighten to the stated torque.

3 **Connect the pressure gauge and valve assembly** to the distance sleeve.

4 **Install the tool** (848020) to the cylinder head. Continue with section 12.A.1.4.

12.A.1.3 Connecting of the tool for Wärtsilä 32DF

1 **Remove injection valve** with neccessary pipes. See section 12.2.

2 **Assembly the distance sleeves** 3V84H85 (848052) and 2V84H97 (848061) with necessary seals.

3 **Connect the pressure gauge and valve assembly** to the distance sleeves.

4 **Install the tool** (848020) to the cylinder head. Continue with section 12.A.1.4.

Testing tool of cylinder tightness

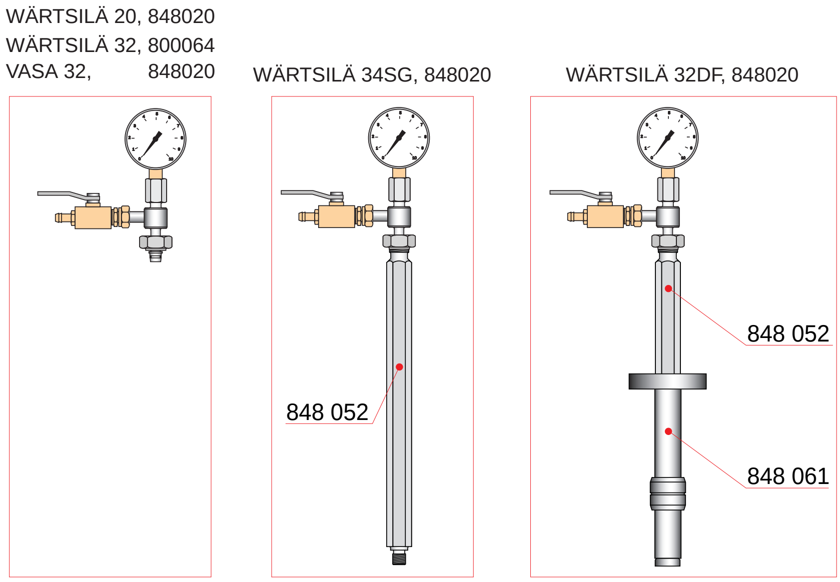


Fig A-1 321260200142

12.A.1.4 Measurement

1 Connect air to the tool with a pressure of 6-7 bar (= normal working air pressure). Open the valve on the tool and record the pressure.

2 Close the valve. Measure the time in seconds it takes for the pressure dropping to 0.5 bar.

- If the pressure from the beginning was 6 bar and it takes more than 10 sec. for the pressure to drop to 0.5 bar, the result is acceptable.
- If the pressure drops directly to 0 bar, it is possible that one or more valves are sticking or the valve(s) are burnt.
  A sticking valve can be found from the immobility of the valve when the engine is turned.
  A burnt valve can normally be seen from the exhaust temperature. If the valve clearance is zero that would also cause an direct pressure drop.
- Carbon particles trapped between the valve and the seat when the engine is stopped could also prevent the valve to close properly thus causing a direct pressure drop. If that is suspected, the engine should be run for a few minutes and after that a new check of the same cylinder.
- If a blow-by between the cylinder liner and piston is suspected e.g. from fast fouling of filters or high crankcase pressure, it is best to take readings of the complete engine and make a comparison.
  For example: From a six cyl. engine you get a serial: 12, 17, 15,

4, 19 and 18 seconds.
This shows that cyl.no.4 is the one to be suspected for a blow-by.
The test can be verified by listening for leaking sounds inside crankcase during testing.

- If the time is limited to overhaul only one piston, it is recommended to dismantle the worst measured blow-by piston for inspection. The result of inspection gives a hint of general engine condition.
- When re-testing the cylinder after an overhaul a rapid pressure drop can be observed. The reason for this is because the running in of piston rings is not yet performed.

Note! **Keep pre-lubricating pump running during test.**

Note! **The turning gear should be engaged during test.**

- In general, the location of leakage can be found by listening when the air valve is open.

Attention! **A general condition of engine is indicated with the test device, but more important is the operation data records.**
The overhauls must be made according to recommended overhaul intervals and not only when the pressure test shows a big blow-by.

12. Cylinder Head with Valves

12.1 Description

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

12.2 Removing and mounting of the cylinder head

12.2.1 Removing of the cylinder head

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

2 **Remove the cover plate (16),** ignition coil (10) and the spark plug extension (9) and the springs (17) by opening the screws (13).

3 **Remove the cylinder head cover,** the side cover and the insulating panel over the exhaust gas connection to the cylinder head.

Cylinder head

5. Cylinder head
6. Discharge pipe
7. Yoke
8. Bearing bracket for rocker arms
9. Extension
10. Ignition coil
11. Inlet valve seat ring
12. Exhaust valve seat ring
13. Screw
14. Main gas admission valve
15. Prechamber control valve
16. Cover plate
17. Spring
18. Fastening plate
19. Hose

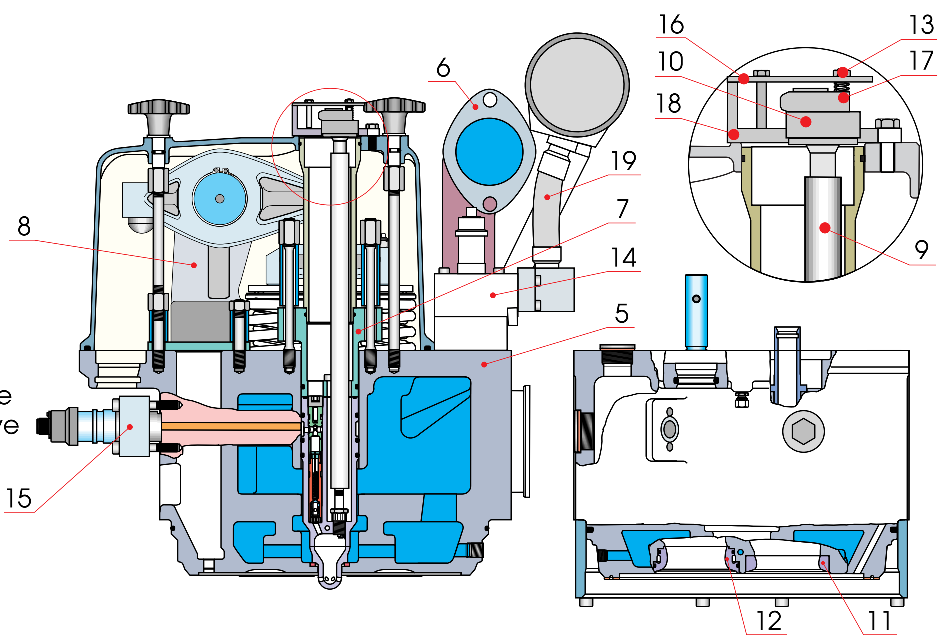


Fig 12-1

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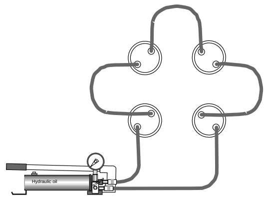
DISMANTLING
1. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



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

4 Disconnect the cables to the main gas admission valve (14), prechamber control valve (15) and to the exhaust gas temperature sensors.

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

6 Remove the gas feed pipes to the main and prechamber gas admission valves. Protect the connections of the gas feed pipes, oil pipe and exhaust pipes.

7 Remove the covers of the cylinder head screws. Put on the distance sleeves and hydraulic cylinders and proceed with opening of cylinder head nuts.

8 Remove the cylinder head nuts.

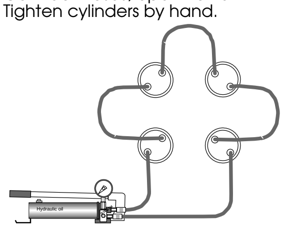
9 Apply the lifting tool.

10 Lift off the cylinder head.

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

12.2.2 Mounting of the cylinder head

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



4. Close the valve and pump pressure to the stated value.
5. Screw the nuts until close contact to face.
6. Open the valve
7. Repeat steps 4, 5 and 6
8. Remove tool set.

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

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

3 Apply the lifting tool to the cylinder head.

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

5 Screw on the cylinder head nuts.

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

7 Apply the protecting caps to the cylinder head screws.

8 Connect the exhaust pipe, charge air pipe, oil pipe and gas feed pipes. Fit the discharge pipe. Put on the exhaust pipe insulating piece.

9 Connect the cables to the gas valves and exhaust temperature box.

10 Adjust the valve clearance.

11 Put on the cylinder head cover and side cover.

12 Apply the spark plug extension, ignition coil, springs, cover plate and tighten the screws. Note! The extension and ignition coil should be put together before assembly.

13 Before starting, fill the engine circulating water system.

12.2.3 General maintenance of the cylinder head

The prechambers are dealt with in chapter 16.
Oil can lead to stocked check valve.

12.2.4 Adjusting valve clearance and yoke

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

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

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

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

Adjusting valve clearance

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

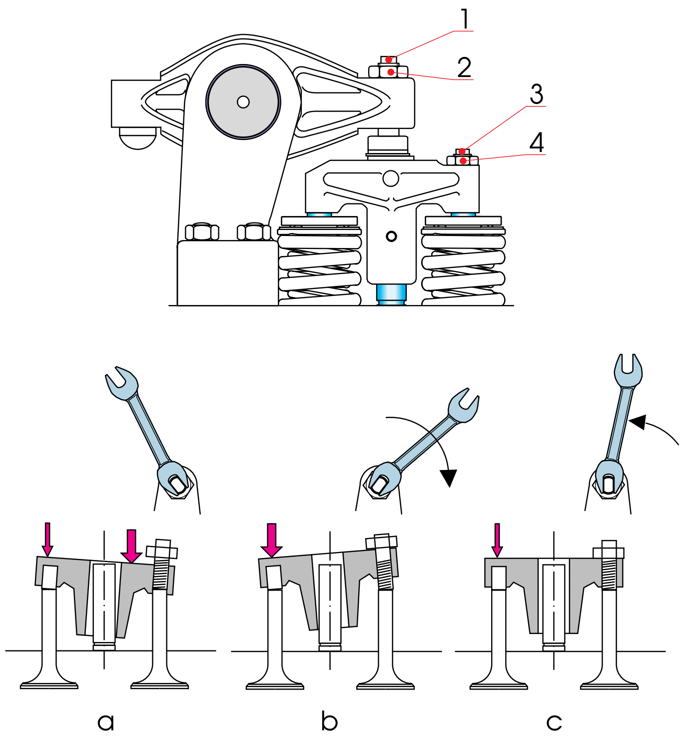


Fig 12-2

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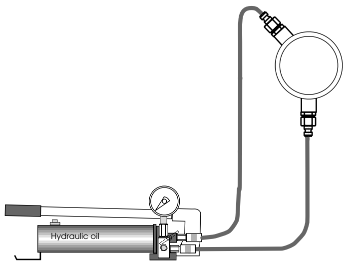
5 **Put a feeler gauge** corresponding to the valve clearance between the surface of the yoke and the shoe at the rocker arm. Tighten the adjusting screw (1) until the feeler gauge can be moved to and fro only with slight force. Hold the adjusting screw and tighten the counter nut. Check that the clearance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

12.3 Maintenance of exhaust and inlet valves

12.3.1 Dismantling valves

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

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



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

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

3 **Knock at the centre of the valve discs** with a soft piece of wood, plastic hammer or similar, whereby the valve cotters come loose and can be removed.

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

5 **Spring holders and springs can now be removed.**

Tool assembly for dismantling valves

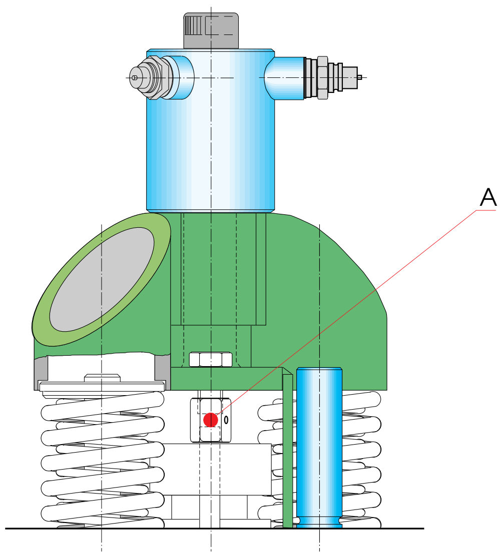


Fig 12-3 3212548932

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

12.3.2 Checking and reconditioning valves and seats

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

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

Control of burning-off on valve

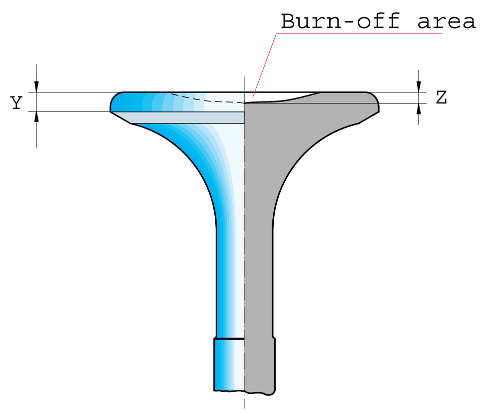


Fig 12-4 3212568932

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

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

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

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

12.3.3 Lapping of inlet valves

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

1 Fit the turning tool 4V84B108 to the valve.

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

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

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

5 Clean the valve and seat carefully after lapping.

Note! Lapping is not allowed for exhaust valves.

12.3.4 Machine grindind of exhaust and inlet valves

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

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

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

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

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

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

12.4 Change of seat ring

12.4.1 Removal of the old ring

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

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

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

12.4.2 Fitting a new inlet valve seat ring

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

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

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

12.4.3 Fitting a new exhaust valve seat ring

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

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

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

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

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

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

6 **Mount the sealing rings** on the cooled valve seat.

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

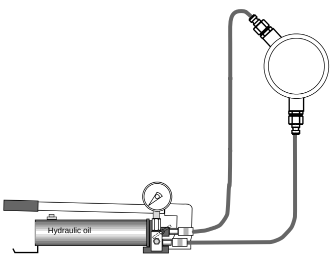
- Put the seat rings into a guiding bush and press in the seat with a guided arbor. A special tool (846050) is also available. This tool can be ordered from the engine manufacturer.
- Insert the seat ring by using an exhaust valve. Knock on the valve until the seat ring is correctly seated.

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

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

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

12.4.4 Reassembling of the engine valves



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

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

2 **Put new seal rings** in the valve guides.

3 **Lubricate the valve stems** with engine oil.

4 **Put in the valves** and check for free movement.

5 **Put on the springs** and spring discs or rotators. Compress the springs with the tool set (834000). Put in the valve cotters and unload the springs. Check that the valve cotters fit properly.

13. Camshaft Driving Gear

13.1 Description

The camshaft is driven by the crankshaft through a gearing. The gear wheel (1) is split and fixed to a flange on the crankshaft by the axial screws (2). These screws as well as the fastening screws (25) are locked with Loctite 262.

The bearing shafts (26) and the intermediate wheels (3), (10) and (11) are journalled in the engine block. The camshaft driving wheel (12) is fixed to the camshaft end (24) by a guiding pin (20) and fastened by means of a flange connection between the end and the camshaft extension (14) and the camshaft extension is equipped with an encoder (40). Lube oil nozzles provide for lubrication and cooling of the gearing.

13.2 Intermediate gears

13.2.1 Removing of camshaft gearing

1 **Remove the gearing covers** and the adjacent camshaft covers. Remove half of the camshaft bolts (13), see Fig 13-1. Turn the crankshaft to TDC at firing for cylinder No.1.

2 **Remove concerned oil distributing pipes** and oil sprays.

3 **Unscrew the fastening** screws on one end of the flexible coupling (41).

4 **Unscrew the fastening screws (18)** for the bracket of the encoder (40) and remove the bracket together with the encoder.

5 **Unscrew the fastening screws (16),** and remove the end flange (15) and housing (19).

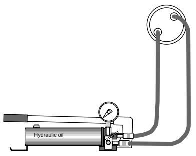
6 **Remove the end cover (6), Fig 14-2,** from the free end of the camshaft.

7 **Unscrew the remaining flange connection screws (13)** and remove the camshaft extension (14).

8 **Unscrew the fastening nuts (1), Fig 14-1,** of all rocker arm brackets, only on the A-bank for a V-engine. Move the camshaft in the direction of the free end (max. 25 mm) by using a suitable lever or the hydraulic jack, and lift the camshaft driving wheel out.

9 **Unscrew the cover fastening screws (7).** Remove the cover (32). Unscrew the shaft plate fastening screws (8) and remove the shaft plate (31).

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



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

10 **Remove the outer thrust bearing ring (30).**

11 **Unscrew the housing fastening screws (9)** and remove the housing (5).

12 **Remove the inner thrust bearing ring (29).**

13 **Unscrew the extension shaft fastening screws (27)** and remove the extension shaft (28). Secure the intermediate wheels (10) and (11) in a nylon strap.

14 **Apply distance sleeve 3V86B135** and hydraulic cylinder 3V86B150 to the fastening bolt (6) and remove the nut (33).

15 **Remove the shaft (35).** The shaft can be pulled out by using suitable screws, i.e. M8 screws.

16 **Unscrew the bolt (6)** by using the tool 3V84G189.

17 **Remove the intermediate gear wheel (11).**

18 **Remove the intermediate wheel (10).** Using lifting tools will make the gear wheel handling easier.

19 **Remove the intermediate wheel (3)** by proceeding as with the intermediate wheels (10) and (11).

Note! **Even though the design of both intermediate gear shafts is similar, the parts must not be mixed with each other.**

13.2.2 Mounting of the camshaft gearing

1 **Turn the crankshaft as follows:**

a) **V-engine; camshaft gearing of both cylinder banks removed:** Turn crankshaft to TDC for cylinder No.A1.

b) **V-engine; gearing of A-bank mounted, gearing of B-bank removed:** Turn crankshaft to TDC at ignition for cylinder No.A1. Then turn 50° in direction of TDC for cylinder No.B1.

c) **V-engine; gearing of B-bank mounted, gearing of A-bank removed:** Turn crankshaft to TDC at ignition for cylinder No.B1. Then turn 50° in direction of TDC for cylinder No.A1.

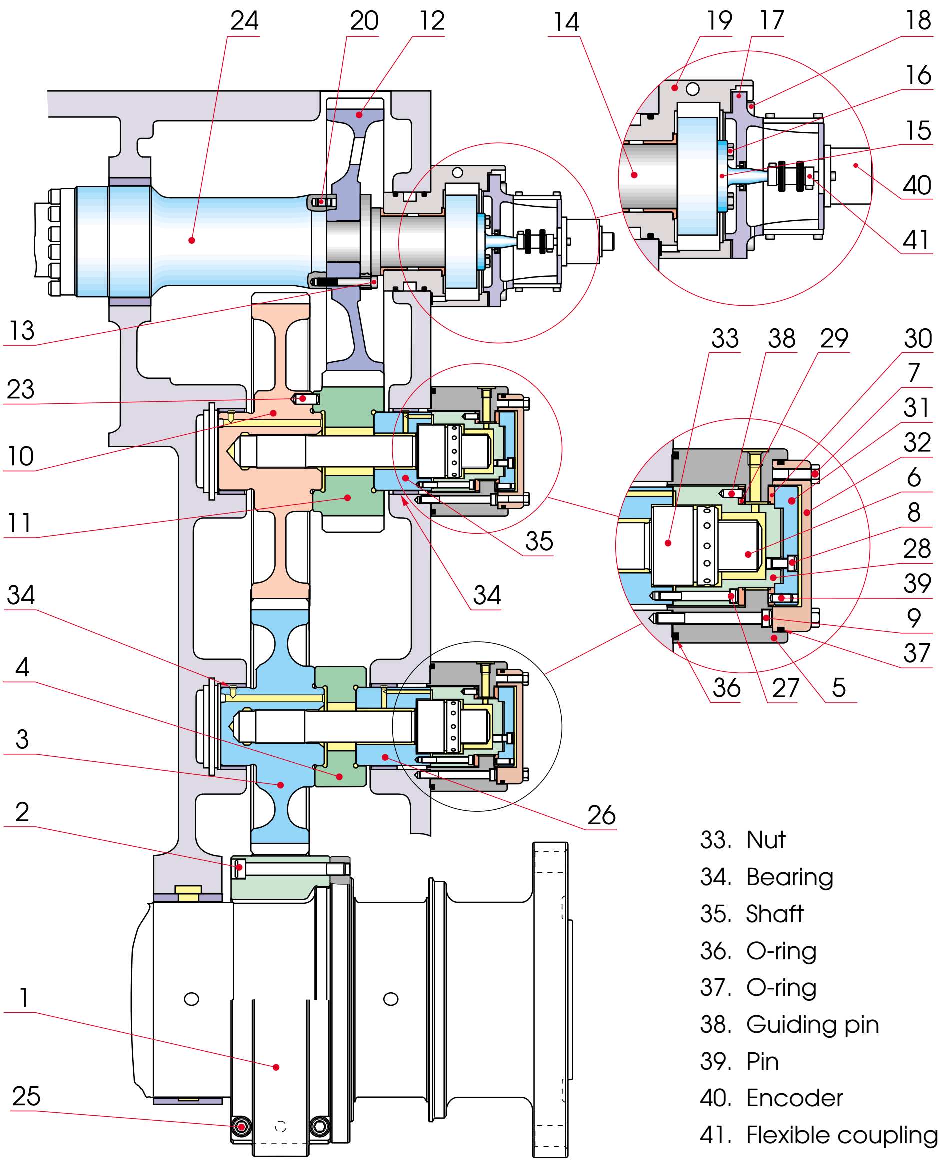
Note! **Make sure that the crankshaft is in TDC at ignition for cylinder No.1 at respective bank in a V-engine before proceeding with the job.**

---

2 **Lift the intermediate wheel (3)** into position. The wheel must be tilted, when inserted, to get free from the rib in the engine block.

Camshaft driving gear

1. Gear wheel
2. Screw
3. Intermediate wheel
4. Distance sleeve
5. Housing
6. Cover
7. Screw
8. Screw
9. Screw
10. Intermediate wheel
11. Intermediate wheel
12. Driving wheel
13. Camshaft screw
14. Camshaft extension
15. End flange
16. Screw
17. Cover
18. Screw
19. Housing
20. Guiding pin
23. Pin
24. Camshaft end
25. Screw
26. Bearing shaft
27. Screw
28. Extension shaft
29. Bearing ring
30. Bearing ring
31. Shaft plate
32. Cover



33. Nut
34. Bearing
35. Shaft
36. O-ring
37. O-ring
38. Guiding pin
39. Pin
40. Encoder
41. Flexible coupling

Fig 13-1

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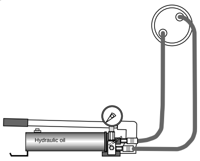
Note! **Insert the intermediate gear wheels and bearing bushes according to the marking of the wheels, see Fig 13-2.**

3 **Insert the distance sleeve (4).**

4 **Screw in the bolt (6)** and tighten to the torque stated in chapter 07.

5 **Insert the shaft (26).**

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.

6 Tighten the nut (33) by hydraulic cylinder 3V86B150 to stated pressure. Release the pressure and pump to stated pressure again. Tighten the nut finally and release the pressure.

7 Mount the guiding pin (38) and insert the extension shaft (28). Tighten the screws (27) to the stated torque.

8 Insert the inner thrust bearing ring (29).

9 Mount the O-ring (36) in the housing (5) and insert the housing. Tighten the screws (9) to the stated torque.

10 Insert the outer thrust bearing ring (30). The gear wheels should be in the outer most position to achieve the correct axial bearing clearance.

11 Mount the pin (39) to the shaft plate (31), and insert it. Apply Loctite 242 to the screws (8) and tighten to the stated torque. Insert the cover (32) and the O-ring (37) and tighten the screws (7) to the stated torque.

12 Check the axial bearing clearance for the gear wheel (3) and the backlash between the wheels (1) and (3).

13 To get the intermediate wheels (10) and (3) into the correct position, mark the meshing teeth of both wheels (10) and (3) with a pencil acc. to Fig 13-2. (The wheel (10) can be marked before mounting by marking the third tooth downwards from a line drawn from the centre point of gear wheel (10), through the dowel pin in the wheel (10)).

V-engines: Do not install the intermediate wheel (10) before camshaft end (24) is installed. Place the intermediate wheel (10) as low as possible in gear train.

14 Mount the gear wheel (10) to the engine block according to meshing marks.

15 Mount the gear wheel (11) to the wheel (10). The dowel pin of the wheel (10) should be in the middle of the groove in the wheel (11) to get enough timing adjustment allowance

16 Screw in the bolt (6).

17 Insert the shaft (35).

18 Tighten the nut (33) by hand.

19 Check the backlash between the wheels (10) and (3).

20 Lift the camshaft driving wheel (12) into position. The marks on the wheels should be aligned with the edge of the engine block according to Fig 13-2.

21 **Fit the camshaft extension (14),** push the camshaft into position, guided by the pin (20), and tighten the flange connection screws (13).

22 **Mount the housing** and the end flange.

Marking of the intermediate gear wheels, V-engines

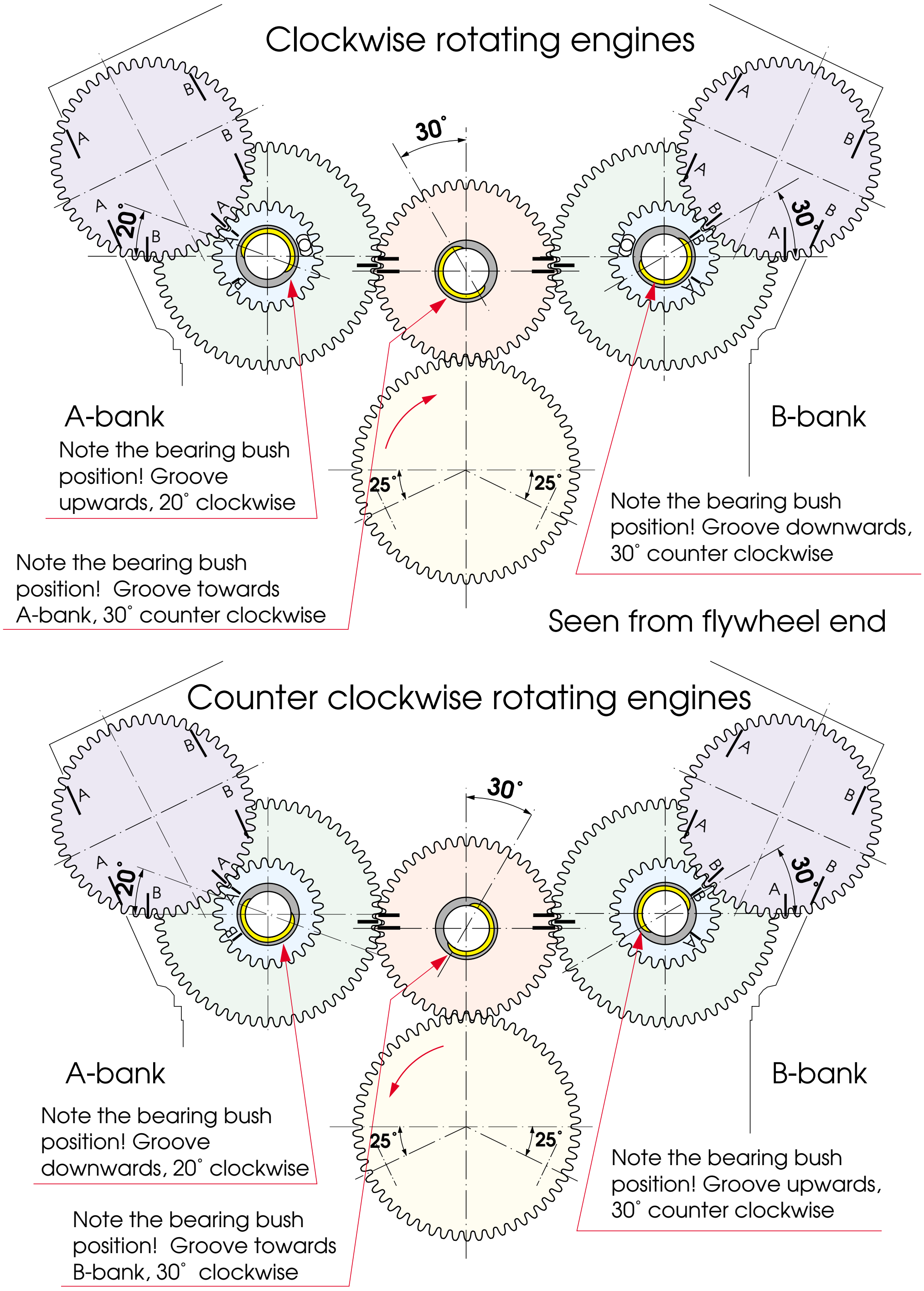


Fig 13-2 3213629501

23 **Mount the bracket** together with the encoder and tighten the screws. On the V-engine B-bank there is only a bearing housing and end flange.

24 **Check the axial bearing clearance** for the camshaft and the backlash between the wheels (11) and (12).

25 **Mount the oil sprays.**

26 **Check the valve timing** of one cylinder. On the V-engine, check the firing sequence of the cylinder banks.

27 **Proceed with tightening** of screws and nuts according to step 6 - 11 above.

28 **Mount the oil distributing pipes, the covers** for the gearing and camshaft.

29 **Check the axial bearing clearance** and the tooth clearance between the wheels (10) and (3).

30 **Check the position** of the encoder, see section 23.3.

13.2.3 Timing of the valves

1 **Turn crankshaft to TDC for** cylinder No.A1, exhaust-/inlet stroke.

2 **Place the dial gauge with feeler pin** pointed perpendicular to the center of ball pin in the inlet valve tappet, see Fig 13-3.

3 **Rotate the flywheel in direction 55° before TDC,** on graduation scale at reading 305°. The downward movement of the feeler pin will be stopped during the last 10°, indicating that the tappet roller is on the base circle of the cam profile. Set the dial gauge reading to zero.

4 **Rotate the flywheel back to TDC** reading on the dial gauge should be 3±0.12 mm. If the reading differs more, continue as follows.

5 **The axial bearings of the intermediate gear** to be dismantled, see section 13.2.1. Loosen the nut (33) by using hydraulic tool to allowed rotation of the intermediate gear (11), see Fig 13-1.

6 **Rotate the camshaft** to obtain the correct dial gauge reading and same time holding the flywheel stationary in TDC.

7 **Tighten the nut (33)** by hydraulic cylinder to stated pressure according to section 13.2.2.

8 **Repeat the steps 3 and 4 above.**

9 **Reassemble the axial bearings** according to section 13.2.2.

10 **Repeat the same procedures** on the B-bank, but turn crankshaft to TDC for cylinder No.B1. **Note the different graduation scale on flywheel for B-bank.**

Timing of the valves

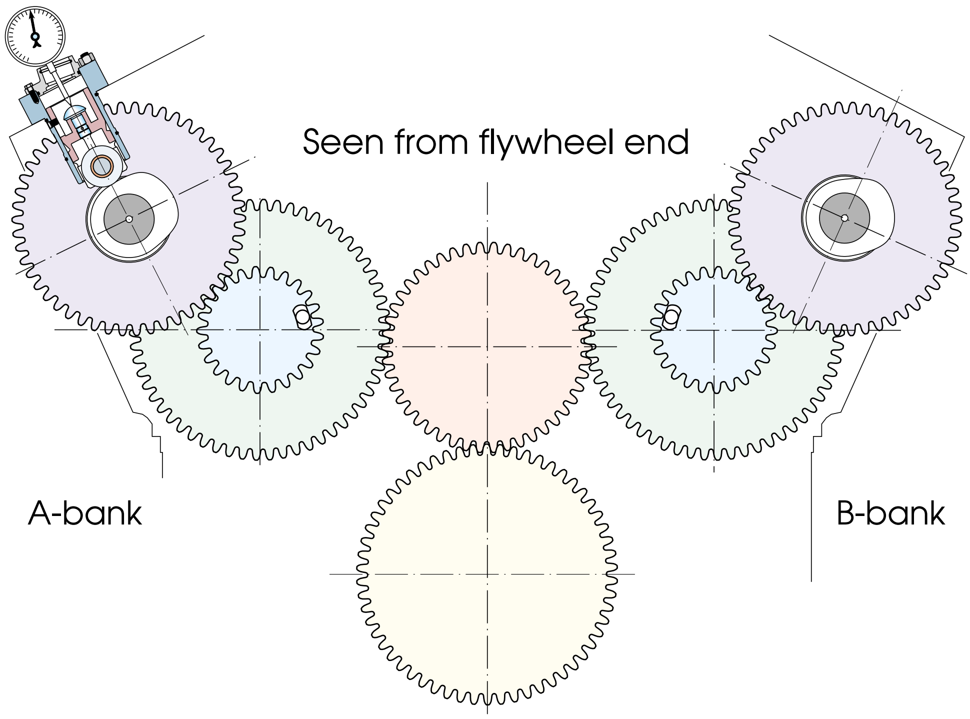


Fig 13-3 3213679701

13.3 Split gear

If only the split gear wheel has to be changed, one half of the wheel can be removed/mounted at a time. Hereby the valve timing will be unchanged and it will not be necessary to adjust it.

13.3.1 Removing of the split gear wheel

After the gearing is removed according to section 13.2.1, the split gear wheel (1) can be removed from the crankshaft.

1 **Lower the bearing cap** for main bearing No.1, see chapter 10., section 10.2.1.

2 **Loosen the fastening screws (25).**

3 **Unscrew the axial screws (2).**

4 **Unscrew the fastening screws (25)** and remove the gear wheel halves.

13.3.2 Mounting of the split gear wheel

1 **Clean the parting surfaces of the wheel halves** and the contact faces of the gear wheel and the crankshaft.

2 **Lower the bearing cap for main bearing No.1,** see chapter 10, section 10.2.1.

3 **Apply Loctite 262 on the threads of the screws (2) and (25).**

4 **Mount the gear wheel halves on the crankshaft** with the parting face at right angles with the crank of cylinder No.1 and fasten the screws (2) and (25) by hand.

5 **Tighten the axial screws (2)** to a torque of 10 Nm and check that contact is established between the gear wheel and the crankshaft flange.

6 **Tighten the fastening screws (25)** to a torque of 40 Nm. The screws closer to the crankshaft flange are to be tightened at first.

7 **Tighten the fastening screws (25)** to stated torque. The tightening order is the same as in the previous point.

8 **Tighten the axial screws (2)** to the stated torque.

9 **Check the gear wheel roundness.** Place a cylindrical pin (ø16 mm) in the tooth gap as shown in Fig 13-4. Turn the engine and use a dial indicator to get an indication for the diameters. The maximum permissible difference between the measured values is 0.05 mm.

10 **Lift the bearing cap for main bearing No.1,** see chapter 10 section 10.2.1.

Measuring split gear wheel

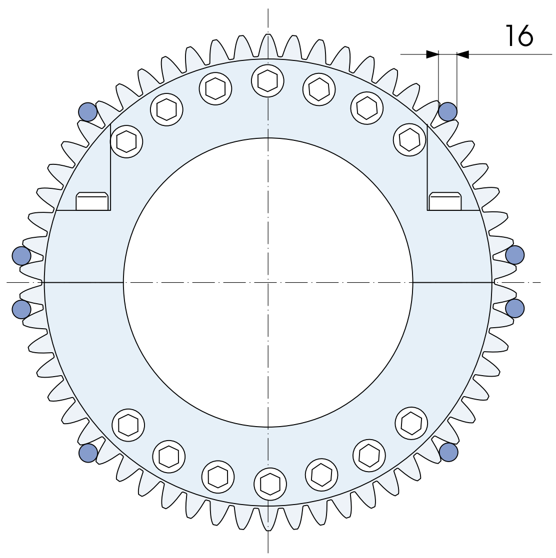


Fig 13-4 3213519045

14. Valve Mechanism and Camshaft

14.1 Valve mechanism

14.1.1 Description of valve mechanism

The valve mechanism consists of valve tappets (11) of the piston type moving in separate guide blocks (7) of cast iron, tubular push rods (4) with ball joints, nodular cast iron rocker arms (3) journalled on a rocker arm bearing bracket (13), and a yoke (14) guided by a yoke pin.

Valve mechanism

1. Nut
2. Retainer ring
3. Rocker arm
4. Push rod
5. Protecting sleeve
6. Nut
7. Guide block
8. Cover
10. Guiding pin
11. Valve tappet
12. Bearing journal
13. Bearing bracket
14. Yoke
15. Cylindrical pin
16. Spring

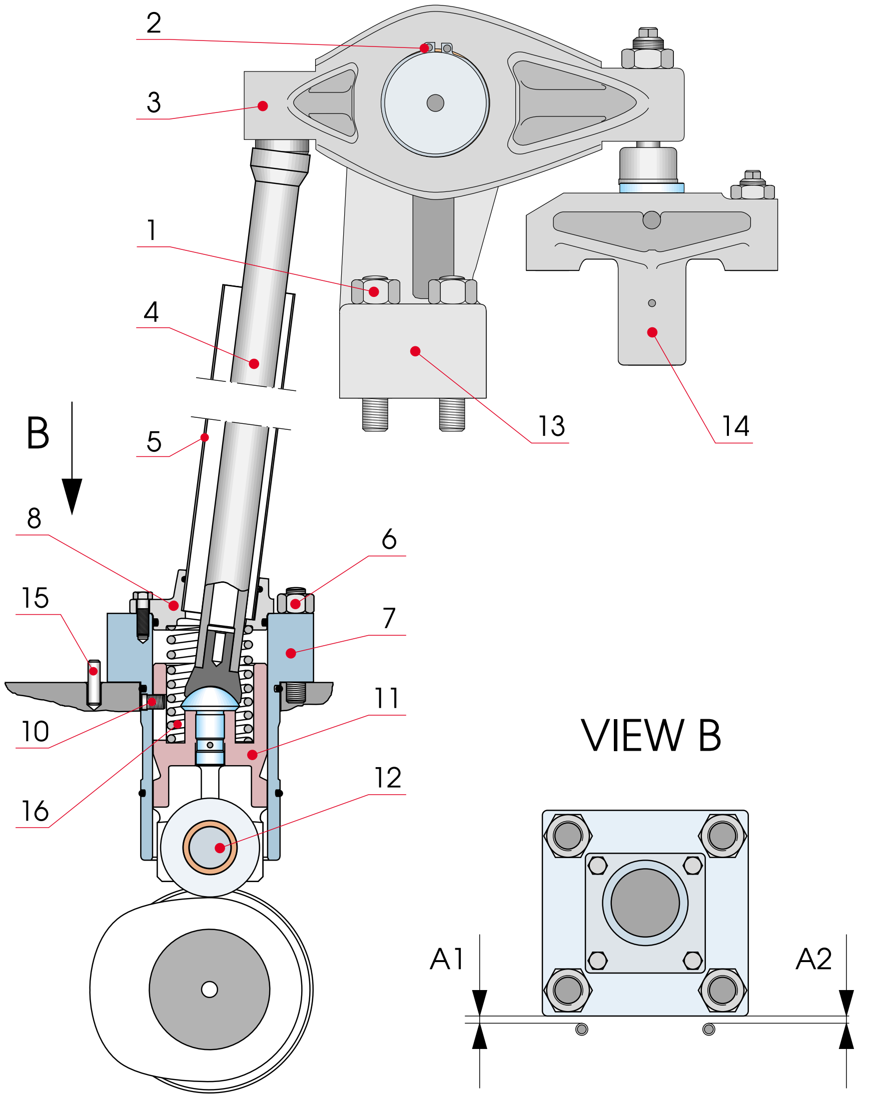


Fig 14-1

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14.1.2 Dismantling of valve mechanism

1 **Remove the covers** of the valve mechanism and camshaft from the cylinder concerned.

2 **Turn the crankshaft** to a position where the valve tappet rollers of the valves are on the base circle of the cam.

3 **Unscrew the nuts (1)** and remove the rocker arm bearing bracket (13) from the cylinder head.

4 **Remove the retainer rings (2)** and rocker arms (3). To remove the retainer rings, use pliers A40 DIN 5254.

5 **Remove necessary pipes.**

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

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

8 **Remove the cover (8)** and the guiding pin (10). An M6 screw can be used to remove the pin.

9 **Remove the valve tappet (11)** and dismantle by removing the bearing journal (12). Before dismantling, mark the parts for mounting into the original positions.

14.1.3 Inspection of valve mechanism parts

1 **Clean the rocker arm bearing bush** and the journal and measure for wear. When cleaning, pay special attention to the oil holes.

2 **Clean and inspect all parts of the valve tappet and guide block.** When cleaning, pay special attention to the angled oil holes.

3 **Measure the valve tappet bearing bush** and the journal as well as the cam roller for wear.

4 **Change the O-rings of the cover (8)** if they are damaged or hard.

14.1.4 Assembling of valve mechanism

1 **Lubricate the parts of the valve tappet** with clean engine oil and assemble. Observe the marks for correct positions.

2 **Insert the valve tappet (11)** into the guide block (7) and apply the guiding pin (10).

3 **Mount the cover (8).**

4 **Mount the guide block** to the engine block and tighten the nuts (6).

5 **Check the parallelism** of the roller axis to the camshaft by measuring the distance to the cylindrical pins on both sides of the guide blocks with a feeler gauge, i.e. measures $A_1 = A_2$ according to Fig 14-1. Tighten the nuts (6) to the right torque, acc. to section 07.1.

6 **Grease the O-rings,** insert the push rods (4) and protecting sleeves (5) into the guide block.

7 **Mount the yoke.** For adjusting the yokes, see section 12.2.4.

8 **Lubricate the rocker arm bearing bushes** and mount the rocker arms (3) on the bracket.

9 **Apply the retainer rings** (2) by using pliers A40 DIN 5254 and check the axial bearing clearance and free rotation of rocker arms.

10 **Mount the rocker arm bracket** on the cylinder head and tighten the nuts (1) to the torque, see section 07.1.

11 **Check the valve clearance** acc. to section 06.1 and mount the covers.

14.2 Camshaft

14.2.1 Description of camshaft

The camshaft is built up of one-cylinder camshaft pieces (1) and separate bearing journals (2). The drop forged camshaft pieces have integrated cams, the sliding surfaces of which are case hardened. The bearing surfaces of the journals are induction hardened. The camshaft is driven by the crankshaft through a gearing at the driving end of the engine. At this end the camshaft is equipped with an encoder (5) and an axial bearings (17).

On a V-engine, B-bank the camshaft has an axial bearing situated at the driving end, similar to A-bank.

Camshaft

1. Camshaft piece
2. Bearing journal
3. Screw
4. Fixing pin
5. Encoder
6. End cover
17. Axial bearing

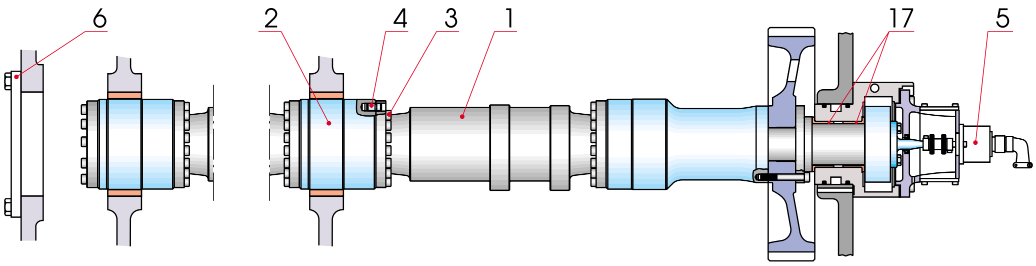

Fig 14-2 3214809720

14.2.2 Removing of camshaft piece

1 Remove the camshaft cover and guide blocks from the cylinder concerned.

2 Unscrew the flange connection screws (3) from both ends of the camshaft piece by using the tool 4V80G17. The flange connection screws are treated with a locking compound and can be used only once.

3 Remove the end cover (6) and unscrew the rocker arm bracket fastening nuts of the cylinders in which the camshaft is to be axially displaced. Move the part of the camshaft locating towards the free end of the engine 15 - 20 mm in direction of the free end by using a suitable lever.

4 Disengage the camshaft piece from the centerings and fixing pins (4) and remove it sideways.

Note! The rocker arm bearing brackets towards the free end side has to be removed if the crankshaft is turned, otherwise there will be contact between the valve and piston.

14.2.3 Mounting of camshaft piece

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

2 Insert the fixing pins (4) with retainer rings, the longer part of the pin in the bearing journal.

3 Mount the camshaft piece (1) on the fixing pin and centering at either end, then press the camshaft together. Use two or three mounting screws, not the fastening screws, because they are applied with locking glue.

4 Insert the flange connection screws, dry and tighten by using the tool 4V80G17. The flange connection screws are treated with a locking compound and can be used only once.

Note! Tighten the screws immediately to correct torque since the screws are treated with a locking compound.

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

6 Mount the end cover (6), guide blocks etc.

7 Check the valve clearances on all cylinders towards the free end.

15. Turbocharging and Air Cooling

15.1 Description

The turbochargers are of the axial turbine type. The insert type charge air cooler is mounted in a welded housing, which, at the same time, serves as a bracket for the turbocharger. The housing is fastened to the engine block by screws, normally at the free end of the engine. V-engines have two identical cooler inserts in a common housing.

The turbocharger is connected to the engine lubricating oil system.

The air outlet is connected to the air duct (2) with metal bellows (1). The exhaust pipes from the engine are also connected to the charger through metal bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions.

The turbocharger is equipped with cleaning device for cleaning the compressor by water injection. On Wärtsilä® 32DF engines the turbine side is also equipped with cleaning device.

Turbocharger and air cooler

1. Bellows
2. Air duct
3. Air vent screw
4. Header
5. Header
6. Drain pipe
7. Thread hole for lifting tool
8. Screw
9. Sleeve

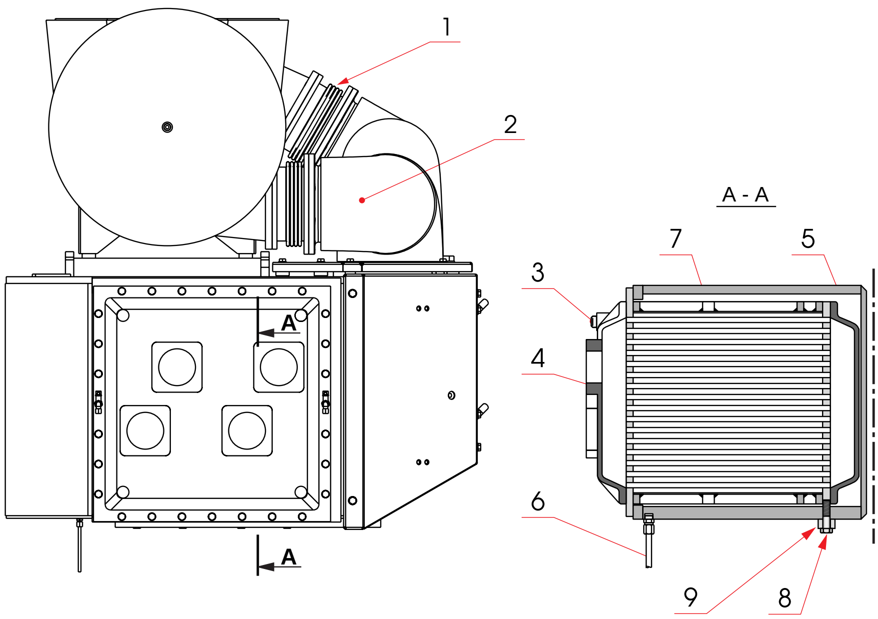

Fig 15-1

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15.2 Turbocharger maintenance

The bearings of the chargers are lubricated by the engine lubricating oil system. The oil drain is connected to a pipe from where the oil is lead to the crankcase.

Normal overhauls can be carried out without removing the whole unit 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.

Maintenance of the turbocharger is carried out according to section 15.3 and to the instructions of the turbocharger manufacturer. It is recommended to use the service organisation of the engine manufacturer or the turbocharger manufacturer.

15.3 Water cleaning of turbocharger during operation

15.3.1 Water cleaning of turbine

Water cleaning instuctions for the turbine doesn't concern Wärtsilä®34SG engines.

As practical experiences show, the dirt deposits on the turbine side can be reduced by periodic cleaning (washing) during operation. The overhaul periods can be extended. Dirty turbines cause higher temperatures of the exhaust gas and higher stresses of the bearings due to imbalances. Usually, though, washing of the turbine side is necessary only when running on heavy fuel.

During long periods of operation, periodic water cleaning prevents the build-up of significant deposits on the turbine blades and nozzle blades. This cleaning method does not work on very dirty turbines which have not been washed regularly.

If the normal water cleaning of the turbine does not effect much on the exhaust gas temperature level, hard deposits have probably built up on the nozzle ring and the turbine blades in the turbocharger, and they have to be cleaned mechanically. For that purpose, the rotor and the nozzle ring have to be removed from the turbocharger.

The water must be injected into the exhaust system with the engine running at reduced output (see 15.3.2, step 2). The disadvantages of reducing the output occasionally is not significant compared with the advantages of cleaning.

The necessary water flow is basically dependent upon the volume of gas and its temperature. The flow should be adjusted so that the major part of the water is evaporated and escapes through the exhaust.

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

Turbocharger gas inlets are provided with an inlet valve (1), one for each bank. The valves are connected to a quick-coupling (2).

The water washing of the turbine should be done as described in section 15.3.2. The water flow is adjusted by a flow meter (4) to the recommended value, see table below.

Water cleaning of turbine	
Pressure difference Δp [(1)]	0.5...1.0 bar
Turbocharger size	**Water flow (l/min)**
HS5800	16 - 19 [(2)]

[(1)] Pressure difference between water injection pressure and gas pressure before turbine.
[(2)] Depends on the water injection pressure and gas pressure before turbine (engine load).

Cleaning should take place regularly according to chapter 04. Maintenance Schedule. Depending on the results obtained, the interval between two washings can be increased or reduced.

Water cleaning of turbine

1. Inlet valve
2. Quick-coupling
4. Flow meter
5. Valve

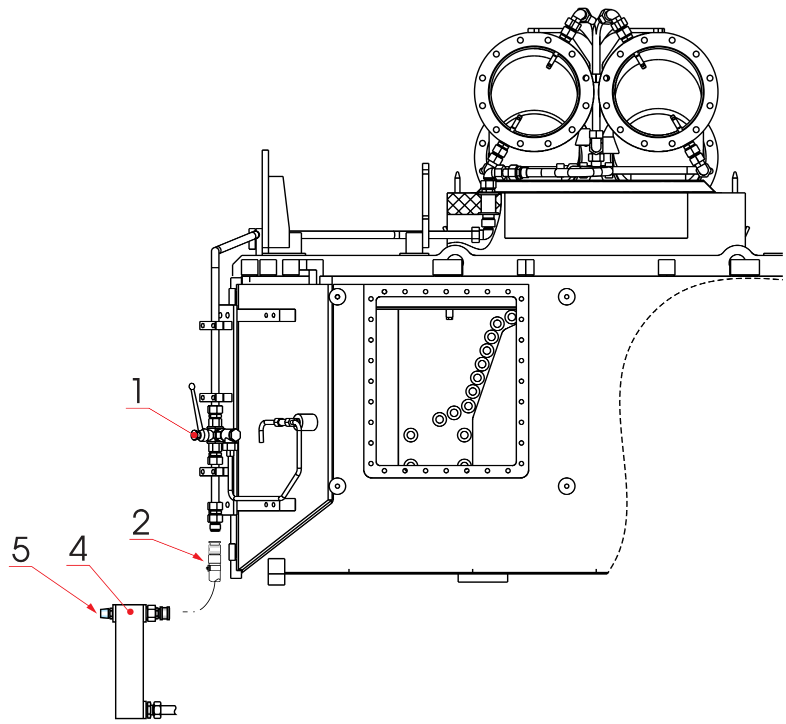

Fig 15-2

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15.3.2 Cleaning procedure

1 **Record charge air pressure,** cylinder exhaust gas temperatures, turbocharger speed, at nominal load for later use to assess efficiency of the cleaning.

2 **In diesel mode, reduce the engine load** to adapt a **maximum allowed exhaust gas temperature after cylinder of 380°C!** Run the engine in **diesel mode** for 5 - 10 minutes on this load before the washing is started.

Note! **If the washing is started earlier than after five minutes on stable load as above, this might have negative consequences for the turbocharger.**

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

4 **Connect water hose.**

5 **Open valve** (5) slowly within 10 s and increase the water flow until the correct flow is reached according to the table shown above.

6 **Close the valve (1) after 60 seconds.** Interval between injections is 60 sec.

Note! **It is not allowed to inject water more than 60 seconds without breaks because the gas outlet casing do not have drain.**

7 **Repeat the injection procedure five times** at the same gas inlet according the step 6. above.

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

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

10 **Resume normal engine operation** at higher output and, as soon as possible, repeat the readings taken in step 1 above at same load for comparative purposes.

11 **Run the engine for 10 to 20 min. more** after the turbocharger has been cleaned by water. Doing so it is ensured that all the parts in the exhaust system are completely dry.

15.3.3 Water cleaning of compressor

Compressors of type HS5800 and HS4800 can be cleaned during operation by injecting water. The method is suitable, provided contamination is not too far advanced. If the deposit is very heavy and hard, the compressor must be cleaned mechanically.

The injected water does not act as a solvent, the cleaning effect is achieved by the physical impact of the drops on the deposit. It is therefore advisable to use clean water containing no additivities either in the form of solvents or softening agents, which could be precipitated in the compressor and form deposits.

Regular cleaning of the compressor prevents or delays the formation of deposit, but it does not eliminate the need of normal overhauls, for which the turbocharger has to be dismantled.

The water must be injected while the engine is running and at the highest possible load, i.e. at a high compressor speed.

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

For an efficient washing, it is important to inject all the water required within 5 - 10 seconds.

Cleaning should take place according to chapter 04. Depending on the results obtained, the interval between two washings may be increased or reduced.

Water cleaning of compressor

1. Valve
2. Water container
3. Slide valve

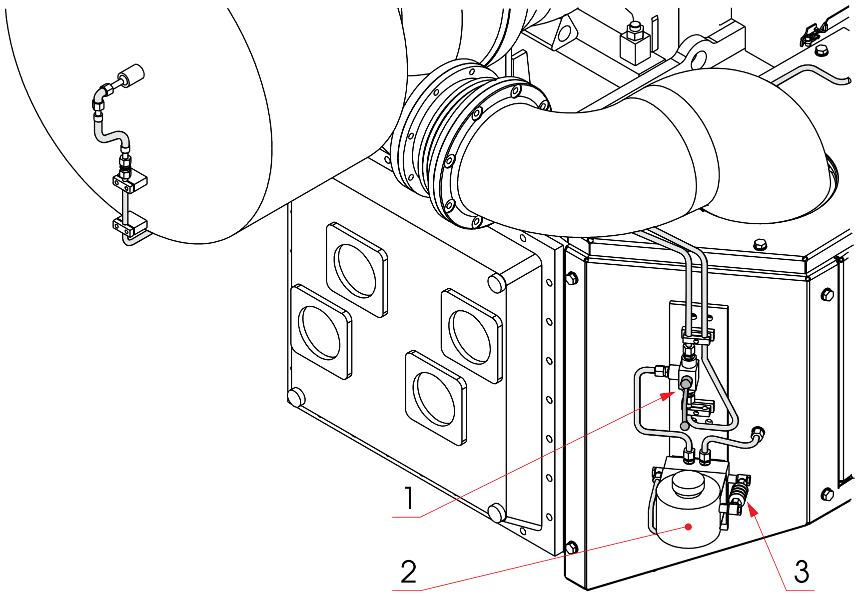

Fig 15-3 321503200105

15.3.4 Compressor cleaning procedure

1 **Record charge air pressure,** cylinder exhaust gas temperatures, charger speed or on gas engines the wastegate position. These for later use to assess efficiency of the cleaning.

2 **Fill the water container (2)** with clean water and close the cover of the water container.

3 **Check and turn the valve (1)** to the choosen compressor.

4 **Open the slid valve (3).**

5 **Close the valve (3)** after 5 - 10 seconds.

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

7 **Run the engine for 5 minutes more** after the compressor has been cleaned with water. Doing so it is ensured that all the parts in the compressor side are completely dry.

8 **Repeat step 1 above** for the other compressor

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

15.4 Maintenance of charge air cooler

15.4.1 General maintenance

1 **Condensate from the air is drained** through a small hole/ pipe (6), Fig 15-1, at the bottom of the cooler housing, after the insert, and at the opposite end plate of the air manifold. Examine regularly that the pipe is open by checking the air flow when running.

If water keeps on dripping or flowing from the draining pipe for a longer period (unless running all the time in conditions with very high humidity), the cooler insert may be leaky and must be dismantled and pressure tested.

2 **At longer stops,** the cooler should be either completely filled or completely empty, as a half-filled cooler increases the risk of corrosion. If there is a risk of that the water level in the system goes down when the engine is stopped, drain the cooler completely. Open the air vent screw (3), Fig 15-1, to avoid vacuum when draining.

3 **Clean and pressure test the cooler** at intervals according to chapter 04. or if the receiver temperature cannot be held within stipulated values at full load.

4 **Always when cleaning,** check for corrosion.

15.4.2 Cleaning of air cooler

Cleaning of the water and air side heat exchange surfaces is imperative for a long and trouble free operation of the engine and must be done at regular intervals.

1 Remove the cooling water pipes. Unscrew the fixing screws (8) at the bottom of the charge air cooler housing, see Fig 15-1. Loosen the cooler flange screws. On the V-engine, withdraw the cooler about 300 mm and fit the tool 32.84G02 (846025). Screw on the tool by using four of the air cooler fastening screws. Then, withdraw the cooler completely towards the tool stop. If necessary, use screws in the two threaded extractor holes in the flange to loosen the cooler.

2 Apply the lifting tool and lift off the cooler.

3 Clean the air side of the cooler by immersing it in a chemical cleaning bath for at least 24 hours. Recommend cleaning detergents, see section 02.4. We recommend that cleaning tank should be equipped with perforated pipes on the bottom for the best cleaning effect, see Fig 15-4. During cleaning steam or pressurised air should be connected to the pipes to get a good circulation.

When cleaning is completed, the cooler should be flushed thoroughly by water.

Note! **The use of a high pressure water jet for flushing, should be avoided because:**
- it will pack the dirt into the middle of the cooler.
- the risk of damaging the cooler fins is great.
Both of above will result in an increased pressure drop over the cooler.

4 Clean the water side by detaching the headers (4) and (5) from the cooler bundle and immersing the tube bundle into a chemical cleaning bath for at least 24 hours. Upon completion, follow the direction given for the air side.

5 Change the gaskets before reassembling the headers.

6 It is also recommended to pressure test the cooler before mounting it on the engine.

7 Mount the cooler on the engine.

8 Vent the cooler and check the tightness when starting up.

Air cooler cleaning tank

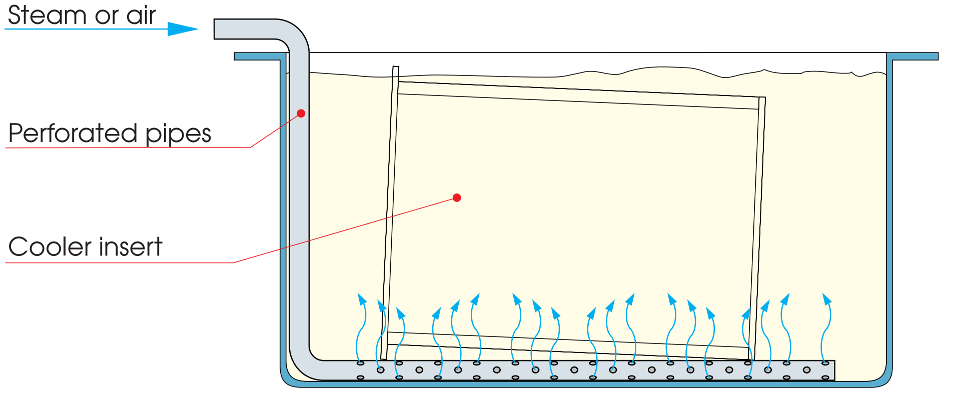

Fig 15-4

3215869701

15.C. Exhaust Gas Wastegate

15.C.0.1 Description

A reliable and safe performance of the engine requires a correct air-fuel ratio during all kind of site conditions. If the air-gas mixture becomes too lean, misfire will occur and if the air-gas mixture becomes too rich, knocking will occur.

To maintain a correct air-fuel ratio, the engine is equipped with an exhaust gas wastegate valve that keeps the air pressure in the receiver at an optimal level all over the power output range. The exhaust gas wastegate valve is by-passing the exhaust gases past the turbocharger. The wastegate valve is working as a regulator and adjusts the air-fuel ratio to the correct value regardless of varying site conditions (ambient temperature, humidity, etc).

The exhaust gas wastegate system is built on the engine and consists of an actuator (1) connected to the butterfly valve (2) which controls the exhaust by-pass flow via pipes (4) and (5) to the distance piece (3) as much as required to get the correct air-fuel ratio according to the preprogrammed values.

Exhaust Gas Wastegate System

1. Actuator
2. Butterfly valve
3. Distance piece
4. Exhaust pipe
5. Exhaust pipe

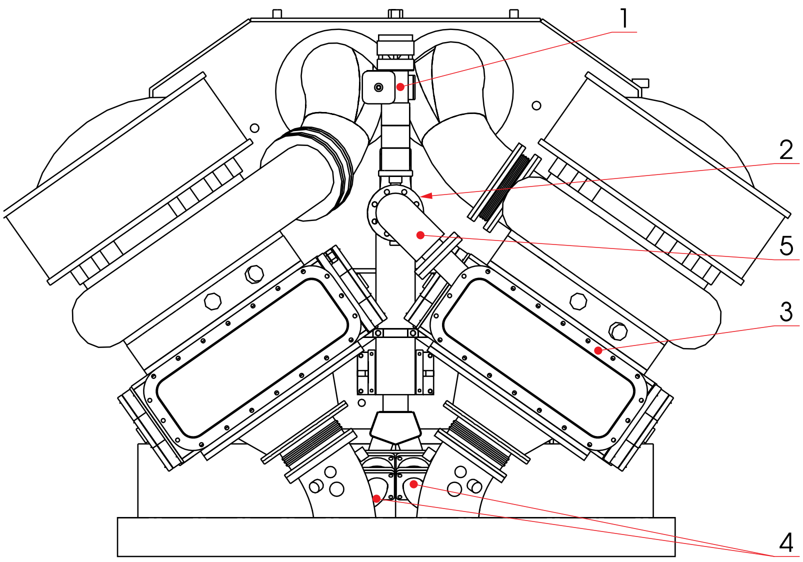

Fig 15C-1

3215909715

15.C.0.2 Function

The wastegate control system gets compressed air from the instrument air system. The pressure is approx. 6 - 7 bar. The instrument air needs to be clean, dry and oil free to secure the function of the components. See also chapter 21.

The wastegate system works as follows:
When the engine is running, the valve (6) is open and supplies air to the I/P converter (8) and to the positioner (9) in the actuator unit (1). The I/P converter maintains a 0.2 - 1.0 bar control air pressure to the positioner according to the incoming 4 - 20mA control signal.
The positioner pilot valve (11), see Fig 15C-4, maintains the actuator (1) with air pressure according to the control air pressure from the I/P converter.

The engine control system (WECS) is monitoring the average exhaust gas temperature after the cylinders. If the average exhaust gas temperature is higher than the set-point, the engine control system will close the wastegate gradually, until tye correct value is reached.

The main purpose of the solenoid valve (6) is to prevent air leakage through the I/P converter to the actuator when the engine is stopped. The control logic is carried out in the engine control system and no external regulators are required

15.C.0.3 Maintenance

15.C.0.3.1 Check of wear of the wastegate system

The systems requires a regular check of the wear and the function.

1 **Check for wear of the key connection** between the actuator and the positioner.

2 **Check for possible wear inside actuator** by moving the shaft.

15.C.0.3.2 Change of positioner pilot valve

The pilot valve (11) in the positioner should be replaced with a new one according to chapter 04 or in case of malfunction.

1 **Remove the cover of the positioner** and the pilot valve screws (12), see Fig 15C-2.

2 **Pay attention to the pilot valve stem** and the lever (13), remove the pilot valve carefully.

3 **Replace the pilot valve (11)** with a new one and re-assemble the positioner in the opposite order.

4 **Adjust the wastegate positioner,** see section 15.C.0.4.

5 **Calibrate the wastegate I/P converter,** see section 15.C.0.5.

6 **Check the function** of the valve by following the positioners movement when the engine is re-started and runs on load.

Wastegate control system

1. Actuator
2. Butterfly valve
6. Solenoid valve
8. I/P converter
9. Positioner

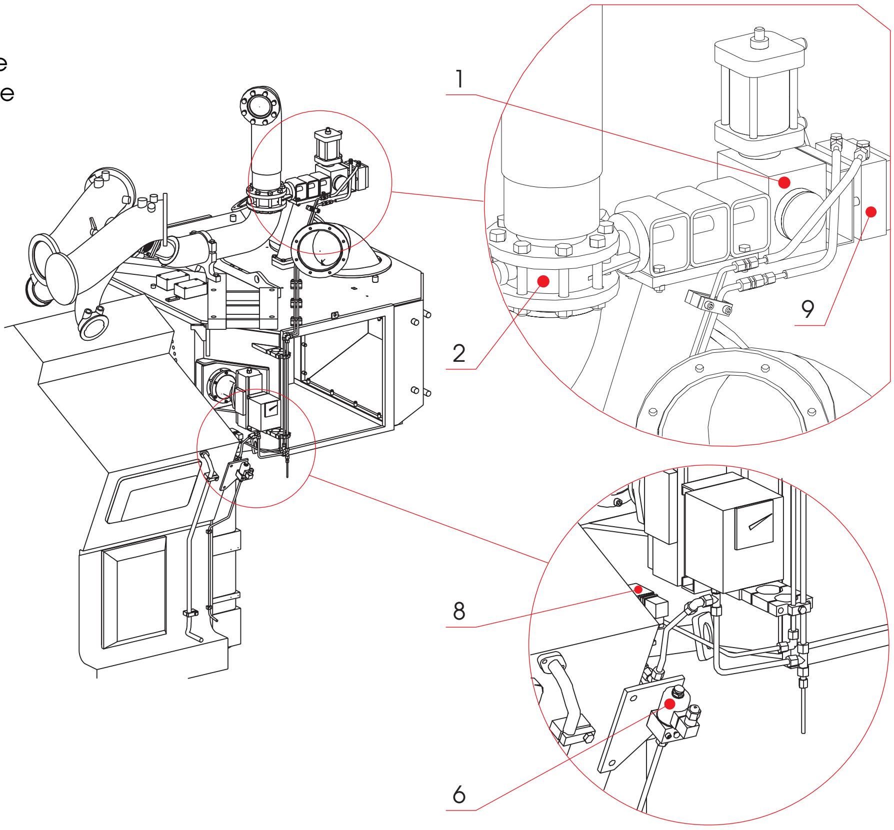

Fig 15C-2

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Actuator position

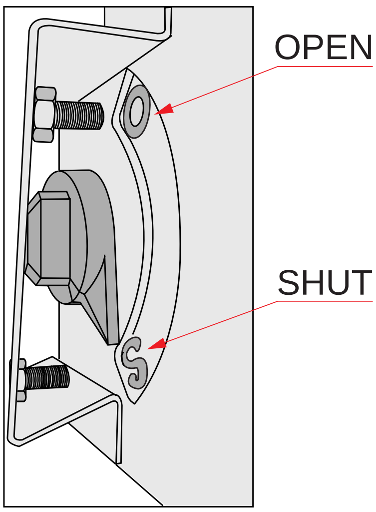


Fig 15C-3

3215106200244

Wastegate positioner

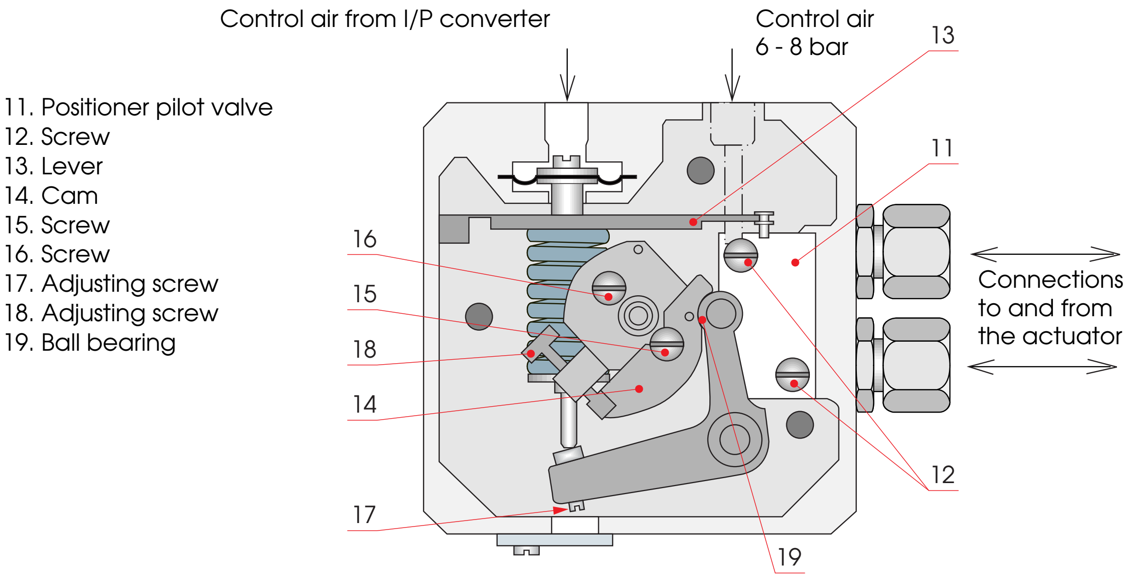


Fig 15C-4 3215100200147

15.C.0.4 Adjustment of wastegate positioner

Remove the cover and the yellow indicator. Make sure the cam (14), is in zero position when the actuator is closed (S-position), see Fig 15C-3.

1 **To adjust the zero position of the cam disc,** loosen the screws (15) and (16) about 1 turn. The cam disc will now go to zero position.

2 **Tighten the screws (15) and (16).**

3 **Calibrate the wastegate I/P converter,** see section 15.C.0.5.

4 **Mount the yellow indicator and the cover.** Indicator reading on the cover should same as on the cam scale (14).

15.C.0.5 Calibrating the wastegate I/P converter

Before starting calibration of the wastegate I/P converter, the wastegate positioner must first be adjusted. See section 15.C.0.4.

The calibration can be done in the following ways:

- Using the software service tool WECSplorer (only for WECS 8000). Contact nearest network office for more information and instructions.
- Using a mA calibrator.

15.C.0.5.1 Manually with mA calibrator (WECS 3000 and WECS 8000)

For the calibration a 4-20 mA current calibrator is needed. Wärstsilä spare part no. 800 119 and 800 120.

1 **The engine must be stopped.**

2 **Enable control air** by connecting 24 VDC to CV311 or by pressing the button on the solenoid (6) (during the whole calibration procedure).

3 **Connect the mA calibrator to the I/P converter.** See Fig 15C-5.

4 **Set the mA to equal 30 degrees on the cam (14).** See table 1 below.

5 **Adjust the zero adjustment screw (20) on the I/P converter** (marked with Z on the coverter) so that the pointer on the wastegate points at 30 degrees.

6 **Set the mA to equal 60 degrees on the cam (14).** See table 1 below.

7 **Adjust the span adjustment screw (21)** (marked with S on the converter) until the pointer points at 60 degrees.

8 **Repeat steps 4-7 above until it shows correct values.**

9 **Check the whole range according to the table 1.** If 4mA does not equal 0 degrees, adjust with the zero adjustment screw.

Table 1.

Degrees (°)	Current (mA)	
	WECS 3000	WECS 8000
0	4,0	4,0
15	6,7	6,4
30	9,3	8,8
45	12,0	11,2
60	14,7	13,6
75	17,3	16,0
90	20,0	18,4

Wastegate I/P converter

20. Zero adjustment screw
21. Span adjustment screw

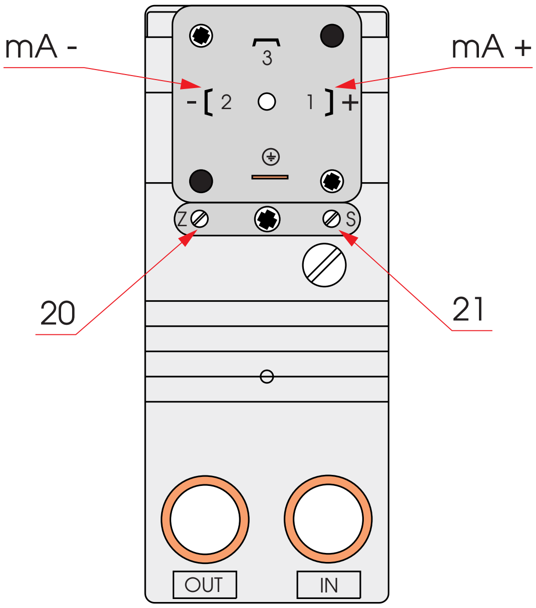


Fig 15C-5

3215105200243

16. Injection and Ignition Systems

16.1 General

The Wärtsilä 34SG is a spark ignited, gas-otto engine working according to the lean burn concept.

In a lean burn gas engine the mixture of air and fuel in the cylinder is lean, i.e. there is more air present in the cylinder than is needed for combustion. In order to stabilize the ignition and combustion of the lean mixture, a prechamber with a richer air/fuel mixture is used. The ignition is initiated with a spark plug located in the prechamber, giving a high-energy ignition source for the main fuel charge in the cylinder.

The prechamber is located in the center of the cylinder head.

Working principle

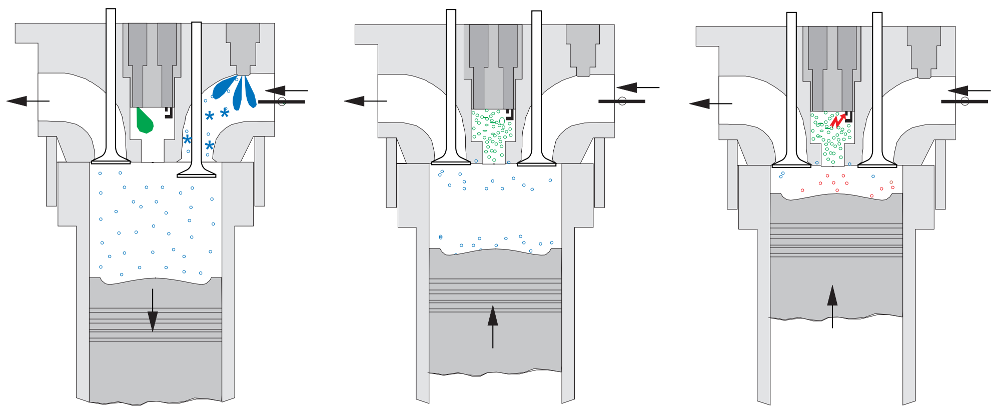


Fig 16-1 3216939548

16.2 Prechamber

16.2.1 Description

The prechamber (13) is casted in a high alloy steel with very good high temperature characteristics, see Fig 16-3. The cooling is optimized to give an even distribution of material temperatures, and to provide the best possible operating condition for the spark plug. A sealing sleeve (6) above the prechamber prevents oil from entering onto the prechamber, and the pipe also houses the high-voltage extension for the spark plug.

16.2.2 Removing the prechamber

1 **Disconnect the cable** from the ignition coil.

2 **Remove the cover plate (2),** ignition coil (3) and the spark plug extension (7) and the springs by opening the screws (1).

3 **Remove the cylinder head cover** and the sealing sleeve (6).

Note! **Drain the cooling system.**

4 **Unscrew the fastening nuts (8)** of the prechamber.

5 **Remove the sleeves (9)** and the yoke (11) for the prechamber.

6 **Remove the prechamber (13)** by using tool 3V83H0176.

7 **Protect the bore** in the cylinder head.

Cylinder head with prechamber

1. Screw
2. Cover plate
3. Ignition coil
4. Fastening plate
5. O-ring
6. Sealing sleeve
7. Spark plug extension
8. Nut
9. Sleeve
10. O-ring
11. Yoke
12. O-ring
13. Prechamber
14. Sealing ring
15. O-ring
16. O-ring

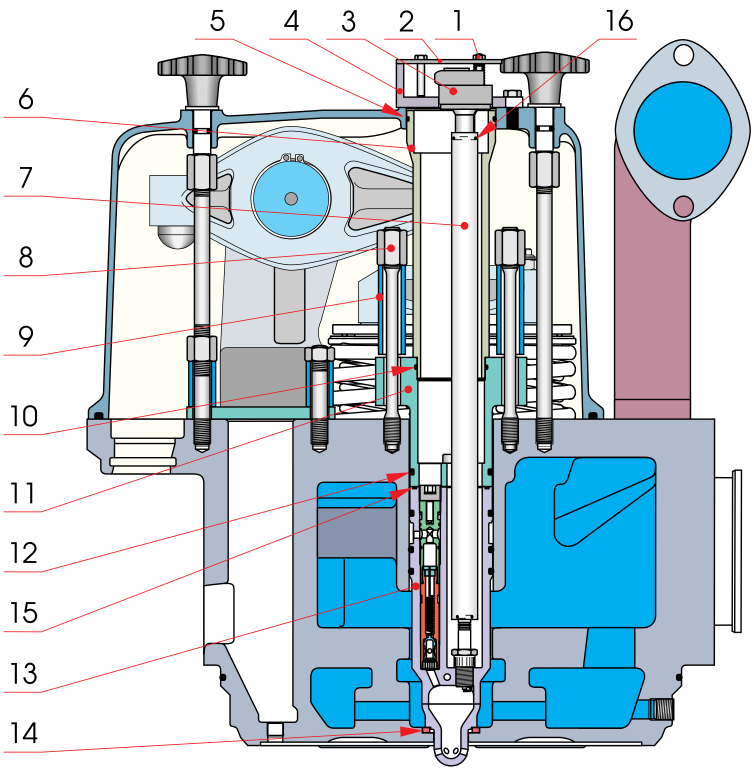


Fig 16-2

3216969720

16.2.3 Overhaul of the prechamber

Clean the prechamber especially the bore for the spark plug. Check the prechamber for cracks and wear, especially around the nozzle holes. Check the sealing faces on the bottom of the prechamber is clean and intact.

Prechamber

7. Spark plug extension
14. Sealing ring
15. O-ring
16. Locking screw
17. O-ring
18. O-ring
19. O-ring
20. Prechamber check-valve
21. Spark plug
22. O-ring

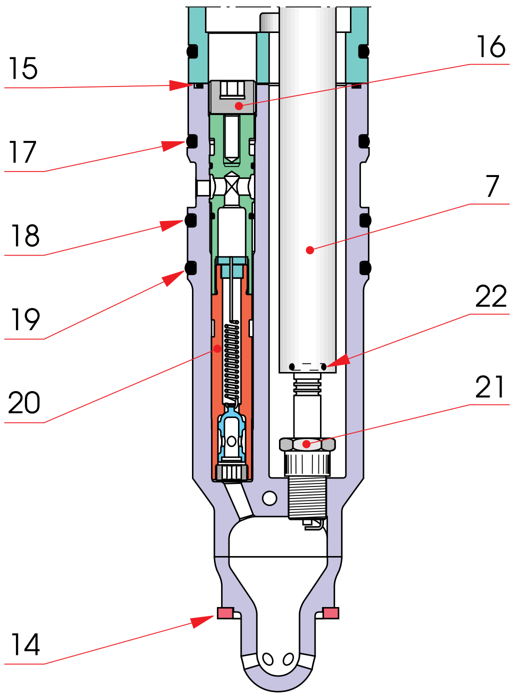


Fig 16-3 3216979720

16.2.4 Mounting the prechamber

1 **Remove the protecting cover** and clean carefully the bore in the cylinder head.

2 **Renew O-rings** (15), (17), (18) and (19) on the prechamber and O-ring (12) on the yoke.

3 **Lubricate O-rings** with oil or vaseline.

4 **Renew seal ring (14) on the prechamber.**

5 **Mount the prechamber,** yoke (11) and sleeves (9) and tighten the fastening nuts (8) crosswise in small steps to stated torque, see chapter 07.

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

7 **Mount the cylinder head** acc. to chapter 12., section 12.2.2.

8 **Renew O-rings (5) and (10)** on the sealing sleeve.

9 **Mount the sealing sleeve (6)** and cylinder head cover.

10 **Renew O-ring (22) on the extension** and O-ring (16) if the extension and ignition coil has been taken apart.

11 **Apply the spark plug extension,** ignition coil, springs, cover plate and tighten the screws. Note! Clean the extension carefully before assembling.

12 **Connect the cable** to the ignition coil.

16.3 Prechamber non-return valve

16.3.1 General description

In order to prevent that the pressure from compression/combustion is entering the prechamber gas supply system, a non-return valve is located close to the prechamber.

Prechamber non-return valve

22. Upper body
23. O-ring
25. O-ring
26. Lover body
27. Piston
28. Plug
29. Spring
30. Guiding pin

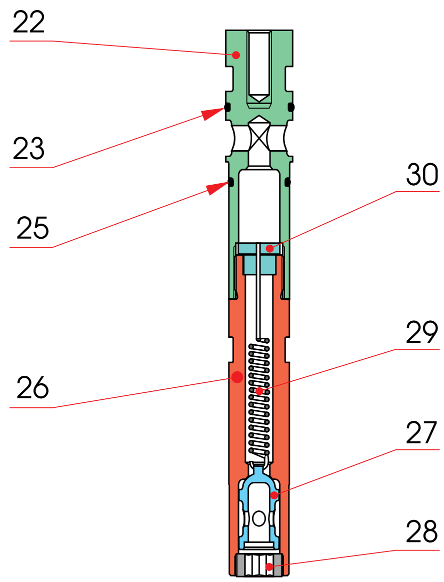


Fig 16-4 3216989549

16.3.2 Removing the non-return valve

1 **Disconnect the cable** from the ignition coil.

2 **Remove the cover plate (2),** ignition coil (3) and the spark plug extension (7) and the springs by opening the screws (1).

3 **Remove the cylinder head cover** and the sealing sleeve (6).

4 **Unscrew the locking screw (16),** see Fig 16-3.

5 **Remove the non-return valve (20)** by using the special tool 3V83H0175.

6 **Protect the bore in the prechamber.**

16.3.3 Overhaul of the non-return valve

1 **Unscrew the upper body (22)** from the lower body (26).

2 **Remove the guiding pin (30).**

3 **Unscrew the plug (28)** in the bottom of the non-return valve.

4 **Remove the piston (27)** and the spring (29) inside the non-return valve.

5 **Carefully clean the piston** and the non-return valve and inspect the sealing surfaces. Inspect the contact surfaces of the spring and change if necessary.

6 **Reassemble the non-return valve** in opposite order. Tighten the lower and upper body to the correct torque, see chapter 07.

Overhaul of non-return valve according to maintenance schedule in chapter 04.

16.3.4 Mounting the non-return valve

1 **Remove the protecting cover** and check that the bore in the prechamber is clean.

2 **Renew O-rings (23) and (25)** on the non-return valve.

3 **Lubricate O-rings** with oil or vaseline.

4 **Mount the non-return valve** and tighten the locking screw (16) to stated torque, see chapter 07.

5 **Mount the cylinder head cover.**

6 **Apply the spark plug extension and** ignition coil in a one package. Apply springs, cover plate and tighten the screws.

7 **Connect the cable** to the ignition coil.

16.4 Ignition system

16.4.1 General

The ignition system is tailor made for this engine type, and is integrated with the engine control system. The control system (WECS) determines the timing of the spark and the timing can be set individually for the cylinders. The ignition coil is located on the top of the cylinder head cover, as close to the spark plug as possible.

The high voltage link between the ignition coil and the spark plug is a stiff, super isolated extension (7), with no joints, see Fig 16-2. This is effectively minimizing the possible disturbances on the ignition system. The spark plug (21) is of a large and durable design, see Fig 16-3.

16.4.2 Ignition coil

16.4.2.1 Removing and mounting of the ignition coil

See sections 16.2.2 and 16.2.4.

16.4.2.2 Overhaul of the ignition coil

The ignition coil requires no maintenance. The ignition coil should be replaced by a new coil in the event of malfunction.

16.4.3 Spark plug

16.4.3.1 Removing the spark plug

1 **Remove the ignition coil** and the spark plug extension (7), see section 16.2.2.

2 **Loosen the spark plug (21)** with the special tool. If it is difficult to loosen, apply penetrating oil.

3 **Unscrew the plug by hand.** If the spark plug seems tight when unscrewing it may be due to deposits in the threaded area. The threads must be cleaned before installing a new spark plug.

4 **Before removing the plug,** blow away the dirt from the spark plug recess to prevent it from falling into the combustion chamber.

5 **Mark the spark plug with the cylinder number** and when all spark plugs have been removed make a visual check to identify any anomalies. If some spark plugs differs from the rest the components of those specific cylinders should be checked.

16.4.3.2 Overhaul of the spark plug

The spark plug requires no maintenance. The spark plug should be replaced by a new plug in the event of malfunction, or according to the maintenance schedule in chapter 04.

16.4.3.3 Mounting the spark plug

1 **Before installing the spark plugs,** make sure that the spark plugs are clean. Any dirt, oil or grease can cause misfire and/or shorten the spark plug lifetime.

2 **Check that the spark plug threads are clean.** If the threads have to be cleaned, prevent the deposits falling into the prechamber.

Note! If the spark plug is removed but not changed, the gasket always has to be renewed.

3 **Re-install the new spark plug by hand** until it contacts the gasket seat. Install all spark plugs by hand before tightened to the stated torque. By this procedure the spark plug temperature have time to stabilize with the cylinder head temperature.

4 **Tighten the spark plug** by using the special tools to stated torque, see chapter 07.

5 **Renew the O-rings in the extension** and clean the extension carefully.

6 **Apply the spark plug extension** and ignition coil in a one package, springs, cover plate and tighten the screws.

Note! Do not lubricate the spark plug threads. Lubricants will reduce the cooling of the spark plug.

16.4.4 Spark plug extension

16.4.4.1 Removing and mounting of the spark plug extension

See sections 16.2.2 and 16.2.4.

16.4.4.2 Overhaul of the spark plug extension

Carefully clean the spark plug extension and replace by a new one if the extension has indications of cross-over or cracks.

17. Fuel System

17.1 General description

Before the gas is supplied to the engine it passes a gas regulating unit. The unit includes filter, pressure regulators, shut-off valves and ventilating valves. The unit have separate outlets for main gas and prechamber gas. The outlet gas pressure is controlled by the control system (WECS) according to engine load and site ambient conditions. As the gas regulating unit can vary from one installation to another, this unit is not described in detail in this manual. See separate instructions.

Gas fuel system

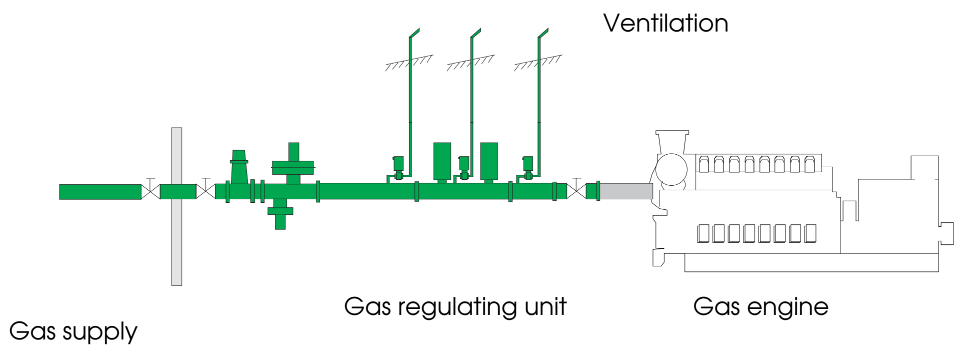


Fig 17-1 3217689801

On the engine the gas is supplied via a common pipe running along the engine, continuing with individual feed pipes to each cylinder. Separate pipes are used to feed the gas to the prechambers.

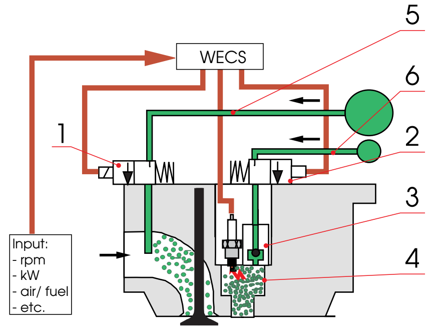
The gas admission is controlled with “Main Gas Admission Valves” for the main charge and with “Prechamber Control Valves” for the prechamber gas. Both valves are direct actuated solenoid valves and controlled by the control system (WECS). In addition a check valve is located in the prechambers to prevent a back-flow into the gas supply line.

Main and prechamber gas pressures at the engine can be checked from the local display unit. Alarms are set for low pressure difference between charge air pressure and the gas pressures.

The prechamber is described in chapter 16.

Gas admission system

1. Main gas admission valve
2. Prechamber control valve
3. Check valve
4. Prechamber
5. Gas hose for main gas valve
6. Gas pipe for prechamber valve
7. Distributing pipe for main gas valves
16. Connection piece



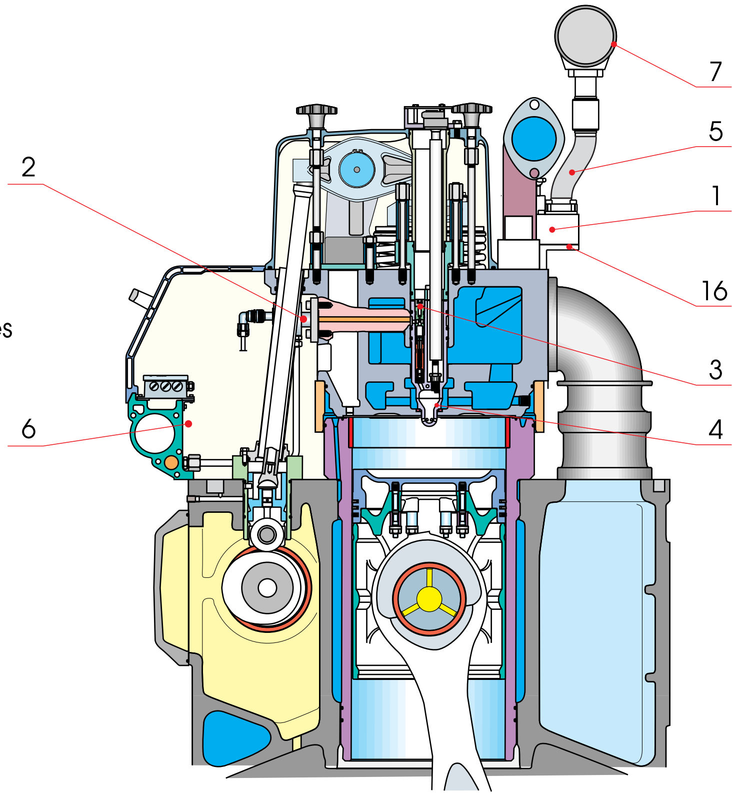


Fig 17-2 3417700242

17.2 Maintenance

When working with the fuel system, always observe utmost cleanliness. Pipes, gas valves, check valves, components in the gas regulating unit, etc. should be carefully cleaned before taken into use.

Note! **Before doing any maintenance work, check that gas supply valves are closed, vent valves are in open position and gas pressure is drained out from the gas lines.**

17.3 Gas pipes

Both A- and B-bank has own distributing pipes which feeding the gas along the engine for the main gas admission valves. Lower part of the side cover includes the separate supply pipes for the prechamber control valves. The gas pipe connections are sealed by O-rings. Always renew the O-rings if a pipe has been removed.

17.3.1 Gas system leak test

1 **Connect compressed air/nitrogen with a pressure** of 3 bar to the inlet flange of the gas system on the engine.

2 **Check all connections** with soap water or leakage spray, beginning from the inlet flange and continuing through the gas line. The last connection on the main gas line is connections between flexible hoses and the main gas admission valves. The last connection on the prechamber gas line are the connections between prechamber admission valves and gas feed pipes.

3 **Growing bubbles on the connection** indicates leakage.

Note! **Release the air pressure in the system before disassembling.**

4 **Disassemble the leaking connection,** examine the O-rings and sealing faces. Replace worn parts.

5 **Repeat the leak test** for the repaired connection(s).

When the engine is running a portable gas leak detector can be used.

17.3.2 Pressure test of the main gas valve

1 **Mount a suitable test prezzurising adapter flange** on the inlet port of the main gas valve.

2 **Connect compressed air of 2 bar** to the adapter flange.

3 **Listen to the outlet of the valve.** If the leakage is inaudible or barely, the valve is OK. If the leakage is appreciable, the valve should be renewed.

17.4 Main gas admission valve

17.4.1 Description

The main gas admission valve is controlling the amount of gas fed to each cylinder of the engine. The valve is located on the cylinder head and the gas is fed into the inlet channel of the cylinder head. The main gas valve is a direct actuated solenoid valve.

With the control system (WECS) it is possible to adjust the amount of gas fed to individual cylinders, even when the engine is running. For further information about engine control, see chapter 23.

Main gas admission valves

1. Main gas admission valve
8. Hose
9. Screw
10. Screw
11. Cable
12. O-ring
13. O-ring

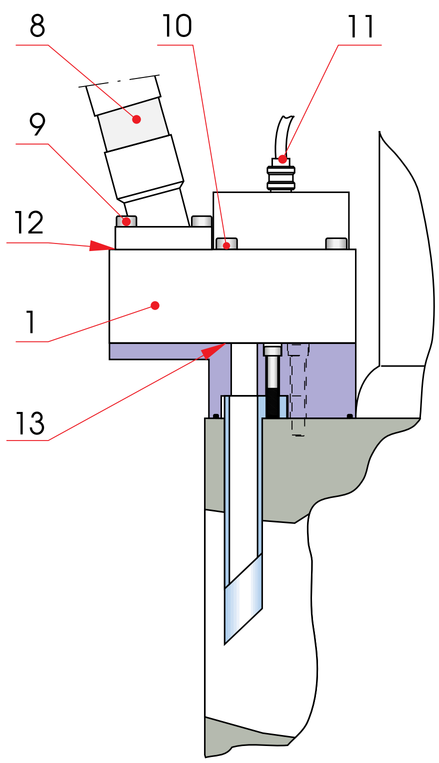


Fig 17-3 3217740241

17.4.2 Removing the gas admission valve

1 **Check that the gas supply valves are closed,** the gas ventilation valve is in open position and gas pressure is drained out from the gas lines.

2 **Unscrew the fastening screws (9)** of the flexible hose connection piece.

3 **Disconnect the cable (11).**

4 **Unscrew the fastening screws (10)** of the gas admission valve and remove the gas admission valve.

5 **Protect the bore** in the cylinder head and the gas pipe end.

17.4.3 Changing of main gas valve filter insert

On every main gas valve, at the connection to the flexible pipe, an interchangeable gas filter (15) is located, see Fig 17-3.
Replace these filters with new ones according to the maintenance schedule, see chapter 04.

1 **Check that the gas supply valves are closed,** the gas ventilation valve is in open position and gas pressure is drained out from the gas lines.

2 **Unscrew the flexible pipe** fastening screws and remove the pipe (8).

3 **Remove the pipe (8),** replace the gas filter (15) and the O-rings (12) with new ones, see Fig 17-3.

4 **Reassemble the parts** and tighten the screws to torque, see chapter 07.

Main gas admission valve filter

1. Main gas admission valve
8. Distributing pipe
9. Screw
12. O-ring
13. O-ring
14. Seal ring
15. Filter
16. Filter flange

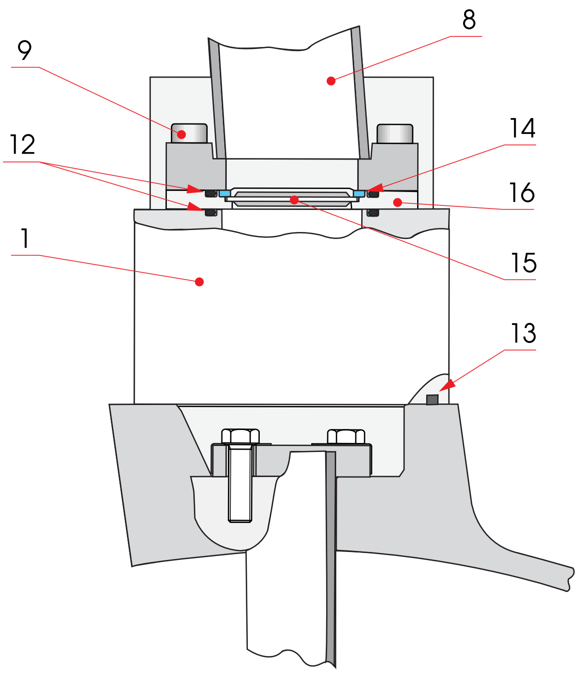


Fig 17-4 3217639548

17.4.4 Overhaul of the gas admission valve

The main gas admission valve requires no maintenance and should preferably be overhauled by authorized personnel.

1 **Unscrew the screws (31)** and remove the coil (24).

2 **Remove the retaining ring (23),** see Fig 17-5.

3 **Carefully remove the valve assembly** with a suitable tool.

Note! **Do not mix the valve parts with other valves parts.**

Caution! **To ensure a trouble free function the valve parts must be kept totally clean and well protected from oil and dust!**

4 **Loosen the screw (22)** keeping the plate (32) in a shielded vice. Be careful not to drop the springs (27).

Main gas admission valve

21. Upper plate
22. Screw
23. Retaining ring
24. Coil
25. O-ring
26. Valve housing
27. Spring
28. Moving plate
29. O-ring
30. Lower plate
31. Screw
32. Plate

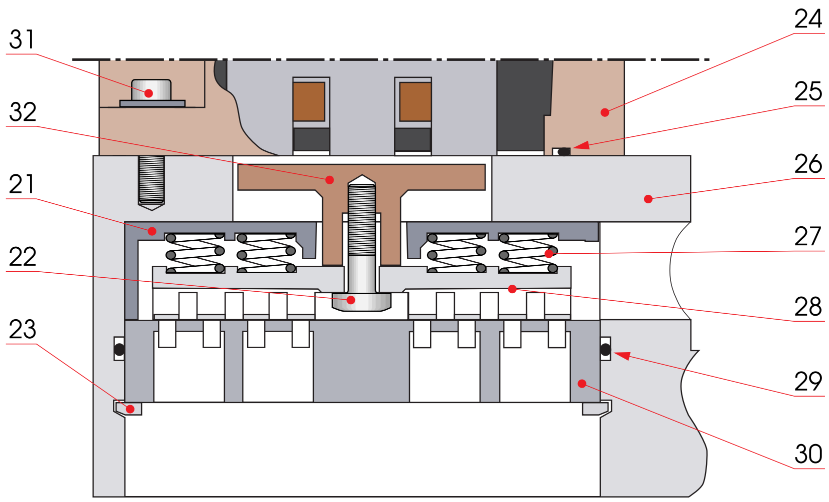


Fig 17-5 3217639548

5 **Check the valve parts** for wear and pay special attention to the sealing surfaces on the moving plate (28) and the lower plate (30). **Renew the complete valve if the sealing surfaces are worn or damaged.**

6 **Renew the screw (22).** Apply one drop of Loctite 271. Mount and and tighten to 20 Nm.

7 **Reassemble the gas valve in the opposite order,** with new O-rings (25) and (29).

17.4.5 Test of main gas valve coil integrity

1 **Measure coil integrity** from one connector pin to the other. At room temperature the coil integrity should be within the following ranges, see table below.

Coil resistance (Low Voltage)	
Type	Resistance
SOGAV105/MS Connector	0.78 - 0.90 Ω

Because of the low resistance, make sure to compensate for the meter lead resistance. If outside this tolerance, the coil assembly should be replaced.

Additional indication of a coil problem can be observed by comparing the coil resistance of a suspect coil to one that is known to be good. This is particularly helpful if the meter's accuracy at low resistance is questionable.

2 **Check for a ground fault.** Measure the resistance from either pin to the solenoid assembly housing. If a low resistance is measured, a ground fault exists and the solenoid valve should be replaced. If a high resistance is measured at first and the reading gradually increases until the meter reading is infinite, the meter has been charging the coils natural capacitance.

17.4.6 Mounting the gas admission valve

1 **Remove the protecting covers** and check that the surface of the cylinder head is clean.

2 **Renew O-rings** (12) and (13) on the gas admission valve, se Fig 17-3.

3 **Mount the gas valve** and tighten the fastening screws (10) to correct torque acc. to chapter 07.

4 **Mount the gas distributing hose** and tighten all fastenings screws for pipe connections (9).

5 **Connect the cable (11).**

17.5 Prechamber control valve

17.5.1 Removing the prechamber control valve

1 **Check that the gas supply valves are closed,** gas vent valve is in open position and gas pressure is drained out from the gas lines.

2 **Remove the side cover.**

3 **Remove the gas feed pipe (6).**

4 **Disconnect the electrical connector (15).**

5 **Unscrew the fastening screws (14)** of the prechamber control valve and remove the valve with the flange.

6 **Protect the bore in the cylinder head** and the hole in the covering structure.

Prechamber control valve assembly

2. Prechamber control valve
6. Gas pipe for prechamber valve
14. Screw
15. Cable connector

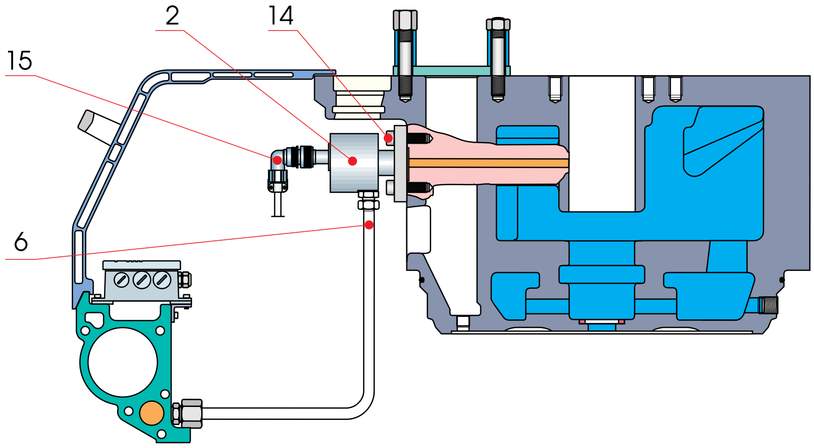


Fig 17-6 3417690242

17.5.2 Overhaul of the prechamber control valve

The main gas admission valve requires no maintenance and should preferably be overhauled by authorized personnel.

1 Unscrew the fastening screws (39) from the flange (37) and dissmantle the valve by removing the screws (35).

2 Check the valve parts for wear and pay special attention to the sealing surfaces. **Renew the complete valve if the sealing surfaces are worn or damaged.**

3 Change the O-rings (34) and (36). Change also the loading springs (33).

Note! **Do not lubricate the O-rings (34) or O-ring grooves.**

4 Reassemle the gas valve and tighten the fastening screws (35) to a torque of 11 Nm.

Prechamber control valve

33. Spring
34. O-ring
35. Screw
36. O-ring
37. Flange
38. O-ring
39. Screw

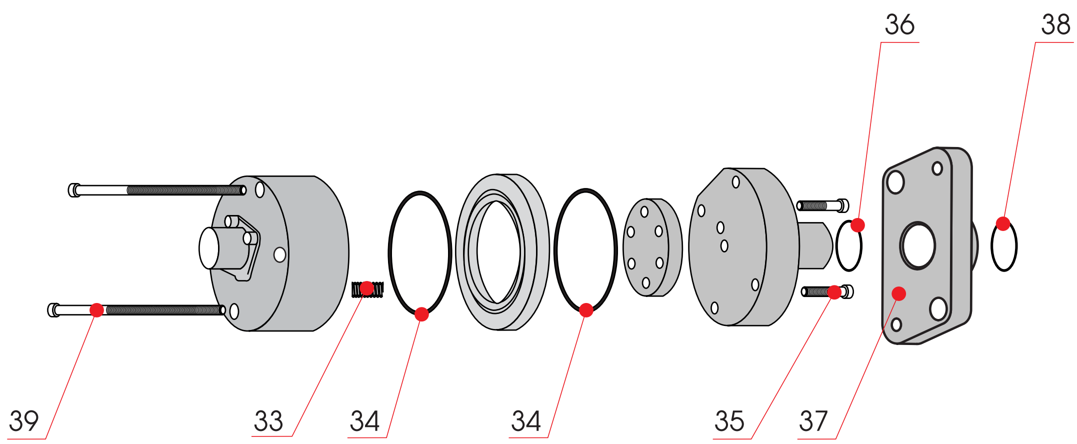


Fig 17-7 3417680242

17.5.3 Mounting the prechamber control valve

1 Remove the protecting covers and check that the sealing surfaces are clean.

2 Renew O-ring (38) on the prechamber control valve.

3 Mount the valve and tighten the fastening screws (14) to correct torque acc. to chapter 07.

4 Mount the gas pipe (6) and tighten the connectors.

5 Connect the electrical connector (15).

18. Lubricating Oil System

18.1 General design

Normally, a wet sump system is used, but also dry sump systems can be used.

The engine is provided with a lubricating oil pump (10) directly driven by the pump gear at the free end of the crankshaft. In some installations there is a separately driven stand-by pump in parallel. The pump sucks oil from the engine oil sump and forces it through the lubricating oil cooler (1) equipped with a thermostat valve (3) regulating the oil temperature, through the lubricating oil main filters (4) to the main distributing pipe (5) in the oil sump, through the hydraulic jacks (in this respect acting as ordinary pipes) to the main bearings and through bores in the connecting rods to the gudgeon pins (6) and piston cooling spaces. Oil is led through separate pipes to other lubricating points like camshaft bearings (7), valve tappets and valves, rocker arm bearings (8) and valve mechanism gear wheel bearings and to oil nozzles for lubricating and cooling. Part of the oil flows through a centrifugal filter back to the oil sump. The oil sump is provided with a level switch connected to the automatic alarm system.

The V-engine is not equipped with a built-on oil cooler nor a filter.

The dry sump system differs from the wet sump system only in that the oil flows freely from the oil sump to a separate tank, and the pump sucks the oil from this tank. (There is also the possibility to mount a second oil pump directly driven by the engine for draining the oil sump to a separate oil tank.)

The electrically driven prelubricating pump is a screw type pump equipped with an overflow valve. The pump is used for:

- filling of the engine lubricating oil system before starting, e.g. when the engine has been out of operation for a long time,
- continuous prelubrication of stopped engine(s) in a multi-engine installation always when one of the engines is running,

In V-engines which have no built-on lubricating oil pump, the prelubrication should be arranged by means of an external pump.

The pressure in the distributing pipe (5) is regulated by a pressure control valve (11) on the pump. The pressure can be adjusted by means of a set screw (Fig 18-2, pos. 17) on the control valve. It is very important to keep the correct pressure in order to provide efficient lubrication of bearings and cooling of pistons. Normally, the pressure stays constant after having been adjusted to the correct value.

A pressure transducer measuring the oil pressure before the engine (in the engine distributing pipe). Transducer is used for measurement of priming pressure, alarm and shut-down for low lube oil pressure (see chapter 23.).

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 (chapter 01., section 01.2). The oil pressure and the oil temperature before and after engine can be checked from the local display unit. An alarm is set for for high lubricating oil temperature (see chapter 23.).

The oil filling opening (12) is located at the free end, and an oil dipstick (13) is located at the middle of the engine.

Connections for a separator are provided on the oil sump at the free end of the engine.

For taking oil sample a valve (15) is available after oil filter.

18.2 General maintenance

Use only high quality oils approved by the engine manufacturer according to chapter 02., section 02.2.

Always keep a sufficient quantity of oil in the system. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level near the max. mark and never allow the level to go below the min. mark. The limits apply to the oil level in a running engine. Add max. 10 % new oil at a time (see chapter 02., section 02.2). One side of the dipstick is graduated in centimeters. This scale can be used when checking the lubricating oil consumption.

Change oil regularly at intervals determined by experience from the installation concerned, see chapter 04. and 02., section 02.2.3.While the oil is still warm, drain the oil system, also the oil cooler and filter. Clean the crankcase and the oil sump with proper rags (not cotton waste). Clean the main filter and the centrifugal filter. Change cartridges in the main filter unless they have been changed recently.

Centrifuging of the oil is recommended, see chapter 02., section 02.2.3.

Utmost cleanliness should be observed when treating the lubricating oil system. Dirt, metal particles and similar may cause serious bearing damage. When dismantling pipes or details from the system, cover all openings with blank gaskets, tape or clean rags. When storing and transporting oil, take care to prevent dirt and foreign matters from entering the oil. When refilling oil, use a screen.

Lube oil system

1. Cooler
4. Lube oil filters
5. Distributing pipe
6. Gudgeon pin
7. Camshaft bearing
8. Rocker arm bearing
10. Lubricating oil pump
11. Pressure control valve
12. Filling opening
13. Oil dipstick
15. Oil sample valve

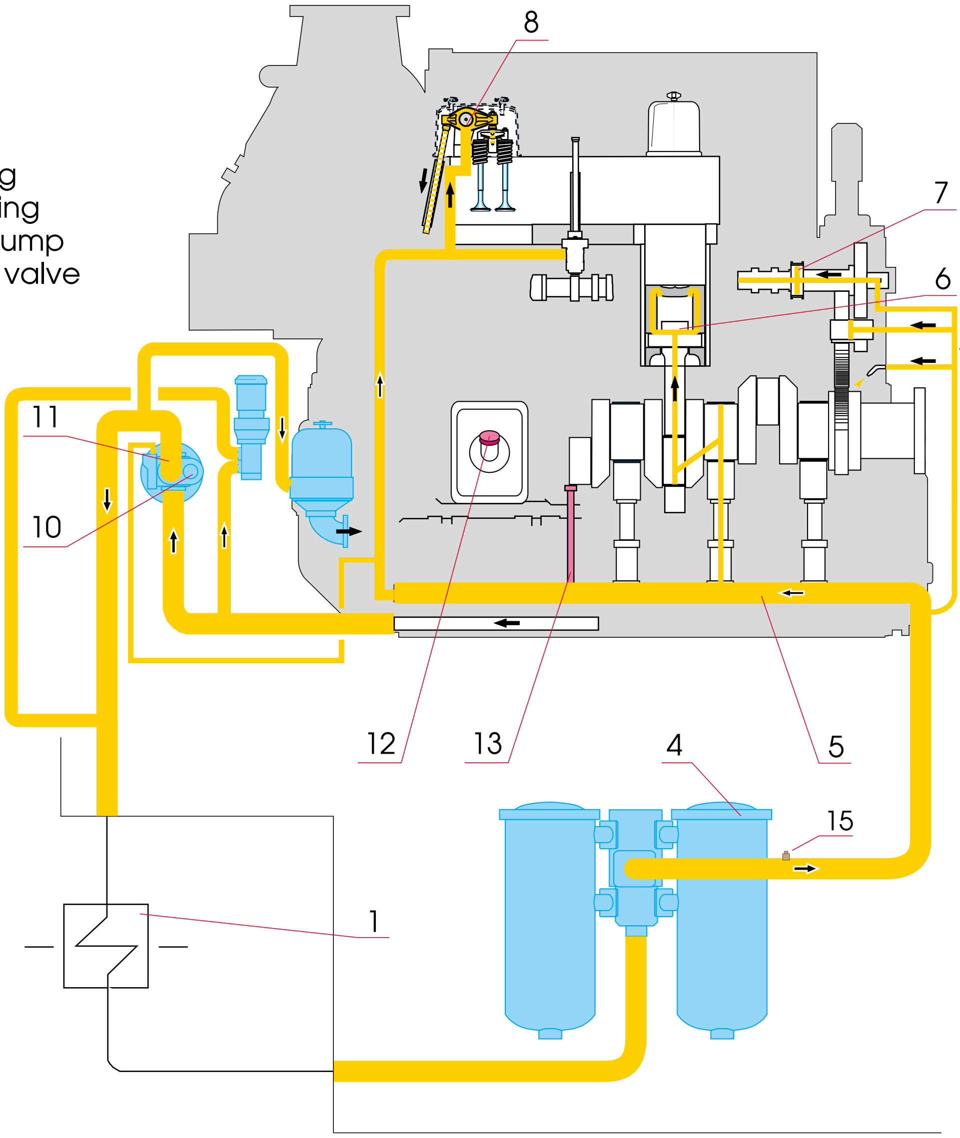


Fig 18-1 3218689601

18.3 Lubricating oil pump

18.3.1 Description

The pump is of the gear type, equipped with a built-on, combined pressure regulating/safety valve. The pump has three pump gears each, and the two-fold pressure and suction spaces are connected by ducts in the pump cover, where the pressure control/safety valve is also located. Identical bronze bearings are used. No outside lubrication is required. The cover is sealed by an O-ring.

Lube oil pump

1. Screw
2. Gear wheel
3. Pressure plate
4. Screw
5. Grooves
6. Pin
7. Cylinder
9. Piston
10. Pipe
11. Sealing ring
12. Ball
13. Drain bore
14. Regulating piston
15. Spring retainer
16. Spring
17. Screw
20. Conical ring elements

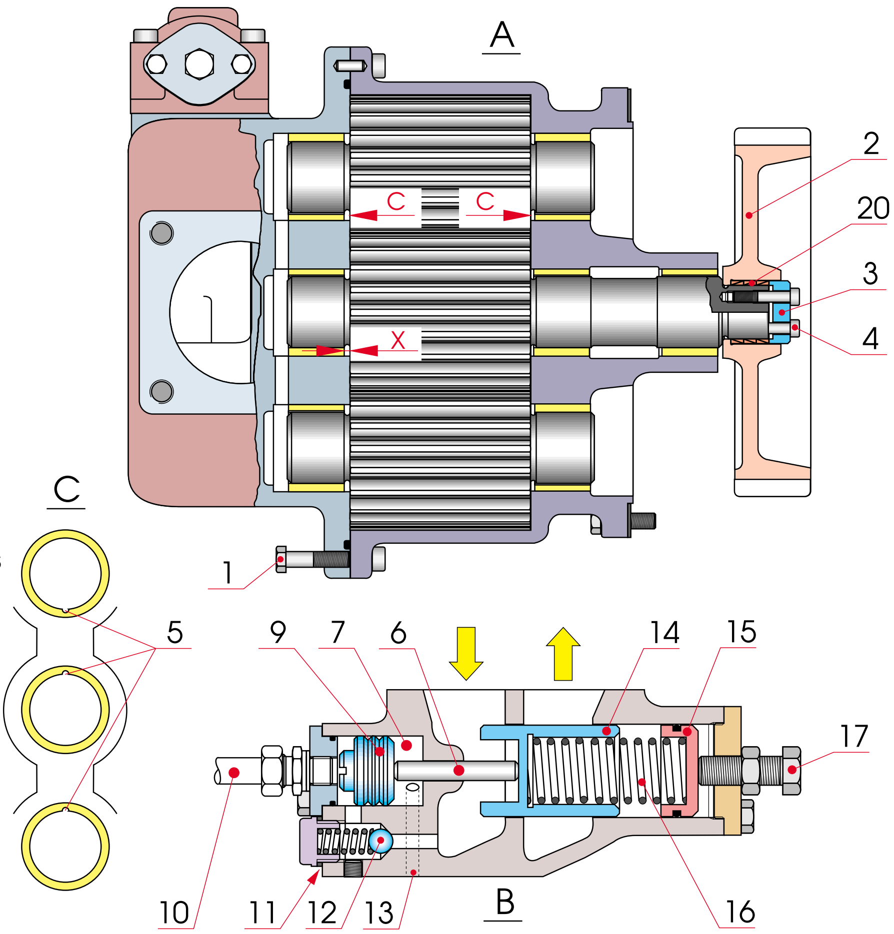


Fig 18-2

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18.3.2 Dismantling

1 **Remove and inspect the regulating valve** according to section 18.4.

2 **Loosen the screws (4)** and remove the pressure plate (3), according to Fig 18-2.

3 **Pull off the gear wheel (2)** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The conical ring elements come loose together with the gear wheel.)

Using an extractor will only damage the shaft (axial scratches).

4 Withdraw the pump cover by using two of the fastening screws (1) in the two threaded holes located in the cover.

18.3.3 Inspection

1 Check all parts for wear (chapter 06., section 06.2) and replace worn parts.

2 Remove worn bearings from the housing by driving them out with a suitable mandrel, from the cover by machining.

3 Mount new bearings (freezing is recommended) so that the bearings are three (3) mm below the cover and housing level (measure X = 3 mm), Fig 18-2 A. Be careful so that bearing lubrication grooves (5) slide into the right position according to Fig 18-2 C.

4 Check the bearing diameter after mounting. Check the gear wheel axial clearance (see chapter 06., section 06.2).

18.3.4 Assembling

1 Clean all details carefully before assembling. Check that the O-ring in the cover is intact and in position.

2 Before re-installing the gear wheel, all contact surfaces should be cleaned and oiled.

3 Re-install the conical ring elements (20).

Re-install the conical ring elements exactly as situated in Fig 18-3. The conical ring elements should fall easily in place and must not jam.

---

4 Re-install the pressure plate.

5 Tighten the screws a little and check that the gear wheel is in the right position.

6 Tighten the screws to torque according to chapter 07.

7 If the gear wheel (2) has been changed, check the backlash after mounting the pump on the engine.

Mounting of gear wheel to oil pump

3. Pressure plate
4. Screw
20. Conical ring elements

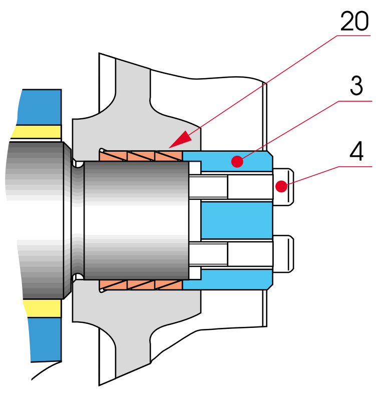

Fig 18-3

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18.4 Lubricating oil pressure regulating valve and safety valve

18.4.1 Description

The pressure regulating valve is mounted on the lubricating oil pump and regulates the oil pressure before the engine by returning the surplus oil direct from the pressure side of the pump to the suction side.

The pipe (10), Fig 18-2, is connected to the engine distributing pipe, where the pressure is kept constant in engines running at constant speed. This pressure actuates the servo piston (9) and the force is transferred to the regulating piston (14) through the pin (6). The spring (16) is tensioned to balance this force at the required pressure. Thus the pressure is kept constant in the distributing pipe, irrespective of the pressure in the pressure side of the pump and of the pressure drop in the system. By tensioning the spring (16) a higher oil pressure is obtained.

In engines which are running at varying speeds, the valve is arranged to give a pressure depending on the speed, according to operating pressures recommended at various speeds (chapter 01).

If, for some reason, the pressure should increase strongly in the pressure pipe, e.g. due to clogged system, the ball (12) will open and allow oil to pass to the servo piston (9), which will open the regulating piston (14) by means of the pin (6).

The valve serves as a safety valve.

18.4.2 Maintenance

1 Dismantle all moving parts. Check them for wear and replace worn or damaged parts by new ones.

2 Clean the valve carefully. Check that the draining bore (13) is open.

3 Check that no details are jamming.

Do not forget copper sealing ring (11) when reassembling. If the sealing's are changed, check that the thickness is correct, (11) = 1.5 mm, as the thickness of these sealing's influences the valve function.

4 After reassembling, check that the piston (14) closes (especially if some details have been replaced by new ones).

18.5 Cooler for lubricating oil

As the oil cooler can vary from one installation to another, this unit is not described in detail in this manual. See separate instructions.

18.6 Thermostat valve

18.6.1 Description

The figure shows the valve in a closed position (left). When the temperature exceeds the nominal value, the contents of the elements (9) expand and force the valve unit (10) towards the seat (11), thus passing part of the oil through the cooler. This movement continues until the right temperature of the mixed oil is obtained. As the cooler becomes dirtier, the temperature will rise a few degrees, which is quite normal, because the valve needs a certain temperature rise for a certain opening to increase the oil flow through the cooler.

Thermostatic valve for oil system

9. Element
10. Valve unit
11. Seat

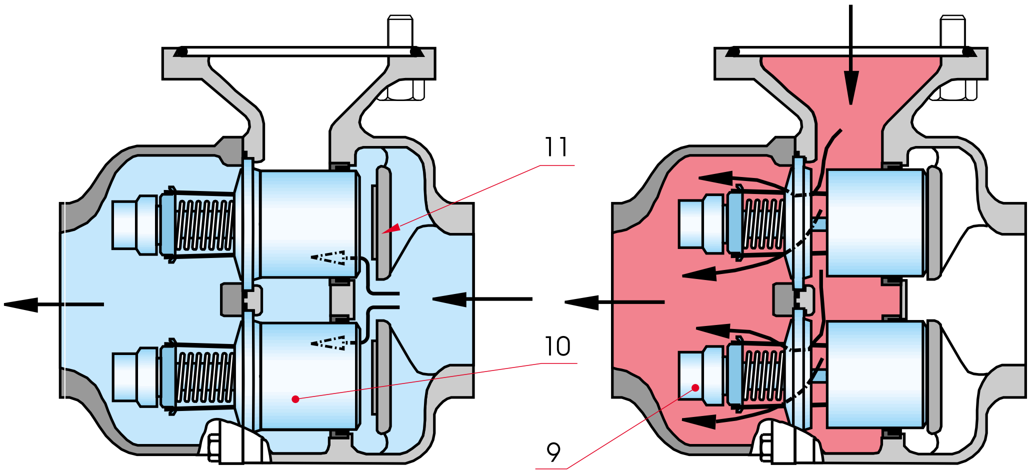


Fig 18-4 3218648932

18.6.2 Maintenance

Normally, no service is required. Too low an oil temperature depends on a defective thermostat. Too high a temperature may depend on defective thermostat, although, in most cases, it depends on dirty cooler.

Remove the elements by unscrewing the pipe after the valve and opening the cover.

Check the element by heating it slowly in water. Check at which temperatures the element starts opening and is fully open. The correct values can be found in chapter 01.; the lower value for lube oil temperature is the opening temperature, the higher for the fully open valve.

Change the defective element. Check O-rings and change, if necessary.

18.7 Lubricating oil main filter

18.7.1 Description

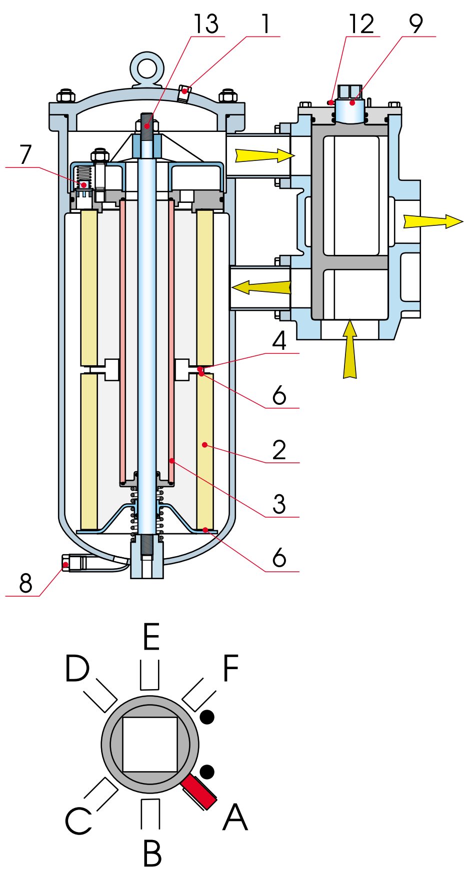
The V-engines can be provided with filters according to Fig 18-5. In that case, 12V34SG has a filter consisting of three filter units connected together. 16V34SG and 18V34SG have four filter units connected together.

The filters are full-flow filters, i.e. the whole oil flow passes through the filter(s). Normally, all filter units should be in operation to provide maximal filtration. When changing a cartridge during operation, one filter half can occasionally be closed.

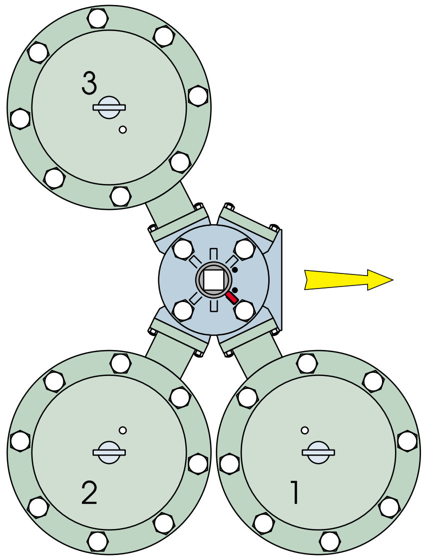
For the V-engine, the pin (12) on the cock (9) shows the direction of the filter unit which is closed according to the table in Fig 18-5.

Lube oil filter for V-engine

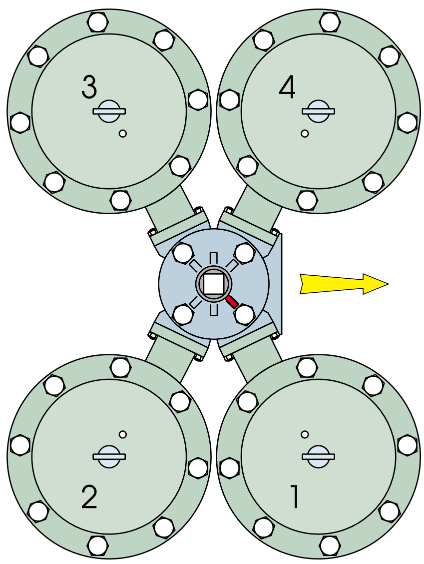
1. Air screw
2. Paper cartridge
3. Cartridge
4. Guide
6. Cartridge end
7. By-pass valve
8. Drain plug
9. Cock
12. Pin
13. Nut



Position	Open	Closed
A	2, 3, 4	1
B	1, 2, 3, 4	
C	1, 3, 4	2
D	1, 2, 4	3
E	1, 2, 3, 4	
F	1, 2, 3	4



12-cylinder engines



16- and 18-cylinder engines

Fig 18-5

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The position of the valve (“position”), which filter units are in operation (“open”) and which one is closed (“closed”) are stated in the table.

The black field states the position of the pin (12). Position B indicates normal operation with all filter units in service. Note that for 12V34SG the filter unit 4 is missing.

The arrows in the figures show the flow through the filters. At first, the oil flows through a cartridge (2), made of special paper, with a nominal fineness of 15 µm, then through a cartridge (3) consisting of a plated wire gauze around a perforated case. The wire gauze insert, with a mesh of 63 µm, serves as a safety filter in case of failure or by-passing of the paper insert.

The filters are provided with by-pass valves (7) over the paper cartridges. The valves open when the pressure drop exceeds 2 - 3 bar.

The filter is provided with a combined visual indicator/electrical switch connected to the automatic alarm system, which indicates high pressure drop over the filter.

The paper cartridges should be changed as soon as possible if a high pressure drop over the filter is indicated.

18.7.2 Changing of filter cartridges and cleaning of filter

Careful maintenance of the filter reduces engine wear. Change cartridges regularly (see chapter 04.) and, if the pressure drop indicator gives alarm, as soon as possible.

As the useful life of the cartridge is, to a great extent, dependent on load, lubricating oil quality, centrifuging and care of centrifugal filter, experience from the installation concerned will give the most suitable intervals between changes of cartridges.

Change of cartridges and cleaning should, if possible, be done during stoppages. By closing one of the filter halves, the cartridge can, however, be changed during operation. As the load on the other cartridges will increase, the change of cartridges should be carried out as fast as possible.

Note! **Release the pressure by opening the air vent screw (1) before the drain plug (8) is opened.**

1 Drain the filter. Open the air vent screw (1) and afterwards the drain plug (8), and discharge oil through the plug (8). **Do not refill the system with drained oil because it is very dirty.**

2 Open the complete cover.

3 Remove the paper cartridges (2) and wire gauze inserts (3). On V-engine filters, open the nut (13).

4 Wash the wire gauze inserts in gas oil and check that they are intact.

5 **Clean and rinse the filter housing** carefully with gas oil.

6 **Change the paper cartridges.** **Paper cartridges cannot be cleaned**. Always keep a sufficient quantity of cartridges in stock.

7 **Check that all gaskets are intact and in position,** especially gaskets against the cartridge ends (6).

Note! **If the filter housing have been divided they must carefully be glued together. New gaskets have to be used and glued to the filter housings (both sides).**

8 **Check that the guide (4) slides into position** when remounting the wire gauze inserts and paper cartridges.

Note! **Do not refill the system with drained oil because it is very dirty.**

18.7.3 Cleaning of the filter by-pass valve

Normally, no regular maintenance is required for the by-pass valve (7), but if malfunction is suspected, the by-pass valve should be cleaned.

1 **Unscrew the plug,** which is holding the by-pass valve slide. On V-engines, remove the insert cover, unscrew the nuts and lift off the flange to have access to the by-pass valve slide.

2 **Withdraw the slide** and wash it with clean diesel oil or similar. If necessary, the slide can be brushed with a brass wire brush.

3 **Clean the slide bore** with a tube brush.

4 **Grease the slide** and check that it moves easily in the bore.

5 **Assemble the safety valve.**

Note! **Handle the slide carefully. The fingers in the end of the slide are easily damaged.**

18.8 Centrifugal filter

18.8.1 Description

A by-pass filter of the centrifugal type is provided as a complement to the main filter. For V-engines two identical filters are used.

The filter comprises a housing (7) containing a hardened steel spindle (2) on which a dynamically balanced rotor unit (3) is free to rotate. Oil flows through the housing, up the central spindle into the rotor.

The rotor comprises two compartments, a cleaning chamber and a driving chamber. Oil flows from the central tube (4) into the upper part of the rotor, where it is subject to a high centrifugal force. The dirt is deposited on the walls of the rotor in the form of heavy sludge.

The oil then passes from the cleaning compartment into the driving compartment formed by the stand-tube (13) and the lower part of the rotor, which carries two driving nozzles (6). The passage of the clean oil through the nozzles provides a driving torque to the rotor and the oil returns through the filter housing to the engine oil sump.

18.8.2 Cleaning

It is very important to clean the filter regularly (chapter 04.) as it collects considerable quantities of dirt. A clean centrifugal filter unloads the main filter, which gives longer lifetime for the paper cartridges.

If it is found that the filter has collected the maximum quantity of dirt (corresponds to an 18 mm thick layer) at the recommended cleaning intervals, it should be cleaned more frequently.

Clean the filter as follows, the engine running, by closing the valve on the oil delivery pipe to the filter:

1 Slacken off the nut on the filter cover clamp (14), unscrew the cover nut (1) and lift off the filter body cover (8).

2 Withdraw the rotor assembly from the spindle (2) and drain oil from the nozzles before removing the rotor from the filter body. Hold the rotor body and unscrew the rotor cover jacking nut (9), then separate the rotor cover from the rotor body.

3 Remove the washer (10) and stand tube (13).

4 Remove sludge from the inside of the rotor cover and body by means of a wooden spatula or a suitably shaped piece of wood.

5 Clean the stand tube.

6 Wash all details, for example in gas oil.

7 Clean out the nozzles with brass wire and compressed air. Examine the top and bottom bearings in the tube assembly to ensure that they are free from damage of excessive wear. Examine the O-ring (15) for damage. Renew, if necessary.

8 Reassemble the rotor complete, align the location pins and tighten the rotor cover jacking nut (9), tightening torque = 100 Nm.

Centrifugal filter

1. Cover nut
2. Spindle
3. Rotor unit
4. Central tube
6. Driving nozzle
7. Housing
8. Body cover
9. Jacking nut
10. Washer
13. Stand-tube
14. Cover clamp
15. O-ring
16. O-ring

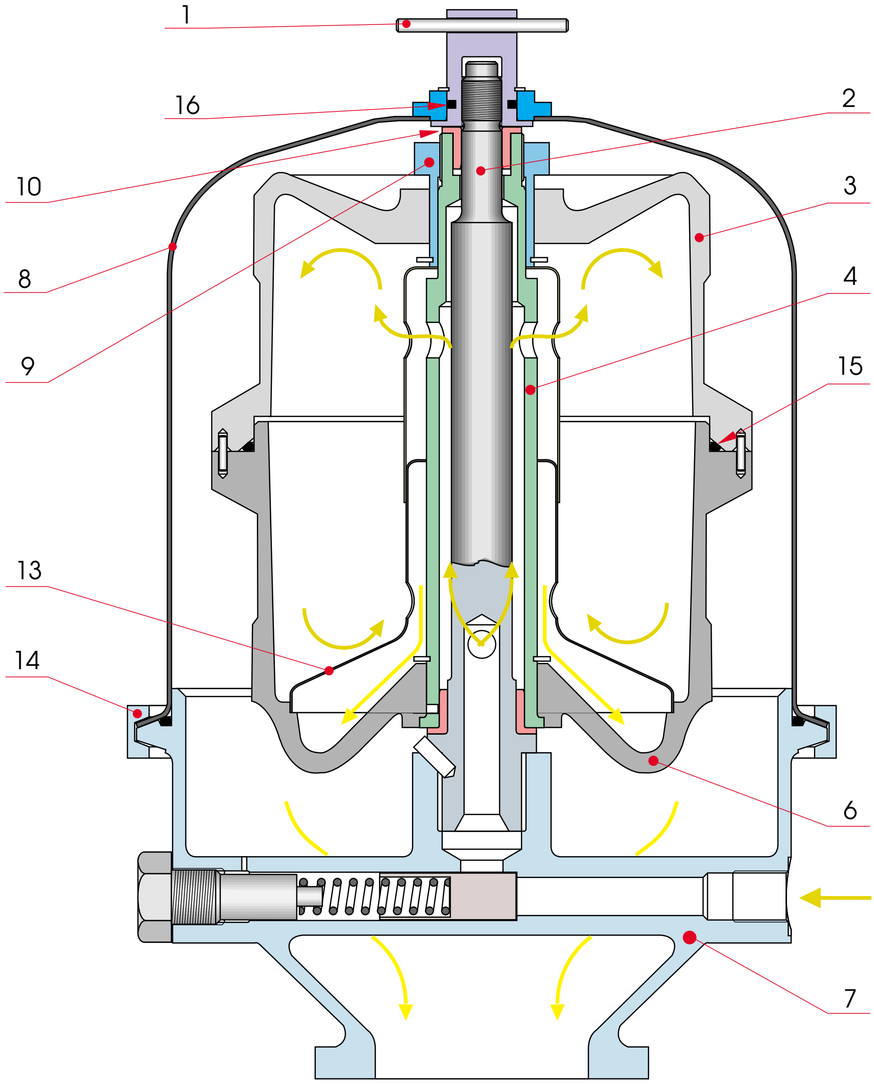

Fig 18-6 3218608932

Over tightening of the rotor cover jacking nut can lead to rotor imbalance, which will effect filter performance.

9 Examine the spindle journals to ensure that they are free from damage or excessive wear. Examine the O-ring (16) for damage. Renew, if necessary.

10 Reassemble the filter complete, checking that the rotor assembly is free to rotate, then replace the filter body cover. Tighten the cover nut and secure the filter cover clamp.

18.9 Prelubricating pump

18.9.1 Description

The pump is of the screw type, driven by an electric motor. The pump is provided with an adjustable pressure control valve (15), Fig 18-7. The pressure should be limited to the min. value, about 2 bar, by unscrewing the adjusting screw (14) to the end position in order to prevent the electric motor from being overloaded when running with very cold oil.

The mechanical type shaft seal consists of two plane sealing surfaces facing each other — one of them (8) rotating with the shaft and the other one (6) being stationary.

18.9.2 General maintenance

See the manual of the manufacturer. Normally, no regular maintenance is required. After three to six years the shaft seal may have to be replaced due to ageing. Oil leaking out of the opening (5) indicates that the shaft seal is defective and has to be changed.

Take care not to damage the sealing ring faces. A slight scratch may disturb the sealing function. The rotating coal ring (8) is very fragile. Avoid touching sealing faces with fingers.

18.9.3 Dismantling

1 **Loosen the pipes and fastening screws (9)** and withdraw the pump.

2 **Draw the coupling half (1)** off the shaft.

3 **Remove the front plate (10)** together with the drive screw (2) and the shaft seal. Place the front plate on two rods, the shaft journal turned upwards.

4 **Remove the drive screw locking ring (3).** Give the shaft journal a few blows with a plastic hammer until the screw is disengaged from the ball bearing. Take care not to damage the screw by dropping it on the work bench.

5 **Remove the sealing ring (8).**

6 **Force the sealing unit (13) off** the drive screw (2). Pressing force may be relatively strong due to the rubber bellows.

7 **Tap the stationary sealing ring (6)** with the O-ring out of the front plate by using a mandrel.

8 **To remove the ball bearing (4)** from the front plate, remove first the locking ring.

Note! **Always clean the ball bearing in fresh gas oil. Protect the bearing when the pump parts are being cleaned as the used washing liquid contains dirt particles that may damage the bearing.**

Prelubricating pump

1. Coupling half
2. Drive screw
3. Locking ring
4. Ball bearing
5. Opening
6. Sealing ring
7. O-ring
8. Sealing ring
9. Screw
10. Front plate
11. Pin
12. O-ring
13. Sealing unit
14. Adjusting screw
15. Control valve
16. Gasket

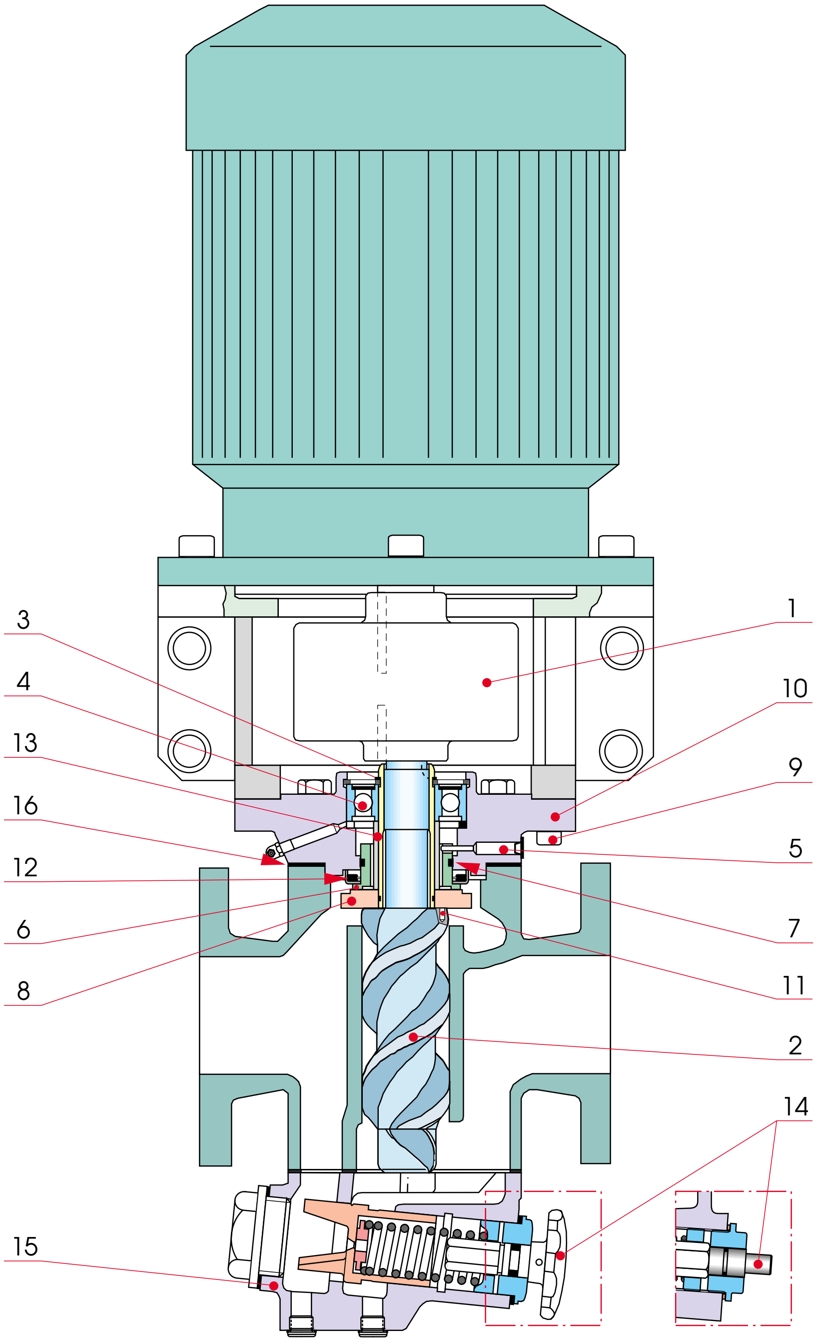

Fig 18-7 3218578932

18.9.4 Reassembly

The reassembly is performed in the reversed order.

1 **Remount the ball bearing** in the front plate, the protective washer turned outwards. Lock with the locking ring.

2 **Oil the O-ring (7).** Insert the stationary sealing ring (6) in the front plate. Take care not to damage the sealing faces and that the ring enters the pin (11).

3 **Clean the drive screw** carefully and enter the sealing unit (13) without the coal ring on to the shaft. Take care that the rubber bellows are pressed against the seal spring, supporting washer. Keep the seal in this position for a moment to enable the bellows to fix. A drop of lubricating oil on the drive screw shaft will facilitate reassembly.

4 **Put the coal ring into position,** the smaller sealing face upwards and the grooves matching the marks.

5 **Place the front plate (10)** over the drive screw shaft journal.

6 **Force the ball bearing inner ring** against its shoulder on the drive screw. Use a suitable sleeve matching the bearing inner ring.

7 **Lock with the ring (3).**

8 **Install the end plate unit** and screw the set in the pump housing. Do not forget the O-ring (12) which seals between the pump housing and the front plate. Fill the ball bearing with grease.

9 **Install the coupling half (1)** on the pump shaft and fasten the pump to the bracket. Check that the clearance between the coupling halves is 2 mm.

10 **If the electric motor has been disconnected or changed,** check that it rotates in the right direction by switching on a few times.

19. Cooling Water System, V-engines

19.1 Description

19.1.1 General

The engine is cooled by a closed circuit cooling water system, divided into a high temperature circuit (HT) and a low temperature circuit (LT). The cooling water is cooled in a separate central cooler.

Cooling water system

1. Expansion tank
2. Venting box
3. Alarm switch
4. Alarm switch
5. Manometer
6. Manometer
7. Charge air cooler
8. LT-water pump
9. HT-water pump
10. LT-temperature control valve
11. HT-temperature control valve
12. Heater
13. Pump
14. Central cooler
15. Lube oil cooler

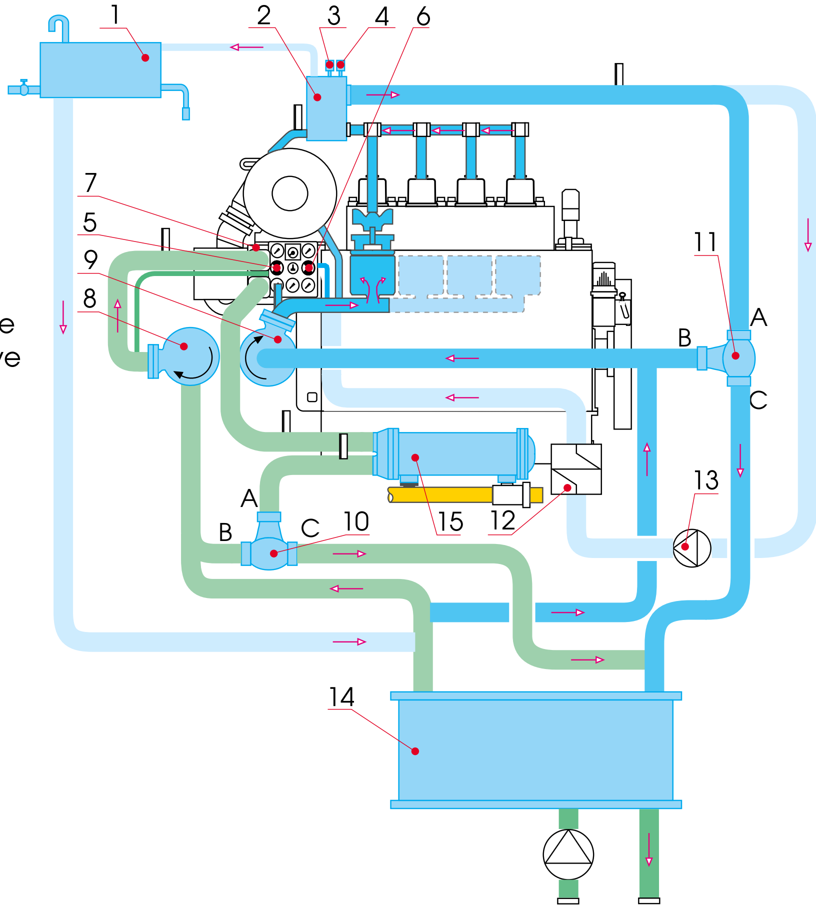

Fig 19-1

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19.1.2 HT circuit

The HT circuit cools the cylinders, cylinder heads and the turbochargers.

A centrifugal pump (9) pumps the water through the HT circuit. From the pump the water flows to the distributing duct, cast in the engine block (in V-engines the water is distributed to the distributing ducts of each cylinder bank through ducts cast into the pump cover at the free end of the engine). From the distributing ducts the water flows to the cylinder water jackets, further through connection pieces to the cylinder heads where it is forced by the intermediate deck to flow along the flame plate, around the valves to the exhaust valve seats, efficiently cooling all these components. From the cylinder head the water flows through a connection piece to the collecting pipe, further to the temperature control valve maintaining the temperature at the right level.

Parallel to the flow to the cylinders, part of the water flows to the turbochargers.

19.1.3 LT circuit

The LT circuit consists of a charge air cooler (7) and a lube oil cooler (15), not mounted on the engine, through which a pump (8), identical to the HT pump, pumps the water. The circuit temperature is controlled by a temperature control valve (10), not mounted on the engine. The necessary cooling is gained from the central cooler (14). The system outside the engine can vary from one installation to another.

19.1.4 Venting and pressure control

The collecting pipes from the cylinder and turbocharger cooling system are connected to a box (2) for venting of the system. From this box the vent pipe leads to the expansion tank (1) from which the expansion pipe is connected to the inlet pipe of the pumps (8 and 9). A static pressure of 0.7...1.5 bar is required before the pumps. If the expansion tank cannot be located high enough to provide this pressure, the system is to be pressurized.

19.1.5 Preheating

For preheating of the circuit, a heater circuit with the pump (13) and heater (12) are connected in the HT circuit before the engine. The non-return valves in the circuit force the water to flow in the right direction.

Before start, the HT circuit is heated up to 70...80°C by a separate heater.

19.1.6 Monitoring

The temperatures mentioned in chapter 01., section 01.2, should not be exceeded.

Ht and LT pressures after the pumps can be checked from the local display unit. The pressures depend on the speed and the installation. Alarms are set for low HT and LT pressure and for high HT water outlet after the engine. Guidance values, see chapter 01., section 01.2.

The HT water outlet after the engine is provided with an alarm switch (3) and a stop switch. Main engines are provided with alarm switches for low HT and LT pressure.

For further information, see chapter 23.

19.2 Maintenance

19.2.1 General

The installation — including expansion, venting, preheating, pressurizing — should be carried out strictly according to the instructions of the engine manufacturer to obtain correct and troublefree service.

The cooling water should be treated according to the recommendations in chapter 02., section 02.3, to prevent corrosion and deposits.

If risk of frost occurs, drain all cooling water spaces. Avoid changing the cooling water. Save the discharged water and use it again.

19.2.2 Cleaning

In completely closed systems the fouling will be minimal if the cooling water is treated according to our instructions in chapter 02., section 02.3. Depending on the cooling water quality and the efficiency of the treatment, the cooling water spaces will foul more or less in the course of time. Deposits on cylinder liners, cylinder heads and cooler stacks should be removed as they may disturb the heat transfer to the cooling water and thus cause serious damage.

The need of cleaning should be examined, especially during the first year of operation. This may be done through one of the plugs in the engine block or by overhauling a cylinder liner and checking for fouling and deposits on liner and block. The cylinder head cooling water spaces may be checked by opening the lower large plugs on the sides of the cylinder heads. The turbochargers can be checked through the covers of the water space and the coolers by removing the water boxes of the inlet water.

The deposits can be of the most various structures and consistencies. In principle, they can be removed mechanically and/or chemically as described below. More detailed instructions for cleaning of coolers are stated in chapter 18., section 18.5.

a) Mechanical cleaning

A great deal of the deposits consists of loose sludge and solid particles which can be brushed and rinsed off with water.

On places where the accessibility is good, e.g. cylinder liners, mechanical cleaning of considerably harder deposits is efficient.

In some cases it is advisable to combine chemical cleaning with a subsequent mechanical cleaning as the deposits may have dissolved during the chemical treatment without having come loose.

b) Chemical cleaning

Narrow water spaces (e.g. cylinder heads, coolers) can be cleaned chemically. At times, degreasing of the water spaces may be necessary if the deposits seem to be greasy (see chapter 18., section 18.5).

Deposits consisting of primarily limestone can be easily removed when treated with an acid solution. Contrarily, deposits consisting of calcium sulphate and silicates may be hard to remove chemically. The treatment may, however, have a certain dissolving effect which enables the deposits to be brushed off if there is only access.

On the market there are a lot of suitable agents on acid base (supplied e.g. by the companies mentioned in chapter 02., section 02.3).

The cleaning agents should contain additives (inhibitors) to prevent corrosion of the metal surfaces. Always follow the manufacturer's instructions to obtain the best result.

After treatment, rinse carefully to remove cleaning agent residuals. Brush surfaces, if possible. Rinse again with water and further with a sodium solution of 5 % to neutralize possible acid residuals.

19.3 Water pump

19.3.1 Description

The water pump is a centrifugal pump and is driven by the gear mechanism at the free end of the engine. The shaft is made of stainless steel, the impeller and the sealing ring of bronze and the remaining details of cast iron.

The shaft is mounted in two ball bearings (13) and (15), which are lubricated by oil entering through the pipe fitting (27). The radial seal (12) prevents the oil from leaking out and, at the same time, dirt and leak water from entering. Also the slinger (11) assists in this.

The gear wheel (17) is fastened to the shaft by conical ring elements (25). When the screws (18) are tightened, the rings exert a pressure between the gear wheel and the shaft. Due to the friction, the power from the gear wheel is transmitted to the pump shaft.

The water side of the pump is provided with a mechanical shaft seal. The ring (3) rotates along with the shaft and seals against it with a protection seal (4) fixed to the ring. The spring (5) presses the rotating ring against a fixed ring (2) which seals against the housing by means of its rubber coat. Possible leak-off water from the sealing can flow out through the opening (9).

Cooling water pump

1. Rear plate
2. Fixed ring
3. Ring
4. Protection seal
5. Spring
6. Screw
7. Impeller
8. O-ring
9. Opening
10. Nut
11. Slinger
12. Radial seal
13. Ball bearing
14. Opening
15. Ball bearing
16. Bearing retainer
17. Gear wheel
18. Screw
19. Pressure plate
25. Conical ring elements
26. Locking screw
27. Pipe fitting

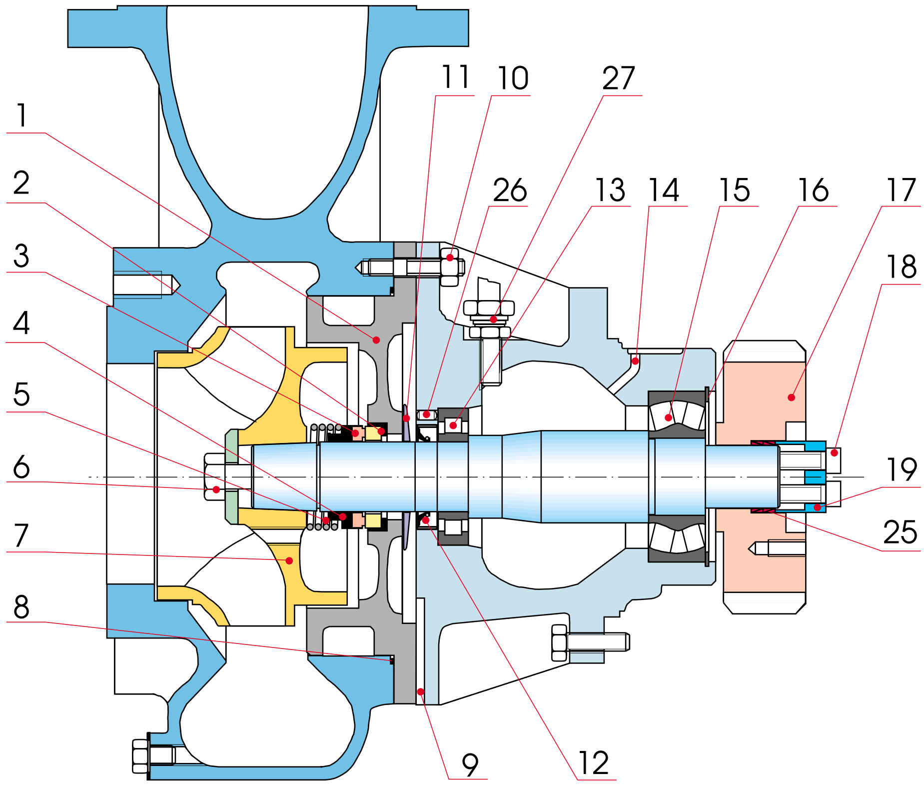

Fig 19-2 3219538935

19.3.2 Maintenance

Check the pump at intervals according to the recommendations in chapter 04. or, if water and oil leakage occurs, immediately.

a) Disassembling and assembling of impeller

1 **Remove the volute casing** by loosening the nuts (10).

2 **Loosen the fastening screws** (6).

3 **Pull off the impeller** by using the tool 32.83H01.

4 **When re-assembling the impeller,** coat the threads with Loctite 242 and tighten the nut to torque, see chapter 07.

5 **Check that the O-ring** (8) is intact and in position when re-installing the volute casing. Check that the volute casing is in position. The opening (14) should be turned upwards when the pump is installed.

If the bearing housing is turned wrongly, the bearings will be left without lubrication. Before mounting the pump on the engine, fill up the bearing housing with oil until oil flows out through the draining holes.

b) **Disassembling and assembling of mechanical seal**

1 **Remove the impeller** according to pos. a) above.

2 **Carefully dismantle all seal details.** Sealing rings are very fragile.

3 **Take particular care** not to damage sealing surfaces as a slight scratch may disturb the sealing function.

4 **Replace the complete seal** if it is leaky, if sealing faces are corroded, uneven or worn. Avoid touching the sealing faces with fingers.

5 **Reassemble the details** in proper order and install the impeller according to pos. a) above

c) **Replacing of bearings**

1 **Remove the pump** from the engine.

2 **Disassemble the impeller** and mechanical seal according to pos. a) and b) above.

3 **Remove the rear plate** (1) by undoing the screws (10).

4 **Loosen the screws** (18) and remove the pressure plate (19).

5 **Pull off the gear wheel** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The conical ring elements come loose together with the gear wheel.)

Using an extractor will only damage the shaft (axial scratches).

6 **Loosen the bearing retainer** (16) and the slinger.

7 **Remove the locking screws (26)** and mount three hexagon screws into the holes. Tighten the screws until the bearings come loose from the housing. Remove the shaft and bearings.

8 **Check the seal** (12) and the bearings for wear and damage, see pos. d) below.

9 **Remove the bearings** from the shaft.

10 **Press the new bearing** (13) by its inner ring with a suitable pipe.

11 **Before fitting the bearing,** oil the collar.

12 **Turn the shaft** according to Fig 19-3.

13 **Fit the distance ring** and oil the collar.

14 **Press the bearing** (15) by its inner ring with a suitable pipe. See Fig 19-3.

15 **Turn the bearing housing** according to Fig 19-3 and oil the outer surfaces of the bearings. Press the shaft into the housing by both the inner and outer ring of the bearing (15) with a suitable pipe.

Mounting of bearings

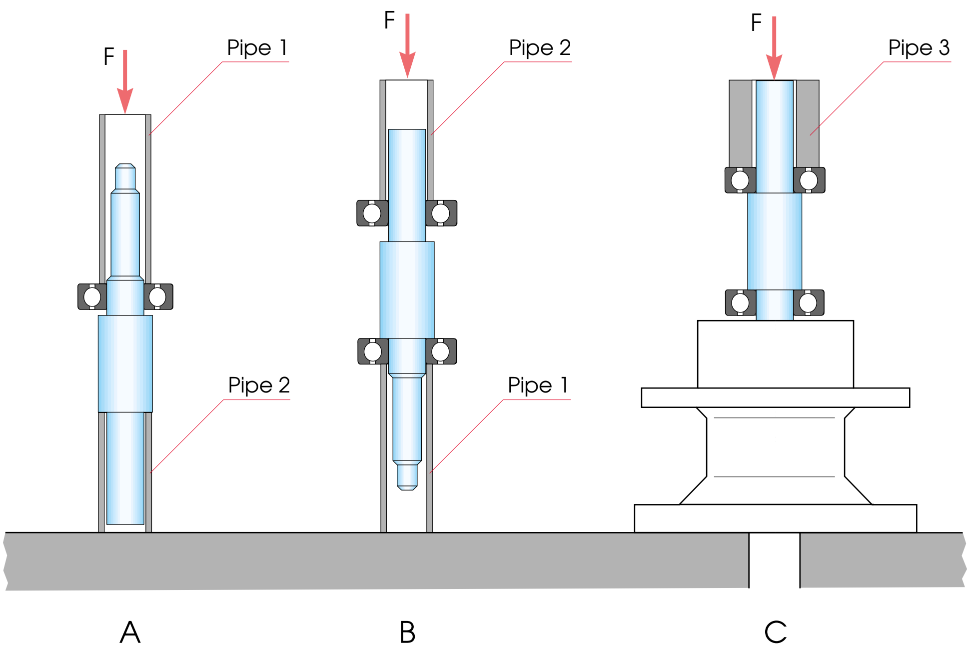

Fig 19-3 3219568935

16 **Fit the bearing retainer** (16).

17 **The axial clearance of the shaft** should be 0.05...0.10 mm. If necessary, use shims between the bearing (15) and the retainer (16).

18 **Before re-installing the gear wheel,** all contact surfaces should be cleaned and oiled.

19 **Re-install the gear wheel.**

20 **Re-install the conical ring elements (25).**

Re-install the ring elements exactly as situated in Fig 19-4.

Mounting of gear wheel to water pump

16. Bearing retainer
17. Gear wheel
18. Screw
19. Pressure plate
25. Conical ring elements

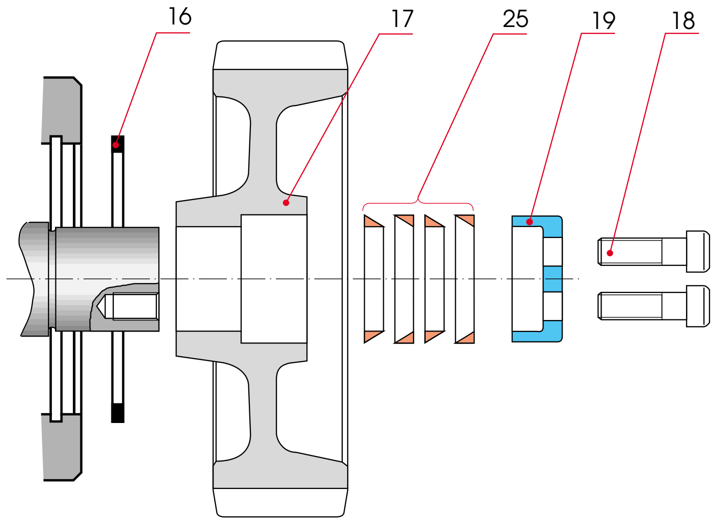

Fig 19-4 3219608935

The conical ring elements should fall easily in place and must not jam.

21 **Re-install the pressure plate** and the screws.

22 **Tighten the screws** a little and check that the gear wheel is in the right position.

23 **Tighten the screws** to torque according to chapter 07.

24 **Re-install the seal** (12), see pos. d) below.

25 **Mount the slinger (11)** and the rear plate (1).

26 **Re-install the mechanical seal,** impeller and volute casing according to pos. a) and b) above.

d) **Replacing of radial seal**

This will be most easily done at the same time as replacing the bearings. If, for some reason, the seal is leaky and there is no need to change the bearing, proceed as follows:

1 **Remove the volute casing** and mechanical seal according to pos. a) and b) above as well as the rear plate (1).

2 **Remove the slinger (11).** Take care not to deform the ring.

3 **Remove the seal (12)** by prying (damaging) without scratching the shaft. In connection with bearing changes the seal can easily be driven out axially.

4 **Inspect the shaft.** In case the seal has worn the shaft by more than 0.5 mm radially, the shaft should be replaced according to pos. c) above.

5 **Oil the new seal** and press it in until it levels with the bearing housing.

6 **Mount the slinger (11)** and the rear plate (1).

7 **Install the mechanical seal,** impeller and the volute casing according to pos. a) and b) above.

19.4 Temperature control system

19.4.1 General description

The LT and HT circuits are equipped with temperature control valves. Temperature ranges according to chapter 01., section 01.2. The valves are normally mounted outside of the engine.

19.4.2 LT and HT thermostatic valve

The thermostatic valve is equipped with positive three-way valve action in which the water is positively made to flow in the direction required. When the engine is started up and is cold, the thermostatic valve causes all of the water to be positively by-passed back into the engine, thus providing the quickest warm-up period possible. After warm up, the correct amount of water is by-passed and automatically mixed with the cold water returning from the heat exchanger or other cooling device to produce the desired water outlet temperature. If ever required, the thermostatic valve will shut off positively on the by-pass line for maximum cooling. The three-way action of the valve allows a constant water flow through the pump and engine at all times with no pump restriction when the engine is cold.

No adjustments are ever required on the thermostatic valve. The temperature is permanently set at the factory. The temperature can be changed only by changing temperature element assemblies which is easily accomplished by unscrewing the housing. The valve is entirely self-contained, and there are no external bulbs or lines to become damaged or broken. There are no packing glands to tighten and no parts to oil.

Water flow in thermostatic valve

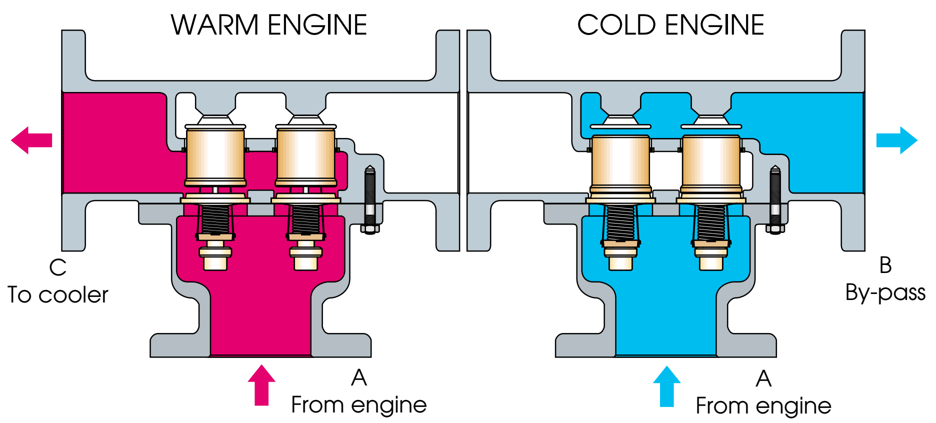

Fig 19-5 3219669250

The power creating medium utilizes the expansion of the element contents (9), which remains in a semi-solid form and is highly sensitive to temperature changes. Most of the expansion takes place during the melting period of approximately two minutes over a temperature change of approximately 8.5°C.

The thermostatic valve is provided with two or more elements (10), depending of the engine size. If failure of one element occurs, the remaining elements will take over with only a slight change in operating temperature. Since flow is diverted either to by-pass or heat exchanger, failure of an element would cause no change in pressure drop.

The contents of the elements (9) has an almost infinite force when heated and is positively sealed. When the elements are heated, this force is transmitted to the piston thus moving the sliding valve towards the seat (11) to the by-pass closed position. This force is opposed by a high spring force, which moves the sliding valve to the heat exchanger closed position when the elements are cooled. The high force available on heating is the basis of the fail safe feature in which failure of the element would cause the engine to run cold.

The HT thermostatic valve in main engine installations are provided with a possibility for manual override.

Cooling water thermostatic valve

9. Content of the element
10. Element
11. Seat

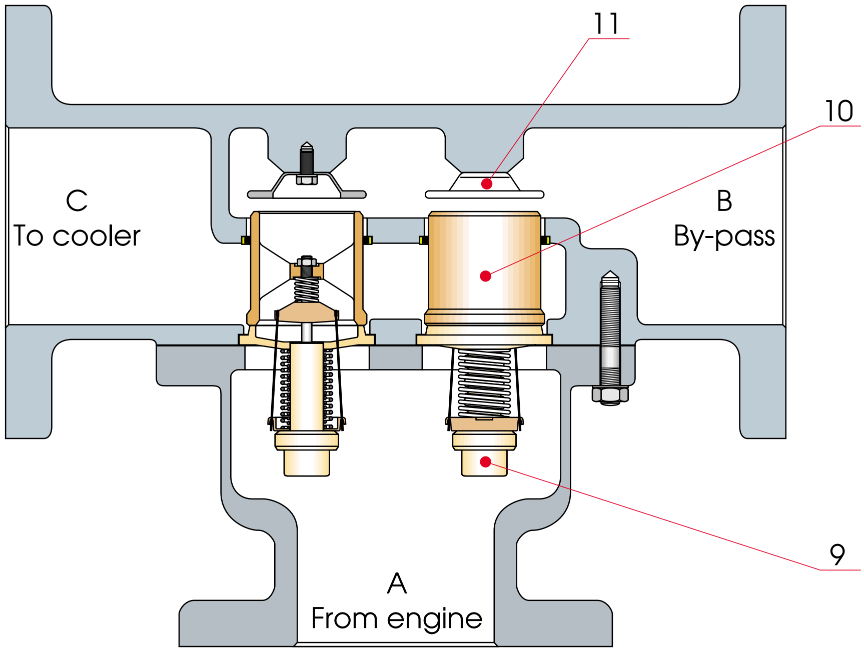

Fig 19-6 3219679250

19.4.3 Maintenance

Normally, no service is required. Too low a water temperature depends on a defective thermostat, too high a temperature may depend on a defective thermostat, although, in most cases, it depends on a dirty cooler.

1 Remove the elements by unscrewing the pipe before the valve and opening the cover.

2 Check the element by heating it slowly in water. Check at which temperatures the element starts opening and is fully open. The correct values can be found in chapter 01.; the lower value for the water temperature is the opening temperature, the higher for the fully open valve.

3 Change the defective element. Check sealings and replace, if necessary.

20. Exhaust System

20.1 Description

The exhaust pipes are cast of special alloy nodular cast iron, with separate sections for each cylinder, fixed by clamp rings (1). Metal bellows of multiply type absorb the heat expansion.

The complete exhaust system is enclosed by an insulation box built up of sandwich steel sheet. Sensors for measuring of the temperatures after each cylinder as well as before and after the turbocharger are mounted.

Exhaust system V-engine

1. Clamp ring
2. Sheet

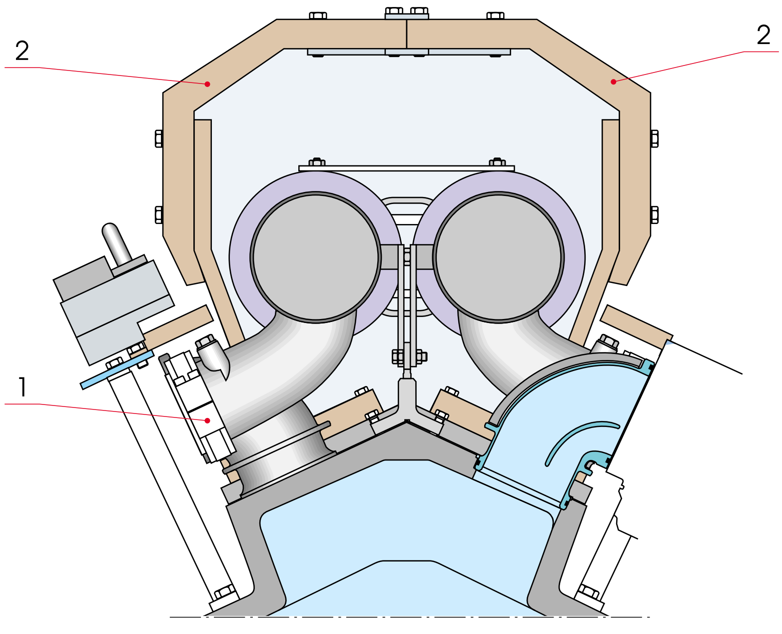

Fig 20-1 3220599548

20.2 Change of expansion bellows

1 **Remove necessary sheets** on the insulation box. On V-engine the sheets (2) on the top, see Fig 20-1.

2 **Remove the screws (3) of the flange connection** and remove the expansion bellows, see Fig 20-2.

3 **Check that the exhaust pipe flanges are parallel** and positioned on the same centre line to avoid lateral forces on the bellows.

Exhaust system

3. Screw

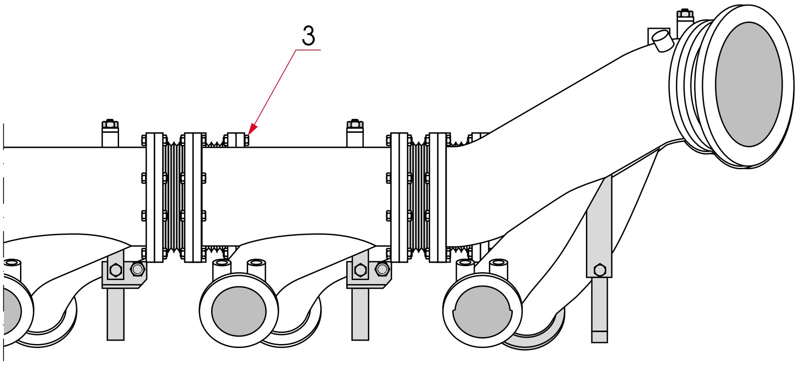

Fig 20-2

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21. Starting Air System

21.1 Description

The starting air supply pressure to the starting system is 20…30 bar. The starting air pressure at the inlet to the starting motor is 8…10 bar. The starting air supply pressure can be checked from the local display unit.

The solenoid valve (4) can be operated by the push button for cranking the engine.

As a precaution the engine cannot be started when the turning gear is engaged. Control air to the air starter is led through a blocking valve (2), mechanically blocked when the turning gear is engaged, thus preventing start.

Starting air and pneumatic system

1. Turbine starter
2. Blocking valve
3. Pressure regulator
4. Solenoid valve
6. Wastegate valve
7. Safety valve
8. Starter valve
10. Solenoid valve
11. I/P converter
301 Starting air inlet
303 Control air inlet

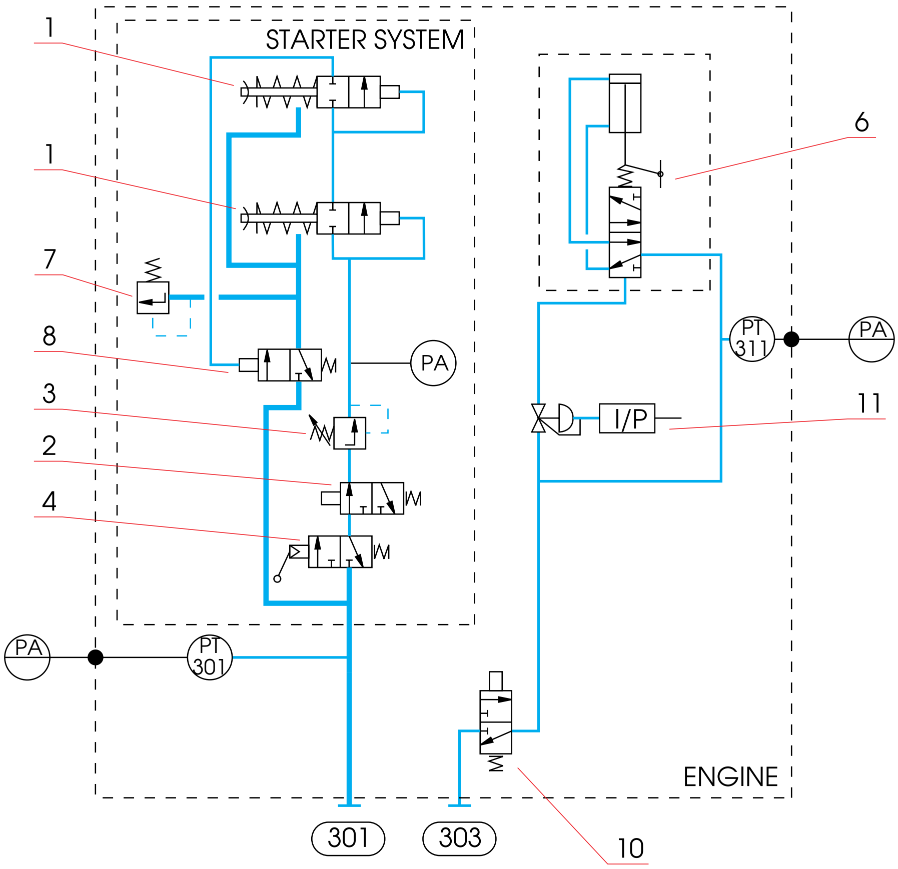


Fig 21-1 3221680407

21.2 Starting device

21.2.1 Description

The engine is provided with two air starters of turbine type. They are air operated, turbine driven, pre-engage starter drives and they are designed for operation with compressed air only. Small amounts of foreign matter or liquid in the air stream will normally not adversely affect the starter and no lubrication is required in the supply air. The air starter can be grouped into five basic segments:

- Housing exhaust cover,
- Motor housing,
- Intermediate gear case,
- Gear case,
- Drive housing.

When the engine has reached a speed of 120 RPM the current is disconnected by the WECS system, and the air starter will be disengaged automatically.

Warning! **Do not operate the starter with compressed air unless it is properly attached to the engine and will engage the flywheel.**

A valve prevents starting with engaged turning device.

21.2.2 Disassembly

Mark each section of the starter for reference during assembly. Note the location of the long male elbow in the nozzle/valve seat and that the control line access hole in the containment ring and the port in the nozzle/valve seat must line up when reassembled. Mark the turbine rotor and note its direction of rotation.

Have a complete set of O-rings, seals, screws and other hardware available for assembly.

Note **Do not wash bearing or the starter drive in cleaning solvents.**

1 **Do not disassemble the starter** any further than necessary to replace worn or damaged parts.

2 **When grasping a part in a vise,** always use leather-covered or copper-covered vise jaws to protect the surface of the part and help prevent distortion. This is particularly true of threaded members.

Air starter

11. Housing exhaust cover
12. Motor housing
13. Intermediate gear cover
14. Gear case
15. Drive housing

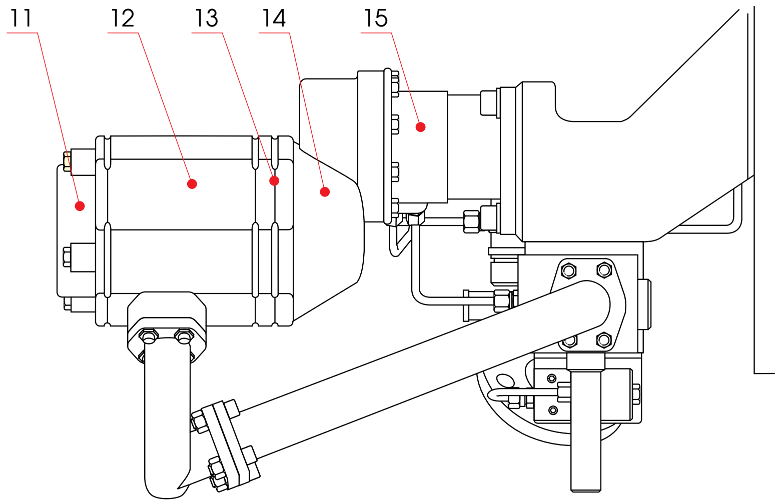


Fig 21-2 3221639601

3 Do not remove any part which is a press fit in or on a sub assembly unless the removal of that part is necessary for replacement or repairs.

4 Always have a complete set of seals and O-rings on hand before starting any overhaul of the starter. Always renew old seals and gaskets.

5 Always mark adjacent parts on the housing exhaust cover (11), motor housing (12), intermediate gear case (13), gear case (14) and drive housing (15) so these members can be located in the same relative position when the starter is reassembled.

6 Do not press any needle bearing from a part unless you have a new needle bearing on hand for installation. Needle bearings are always damaged during the removal process.

21.2.3 Cleaning and inspection

1 Degrease all metal parts except bearings and the starter drive using commercially approved solvents.

2 Dry parts thoroughly.

Caution! Never wash the starter drive or shielded bearings in cleaning solvents.

3 **Clean aluminum parts** using a cleaning solution, soak for five minutes. Remove parts, rinse in hot water, and dry thoroughly.

4 **Clean corroded steel parts** with commercially approved stripper.

5 **Clean corroded aluminum** parts by cleaning as stated above and then immersing the parts in a chromic-nitric-phosphoric acid pickle solution. Rinse in hot water and dry thoroughly.

6 **Check for acceptable condition of parts.**

7 **Check all threaded parts** for galled, crossed, stripped, or broken threads.

8 **Check all parts** for cracks, corrosion, distortion, scoring, or general damage.

9 **Check the splash deflector** and retaining spring for wear.

10 **Check all bearing bores** for wear and scoring. Bearing bores shall be free of scoring lines.

11 **Check gear teeth** for wear. If wear is apparent, check gear teeth dimensions.

21.2.4 Assembly

1 **Always press on the inner ring** of a ball-type bearing when installing the bearing on a shaft.

2 **Always press on the outer ring** of a ball-type bearing when pressing the bearing into a bearing recess.

3 **Whenever grasping a starter or** part in a vise, always use leather-covered or copper-covered vise jaws. Take extra care with threaded parts or housings.

4 **Except for bearings, always clean** every part and wipe every part with a thin film of oil before installation.

5 **Check every bearing for roughness.** If an open bearing must be cleaned, wash it thoroughly in a suitable cleaning solution and dry with a clean cloth. sealed or shielded bearings should never be cleaned. Work grease thoroughly into every open bearing before installation.

6 **Apply a film of O-ring lubricant to** all O-rings before final assembly.

7 **Unless otherwise noted, always press** on the stamped end of a needle bearing when inswag the needle bearing in a recess. Use a bearing inserting tool.

All screw threads are treated at the factory with a fastener retention compound. Every screw, 1 inch diameter or larger, must have a drop of Loctite 290 applied to the threads before being re-used, screws smaller than 1 inch diameter must have a drop of Loctite 222 applied to the threads.

Note! **See also chapter 08.2 Trouble shooting for air starter.**

21.3 Starting air vessel and piping

An oil and water separator should be located in the feed pipe (see installation specific instruction), between the compressor and the starting air vessel. At the lowest position of the piping there should be a drain valve.

Drain the starting air vessel from condensate through the drain valve before starting.

The piping between the air vessels and the engines should be carefully cleaned when installing. Also later on they should be kept free from dirt, oil and condensate.

The starting air vessels should be inspected and cleaned regularly. If possible, they should then be coated with a suitable anti-corrosive agent. Let them dry long enough.

At the same time, inspect the valves of the starting air vessels. Too strong tightening may result in damages on the seats, which in turn cause leakage. Leaky and worn valves, including safety valves, should be reground. Test the safety valves with pressure.

21.4 Pneumatic system

21.4.1 General description

The engine is equipped with a pneumatic system for control of the wastegate valve. The control is described in chapter 23. The system includes a shut-off valve and an I/P-converter, see Fig 21-3.

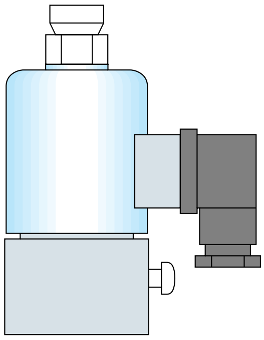
21.5 Maintenance

The system is built up of high class components. Usually it requires no other maintenance than check of function.

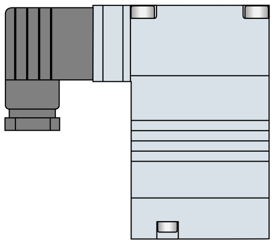
21.5.1 Maintenance

The components requires no maintenance. Should there be malfunction, change the complete component.

Pneumatic components



Solenoid valve



I/P converter

Fig 21-3

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22. Control Mechanism

22.1 General

The SG engine does not have any injection pumps and due to that the engine is not equipped with any speed governor, control shafts or mechanical overspeed trip device.

23. WECS 3000

23.1 General

This chapter describes the functionality of the WECS 3000 (Wärtsilä Engine Control System) engine control and monitoring system.

23.2 System configuration

This section describes the different main components in the WECS 3000 engine control & monitoring system and how they communicate with each other and external systems.

23.2.1 General

The WECS 3000 is a physically distributed system. The system consists of four types of units located at different positions on the engine. All units can communicate with each other over the CAN-bus (in case of SMU's, polling over a RS-485 serial link is provided). See 23.4.1.

Main components in the WECS 3000

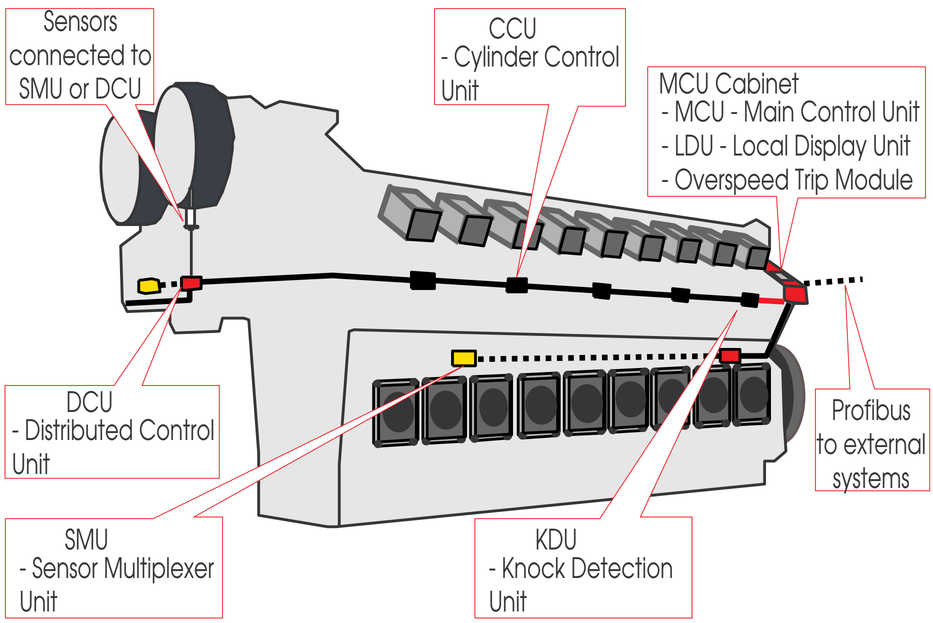

Fig 23-1 3223889601

There are four different types of units communicating with each other. These are:

- MCU Main Control Unit
- CCU Cylinder Control Unit
- KDU Knock Detection Unit
- DCU Distributed Control Unit
- SMU Sensor Multiplexer Unit

There is one MCU on each engine, and this unit is mounted in a resiliently mounted cabinet situated at the flywheel end of the engine. The CCU’s, DCU’s and SMU’s are mounted at various locations on the engine close to the sensors/actuators they are monitoring/controlling.

The MCU is the master in the system, controlling references for ignition, gas pressure, gas injection timing and duration. It also handles tasks as the speed/load control, charge air control, start sequences, safety, monitoring etc. The MCU handles bus communication with external systems as well as digital and analogous input and output signals.

The CCU units handle all cylinder related control and monitoring such as ignition and gas injection to the precombustion chamber and main chamber and measures also the exhaust gas and cylinder liner temperatures. The CCU activates the ignition module and gas admission solenoid valves according to the timing and duration references received from the MCU. The engine angular position and speed is calculated in the CCU. For this calculation it uses the pulses received from a rotary encoder attached to the camshaft. One CCU unit is designed for controlling and monitoring two cylinders.

The KDU is used to measure the “knock” signals from accelerometers mounted on each cylinder head. The KDU filtrates, amplifies and converts these signals to digital information and sends it over the CAN-bus to the MCU for further processing. One KDU is designed to handle up to nine cylinders.

The DCU/SMU units are used for measuring purposes. They convert different types of sensor signals to digital information which is sent over a network to the MCU for further processing.

23.3 Speed measuring

This section describes how the engine and turbocharger speeds are measured.

23.3.1 Engine speed measuring

The engine speed measuring units on WECS 3000 receive signals from two different types of sensors. A rotary encoder connected to the camshaft is the master unit. The rotary encoder is used to calculate engine angular position as well as engine speed. The other speed sensor is an inductive proximity switch installed at the camshaft gear. This speed sensor is used as a redundant overspeed protection device. The speed measured from the rotary encoder is compared with the speed signal from the inductive proximity switch in the MCU. A shutdown is activated if a deviation in speed signals is over 50 rpm. Refer to section 23.7.3 for shutdowns.

Engine speed measuring

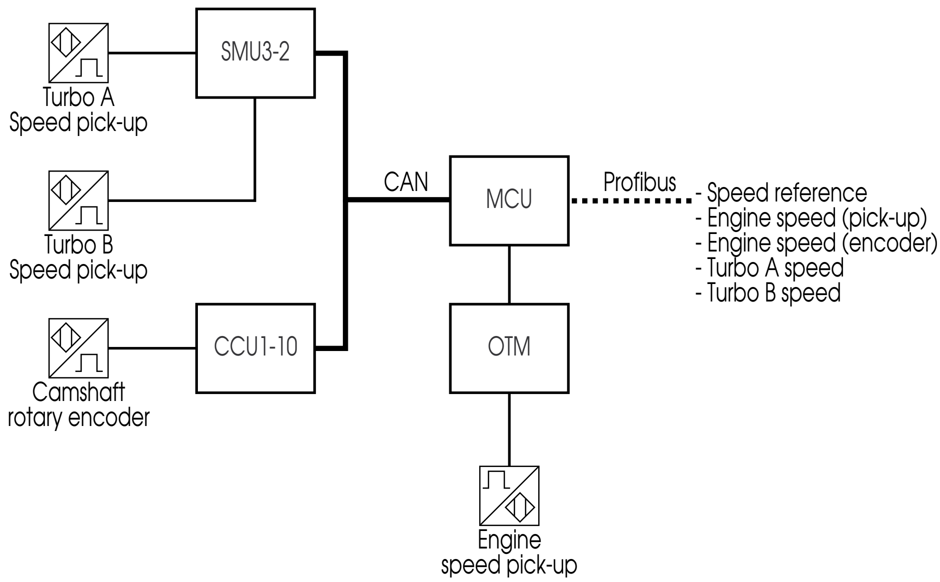

Fig 23-2 3223899601

23.3.1.1 Rotary encoder on camshaft

The rotary encoder on the camshaft is an optical incremental encoder with marker pulse. The encoder has two signal outputs. One which provide 900 pulses/camshaft revolution and the other one providing one synchronization pulse per camshaft revolution. One revolution on camshaft is the same as two on the crankshaft. This gives an resolution of 450 pulses/rev on crankshaft, i.e. 0.8° crankangle /encoder pulse.

The encoder is supplied from a 24 VDC supply source. The output circuit is protected against short circuiting and reverse polarity.

The encoders output signals (speed pulse train and sync. pulse) are connected to each CCU on the engine (hard wired). The encoder output signals are galvanically separated from the CCU electronic circuits via an optocoupler circuit in the input stage on each CCU I/O board. Each CCU calculates the engine speed derived from the encoders speed pulse train and transmit it via the CAN bus to the MCU. If any of the CCU’s is transmitting a deviating speed value over CAN, a shutdown will occur.

Rotary encoder. Layout and signal definition

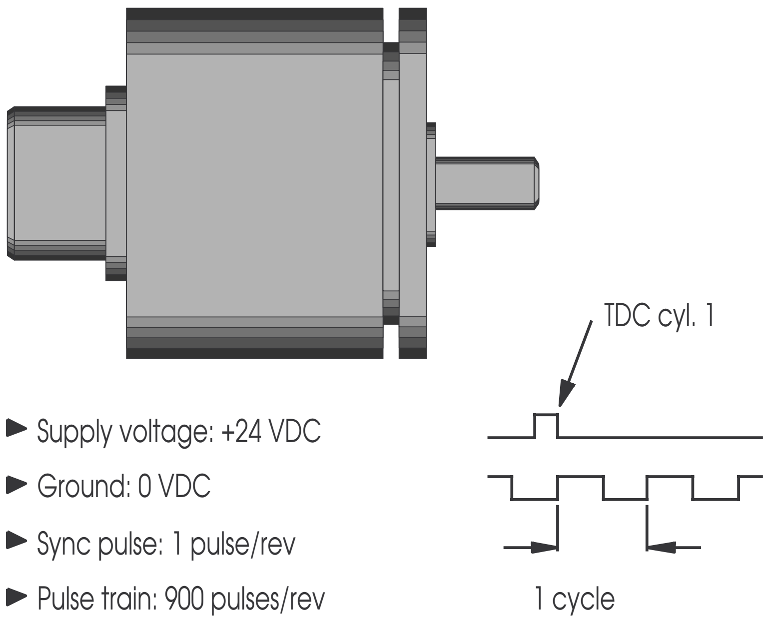

Fig 23-3 3223909601

The rotary encoder is mechanically adjusted to give the synchronization pulse when piston number A1 is in Top Dead Centre (TDC) position at power stroke. This pulse is then used to synchronize the ignition and the gas admission valve timing for all cylinders.

The MCU supervises that the encoder gives 900 pulses/rev. Alarm or emergency stop is activated if the amount of pulses during one revolution deviates more than a predefined number of pulses from 900 pulses. Alarm and emergency stop limits are defined under section 23.7.4.

23.3.1.2 Engine speed pick-up

The engine speed measured with this pick-up is used for redundant engine overspeed protection purposes, and also to verify the engine speed signal from the rotary encoder on the camshaft. The sensor is an inductive proximity switch with built-in signal amplifier which provides a square-wave output signal. The sensor is directly connected to the Overspeed Trip Module in the MCU cabinet, from which it is supplied with 24 VDC. The sensor gives one pulse for each cog on the camshaft gear passing the head of the sensor.

The output of the sensor is providing a speed proportional pulse train which is opto-coupled and transduced into an analogue 4-20 mA signal in the Overspeed Trip Module. This signal is connected to the MCU, which monitors the signal and compares it with the calculated speed value from the CCU’s. If there is a deviation between these values, the MCU will initiate an alarm.

Engine speed pick-up

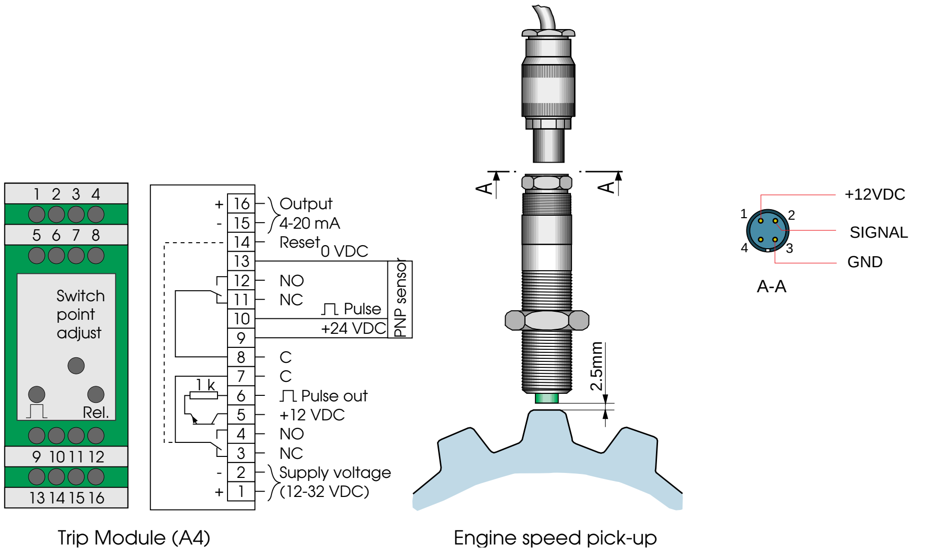

Fig 23-4 3223919601

23.3.2 Turbocharger speed measuring

The turbocharger speed is measured by means of a magnetic speed pick-up. One sensor is mounted on each turbocharger, and produces a signal with two pulses for each turbocharger revolution. The sensor is connected to a DCU/SMU, in which the speed calculation is carried out.

Turbo speed pick-up

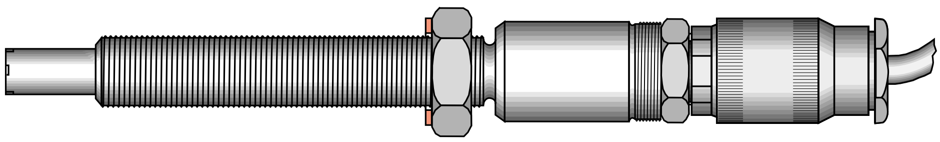

Fig 23-5 3223929601

23.4 Engine mode control

This section describes how the engine status is declared as five different engine modes in the MCU software. It also describes what takes place in each of these modes and what makes the engine mode change.

23.4.1 Engine Modes

There are five engine modes defined in the software. These are in descending priority;

- Emergency mode
- Shutdown mode
- Run mode
- Start mode
- Stop mode

These modes are described in the following sections. When the MCU is powered up it goes automatically to stop mode if there is not a request for emergency or shutdown mode. Since these modes have higher priority these requests will change the engine mode according to the request. The engine mode controller checks cyclically if there are any requests to change engine mode. If a request to change engine mode is active and if the mode change is valid, the engine mode controller will activate the new mode control task in order to change mode.

Engine Mode Control

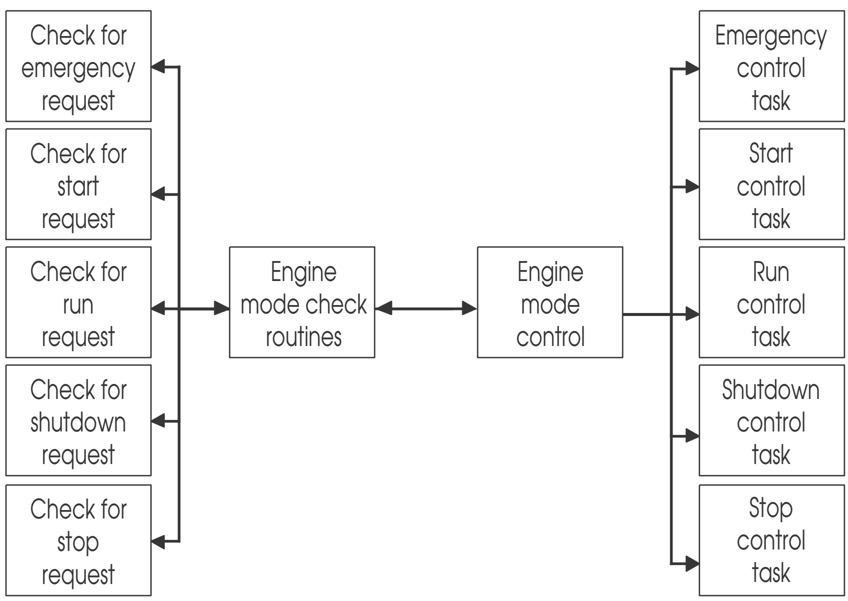

Fig 23-6 3223939601

A valid change of engine mode is when the requested engine mode has a higher priority than the active engine mode. For instance, there will not be an engine mode change if a shutdown mode request is true when the engine is in emergency mode. The engine mode change must also be according to Fig 23-7.

Valid engine mode changes

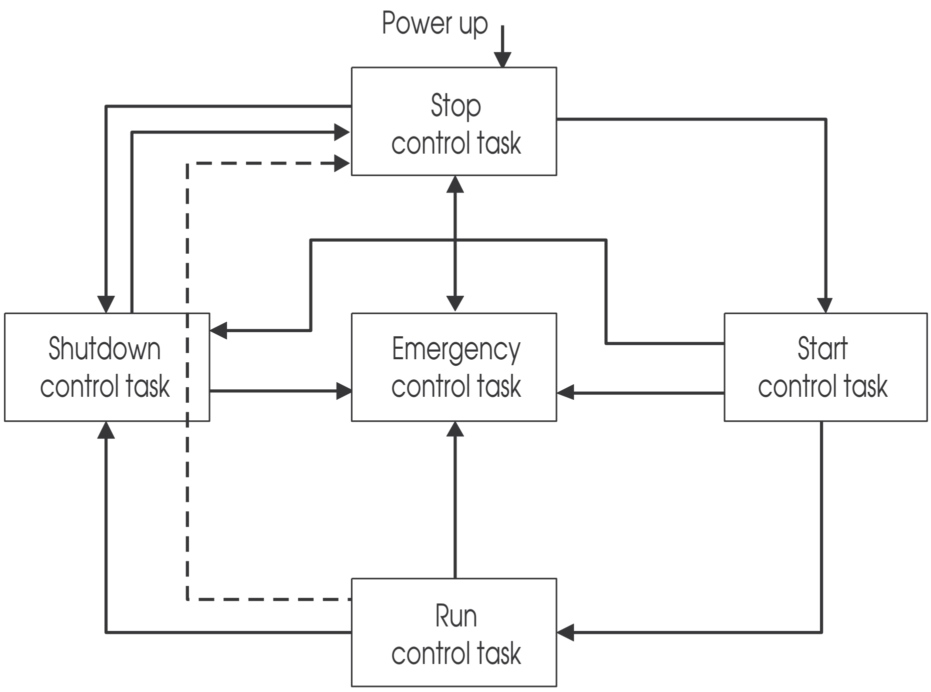

Fig 23-7 3223949914

23.4.2 Start mode

In order to get a start request, the PLC has to activate the MCU digital input “engine start”. If the engine is in stop mode and no start blockings (see section 23.7.1) are active the engine mode controller will activate the start control task. The start control task will perform a sequence of actions in order to start the engine. The sequence include the following actions:

1 **Activate inlet gas pressure control.**

2 **Activate air driven start motor.** This starts the ventilation of the charge air receiver, cylinders and exhaust system. The gas injection and ignition will not be activated for a number of engine revolutions, determined by the PLC via Profibus, in order to ventilate the engine.

3 **When the engine is ventilated** and the engine speed is above 50 rpm the speed control, gas injection and ignition system will be activated.

4 **When the engine ignites** and the engine speed rises higher than 120 rpm the air driven start motor will be disengaged and the charge air pressure control will be activated.

5 **When the engine speed reaches 250 rpm** the run mode request is activated and the start control task is ended.
There are three reasons why the start control task could be interrupted:

- The measured inlet gas pressure did not correspond with the reference set by the MCU within 5 seconds after the inlet gas pressure control was activated.
- The engine does not reach 250 rpm within 20 seconds.
- Cylinder temperature under 120°C in any cylinder.

All of these faults activate the shutdown control task and an alarm is given to the PLC via Profibus. The failed start attempt must be reset by the operator before next start attempt can be made.

23.4.3 Run mode

The run control task is activated when the start mode is active and engine speed reaches 250 rpm. The run control task will, as the start control task, perform a sequence of actions. The sequence comprise the following actions:

1 **When the actual engine speed** is 20 rpm below reference speed the start fuel limit will be disabled. The engine is now running at the preset reference speed (rated). The engine is now ready to be synchronized to a utility or to be connected an isolated net for loading.

2 **The exhaust gas temperature** control starts 20 rpm below rated speed.

3 **Monitoring of pressures** (which is suppressed during standstill) will now be activated after a time delay.
The engine will remain in run mode until a stop, shutdown or emergency request is activated.

23.4.4 Shutdown mode

A shutdown request can be activated from a number of different sources. A normal stop from the operator results in the PLC deactivating the MCU digital input “engine stop”. There is also a number of sensors which activate a shutdown request. These are listed in section 23.7.3. If not in emergency mode, a shutdown request will make the engine mode controller change to shutdown mode. The sequence in shutdown mode comprise the following actions:

1 **Deactivate relay K2** in the MCU cabinet. This causes the generator circuit breaker to open and also makes the PLC shut down the gas supply to the engine.

2 **Deactivation of the main** and PCC gas pressure control.

3 **When the engine speed becomes** less than 600 rpm the gas injection is deactivated.

4 **When the engine speed becomes** less than 50 rpm the ignition is disabled.
Since the gas injection and ignition are activated during deceleration the gas in the pipes will be consumed. This minimizes the risk that the gas is gathered in the cylinders and exhaust system which could be hazardous at the next engine start.

If the shutdown mode was due to a sensor shutdown request the engine will remain in shutdown mode until the engine speed is 0 rpm and the reason for the shutdown has been clarified and the shutdown indication reset by the operator.

23.4.5 Emergency mode

An emergency request can be activated from one of the emergency stop push buttons or from a number of sensor or communication failures (see section 23.7.4). An emergency request will make the engine mode controller change into emergency mode. The sequence in emergency mode include the following actions:

1 **Deactivate relay K2 in the MCU cabinet.** This causes the generator circuit breaker to open and also makes the PLC shut down the gas supply to the engine.

2 **Deactivate ignition system,** gas injection and main & PCC gas pressure control.

3 **Deactivate relay K1 in the MCU cabinet.** This relay cuts the power supply to the CCU's making ignition and gas injection totally disabled.
When the engine speed becomes 0 rpm relay K1 in the MCU cabinet is activated again. Still, the reason for the emergency request must be clarified in order to activate relay K2. When this action is performed and the emergency indication have been reset by the operator the engine is ready to start again.

23.4.6 Stop mode

A manual stop of the engine will request the stop mode. After such an operation, no reset is required at re-start. In case of a shutdown or emergency stop, a stop request is activated when the engine speed has reached 0 rpm. A stop request will make the engine mode controller change to stop mode when the active mode no longer is not shutdown or emergency (when cleared and reset). The sequence when moving from shutdown/emergency mode to stop mode comprise the following action:

1 **Activate relay K2 in the MCU cabinet.** If no start blockings are active, the engine will be ready to start.

23.5 Data acquisition

In the WECS the data acquisition is distributed. This means that sensors are connected to Distribution Units (SMU's or DCU's) that are located close to groups of sensors. Only start and stop related switches are connected to the MCU. See Fig 23-8.

Sensor connection principle in the WECS 3000

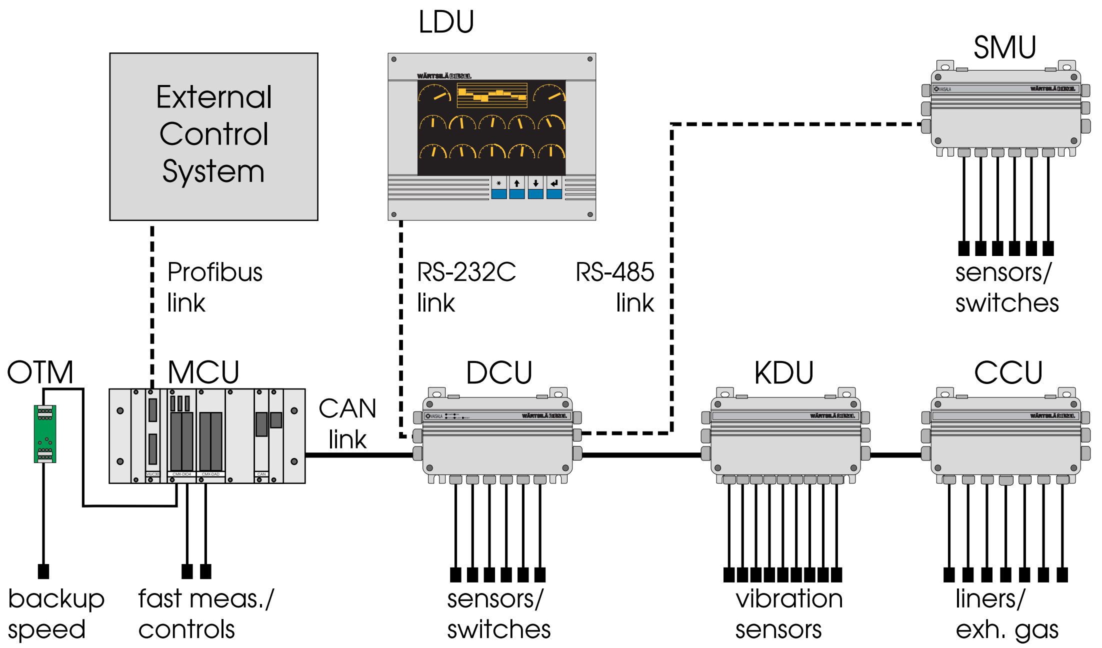

Fig 23-8 3223959601

The distributed data acquisition has many advantages compared to a centralized system:

- less cabling,
- noise immunity because of digital communication,
- flexibility,
- easy to customize for various engine types.

In the WECS measured values are transferred in analog mode only from the sensor to the CCU/DCU/SMU. After that the values are in digital mode. Various types of communication standards and protocols are used.

23.5.1 DCU/SMU

In the WECS sensors are normally connected to DCU/SMU's. The DCU includes the same sensor connections as the SMU, but an additional PCB for CAN communication and data processing. Only two types of Distribution Units are needed because their measuring channels are multiusage type. Various types of sensors can be connected to these channels:

- 4-20 mA current loop,
- current transducer,
- voltage transducer,
- Pt-100,
- thermocouples of type J, K, S and T,
- resistant,
- potentiometer,
- switch (max. 2 way).

Every measuring channel has an option to supply voltage for the sensor connected to it. Eight (8) channels supply either 12 V DC or 15 V DC and two channels supply 5 V DC.

There are also eight (8) digital inputs in the DCU/SMU's. Selectors are recommended to be connected to these inputs. For the speed measuring there are two (2) frequency inputs in the DCU/SMU.

The measuring frequency of digital inputs and measuring channels may vary, but in most cases it is 1 Hz.

23.6 Instrumentation

The instrumentation connected to the WECS depends on engine type and installation. In this section all the instrumentation options are described in their own sections.

23.6.1 Local Display Unit

The Local Display Unit (LDU) replaces the traditional pressure gauge panel, the thermometers and other instruments.

It is connected to a DCU, which sends the necessary data to the LDU. The software of the LDU is possible to use as it is on a normal PC, i.e.

it is possible to get exactly the same information to a PC connected to the serial port reserved for the LDU. The updating frequency of all data (on the active page) follows the updating frequency of the DCU database.

The operator is able to give all necessary commands with the four buttons existing on the LDU frame. If a PC is used instead of the LDU the same keys on the PC keyboard are used. The following buttons exist:

- Asterisk (*) key ,
- Up arrow (↑) key,
- Down arrow (↓) key,
- ENTER (↵) key.

The Fig 23-9 shows the buttons on the LDU frame. The Up and Down arrow keys are used for changing pages. If no operator actions have been made for the last 15 minutes the LDU always returns to the meter page automatically.

Control buttons of the LDU

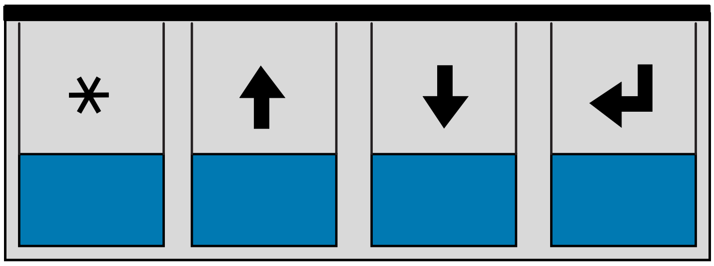

Fig 23-9 3223099601

On the upper right corner of the LDU there is a rotating indicator showing that the LDU is receiving data. No data is received, when the indicator is stopped.

The values shown on the LDU are inverted, if they are not normal, i.e.. the value is at old, default, shutdown or alarm condition or the LDU is not receiving data.

The display consists of two different kinds of pages: the meter page and the status pages. These page types are described in the following sections.

23.6.1.1 Meter page

The upper part of the display area contains three important parameters of the engine:

- the engine speed,
- the load balance of the cylinders,
- the engine load.

The load balance of the cylinders is shown as the temperature deviation for each cylinder from the average temperature of all cylinders.

In the middle of the meter page there are ten analog meters showing the values of the most critical pressures and temperatures of the engine.

LDU meter page

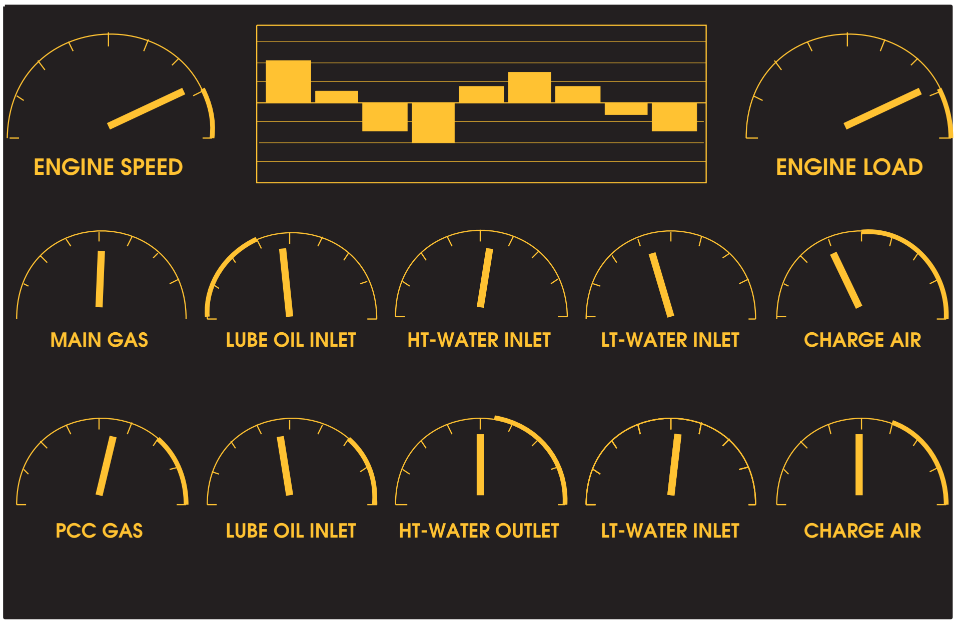

Fig 23-10 3223989601

23.6.1.2 Status pages

One status page shows all connections (including the internal enclosure temperature) to one unit or values of a logical sensor group like main bearing temperatures. The connections to the MCU are also shown on one page. The number of the pages will be according to the WECS build-up.

The status column is blank if the value is normal. The following status letters can be shown, if the value is not normal:

- O = Old
- D = Default
- S = Shutdown
- A = Alarm

The value text is inverted when the value is not normal. An error code with explaining text is shown, when the sensor is not measured correctly. One status page with fictional sensors and values is shown in Fig 23-11.

Status page of the LDU

SMU3-3 --

Terminals	Sensor code	Sensor type	Status	Value
1..4	PT201	4-20mA		4,5 bar
5..8	PT311	4-20mA		9,1 bar
9..12	PT401	4-20mA		3,5 bar
13..16	PT451	4-20mA		2,8 bar
17..20	LS204	Switch		0
35..38	TE402	Pt100		95 C
39..42	TE451	Pt100		65 C
43..46	TE452	Pt100	_O____A	-905 Sensor Short Error
47..50	TE201	Pt100		75 C
51..54	TE622	Pt100		69 C

Fig 23-11 3223969601

"Terminals", "Sensor code" and "Sensor type" columns can be replaced with "Sensor names" column by pressing the asterisk key. A status page with sensor names is shown in Fig 23-12.

Status page with sensor names

SMU3-3 --

Sensor names	Status	Value
Lube oil pressure, inlet		4,5 bar
Control air pressure		9,1 bar
HT water pressure, inlet		3,5 bar
LT water pressure, inlet		2,8 bar
Lube oil level (0=OK)		0
HT water temp., outlet		95 C
LT water temp., inlet		65 C
LT water temp., outlet	_O____A	-905 Sensor Short Error
Lube oil temp., inlet		75 C
Charge air temp., CAC outlet		69 C

Fig 23-12 3223979601

23.6.2 Controls

The only local control button on WECS 3000 is the emergency stop button. Pressing the emergency stop button shuts down the engine immediately. It can also be used to prevent the start of the engine.

23.7 Alarm and safety system

23.7.1 Start blockings

Before the PLC activates a start request the engine must be ready for start. Below is a list of all the conditions that must be fulfilled to get the engine ready for start. Status for all start blockings (alarms) and engine ready to start is sent to the PLC via Profibus.

- CCU configuration valid.
- If the MCU has been restarted it must be reset via the operator terminal. MCU restarted is activated when power is switched on.
- Engine must be in stop mode.
- The emergency stop button on the MCU cabinet must be in normal position.
- Limit switch indicating turning gear engaged must not be activated.
- Start air pressure must be over the start block limit.
- The prelubrication pressure must be over a preset level.
- The MCU digital input “engine stop” must not be deactivated.
- PLC configuration received.
- HT-water temperature over start blocking limit.
- Engine speed from encoder is 0.
- Engine speed from redundant pick-up < 20.
- CCU power supply ok.

23.7.2 Alarms

There are a number of alarms generated in the MCU and sent via Profibus to the PLC. Below is a list of all these alarms. Start blockings are not mentioned here since they are described in section 23.7.1.

- Sensor failure. All sensors connected to WECS 3000 are monitored. If the signal level/value is abnormal (out of range) an alarm will be initiated. Sensors with digital signals are wired so that they normally give a high (NC) signal to measuring unit. If a wire breaks there will be an alarm initiated. Some sensors of vital importance to the engine performance or safety will activate a request for shutdown mode or emergency mode while others only activate an alarm. Failure of sensors used for only measuring (no alarm limit) will also initiate an alarm. See sections 23.7.3 and 23.7.4 for further information.

- Main & PCC gas pressure deviation. The actual gas pressure is compared with the charge air pressure. If the gas pressure is less than a preset level over the charge air pressure, an alarm is activated.
- Crankcase pressure high
- Degassing failure
- Derating from knocking
- Emergency stop activated
- Engine overload
- Generator water leakage (optional)
- Generator hot cooling air high (optional)
- Generator cold cooling air high (optional)
- High lube oil temperature, engine inlet
- High HT water temperature, engine outlet
- High exhaust gas temperature after cylinder (each)
- High exhaust gas temperature deviation between cylinders
- High cylinder liner temperature
- High main bearing temperature
- High charge air temperature
- High internal temperature in CCU
- High internal temperature in DCU
- High internal temperature in SMU
- HT-water temperature engine inlet low
- KDU failure
- KDU-can failure
- Light knocking
- Load reduction
- Load deviation between reference and actual
- Low lube oil pressure
- Low control air pressure
- Low starting air pressure
- Low HT water pressure
- Low LT water pressure
- Low knocking margin
- Low lube oil sump level
- Turning gear engaged
- Too lean air/fuel mixture
- Too rich air/fuel mixture
- Start attempt failed

Alarms can only be reset by the operator. They will not be reset automatically if engine conditions return to normal.

23.7.3 Shutdowns

There are a number of reasons for a shutdown of the engine. The shutdown is generated in the MCU because of a shutdown request. The status of the shutdowns are all sent via Profibus to the PLC. Below is a list of all the shutdown requests:

- A normal stop order from the PLC. MCU digital input “engine stop” is deactivated
- Can-bus failure CCU
- Can-bus failure DCU
- Charge air temperature high
- Crankcase pressure high
- Engine overload
- Engine speed deviation, between reference and actual speed
- Generator kW-sensor failure
- Generator water leakage (optional)
- Generator hot cooling air high (optional)
- Generator cold cooling air high (optional)
- Heavy knocking
- High HT water temperature
- HT water temperature sensor failure
- High charge air temperature
- High exhaust gas temperature after cylinder (each)
- High exhaust gas temperature deviation between cylinders
- High cylinder liner temperature
- High main bearing temperature
- HT-water pressure engine inlet low (optional)
- High generator bearing temperature. Shutdown limit set via Profibus by PLC.
- High generator winding temperature. Shutdown limit set via Profibus by PLC.
- Load deviation between reference and actual
- Low lube oil pressure
- Lube oil pressure sensor failure
- Maximum idle time exceeded
- MFI duration maximum time
- Minimum exhaust gas temperature not reached
- Power supply failure KDU
- Speed deviation between encoder and redundant pick-up
- Start failure in start mode

23.7.4 Emergency stop

There are a number of reasons for an emergency stop of the engine. The emergency stop is generated in the MCU because of an emergency stop request. The status of these are all sent via Profibus to the PLC. Below is a list of all the emergency stop requests:

- Emergency stop push button on engine or externally pressed
- Rotary Encoder sensor failure
- Overspeed from rotary encoder
- Overspeed from speed pick-up
- Overload
- Speed deviation between rotary encoder and engine speed pick-up
- Degasing failure in autostop mode. Activated if the gas pressure is still present after the shutdown control task has disabled the inlet gas pressure control.
- CCU power supply failure

23.8 Gas injection

23.8.1 Gas supply

The supply gas first passes through a gas regulating unit, before it enters the engine. The gas regulating unit consists of a filter, pressure regulating valves, safety (shutoff) valves and vent valves, see Fig 23-13. The system is built for common gas supply to the main combustion chambers and to the precombustion chambers (PCC). See specific installation instructions.

The solenoid valves (safety and vent valves) on the gas regulating unit are controlled by the PLC. The pressure regulating valves are controlled by the MCU via built-on I/P-converters (current to pressure). The gas supply pressure reference from the MCU is depending on the engine load. The actual pressure is measured and compared with the reference pressure, see Fig 23-14. If the deviation is too high an alarm will be initiated and sent to the PLC via Profibus. If the deviation increases more, the safety valves on the gas regulating unit will cut the gas supply to the engine immediately. Both references and actual pressures are sent to the PLC via Profibus for both main chamber and PCC.

Gas regulating unit

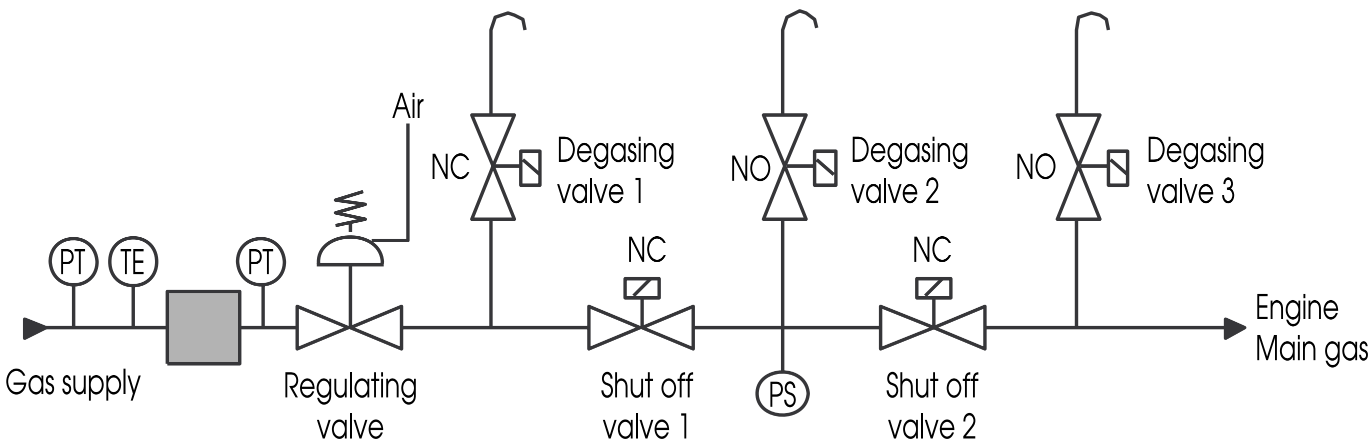

Fig 23-13 3223990408

Gas supply pressure control

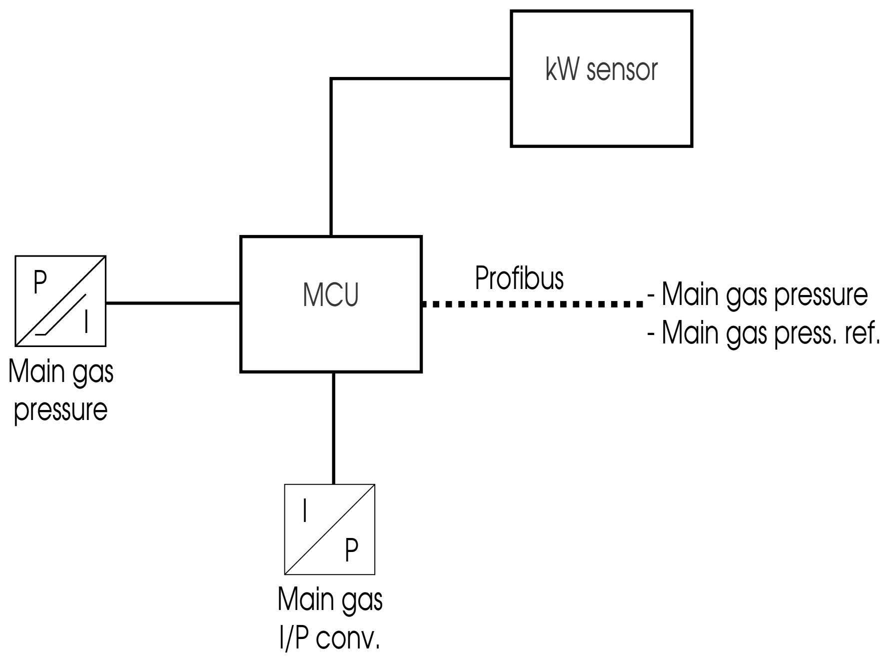

Fig 23-14 3223010408

23.8.2 PCC gas injection

The amount of gas admitted to the precombustion chamber is controlled by the PCC solenoid valve which is connected to the CCU, see Fig 23-15. The amount of gas is admitted depending on the gas supply pressure and the time the PCC solenoid valve is open (duration). The gas can be admitted further away or closer to TDC by changing the PCC solenoid valve opening moment (timing) in order to obtain optimal mixture.

Valve duration and timing are sent to the CCU from the MCU via the CAN-bus. Valve duration and timing can be controlled individually between the cylinders. The timing and duration are depending on engine load. The gas admitted into the precombustion chamber should create a stochiometric mixture which is easy to ignite.

The CCU uses the pulses from the rotary encoder to calculate engine angular position and engine speed in order to open the valve according to the duration and timing references. Both duration and timing references are sent via Profibus to the PLC.

23.8.3 Main chamber gas injection

The amount of gas admitted to the main chamber is controlled by the main chamber solenoid valve which is connected to the CCU, see Fig 23-15. The amount of gas admitted is depending on the gas supply pressure and the time the main chamber solenoid valve is open (duration). The gas can be admitted further away or closer to TDC by changing the main chamber solenoid valve opening moment (timing) in order to obtain optimal mixture.

Valve duration and timing are sent to the CCU from the MCU via the CAN-bus. Valve duration and timing can be controlled individually between the cylinders. The timing is depending on engine speed and load. The duration is controlled by the load/speed PID-controller so that speed or load always matches their references.

The CCU uses the pulses from the rotary encoder to calculate engine angular position and engine speed in order to open the valve according to the duration and timing references. Both duration and timing references are sent via Profibus to the PLC.

PCC and main chamber gas injection

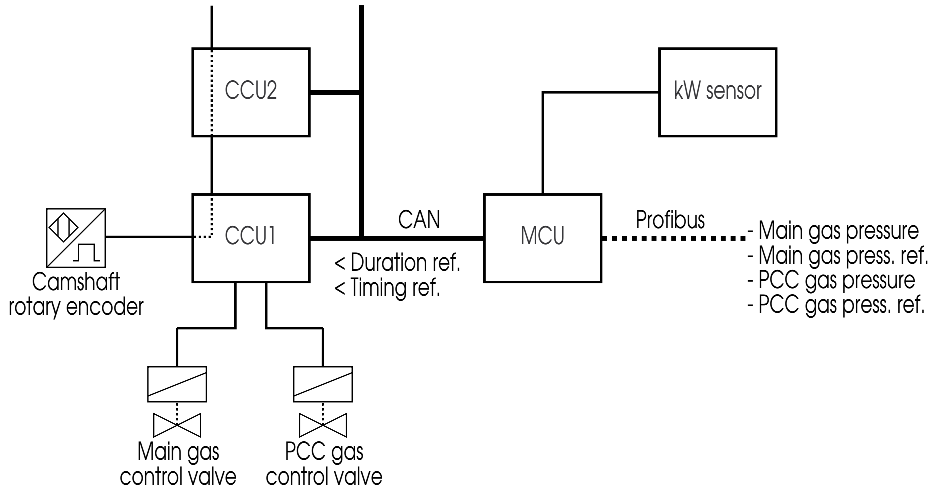

Fig 23-15 3223029601

23.9 Air/Fuel ratio control

The inlet air is compressed in the turbocharger, cooled to optimal level in the charge air cooler and enters the charge air receiver in the engine block. The air pressure in the receiver is controlled by a proportional exhaust waste-gate valve located on the turbocharger support. The valve reduces the turbocharger efficiency and controls thereby the air pressure in the receiver. By adjusting this pressure, the λ i.e. air/fuel ratio in the cylinder is optimised.

The charge air pressure control is based on a PID-controller, which compares the actual pressure with a mapped pressure reference table. In this table, the reference is engine load dependent. The reference is offset according to the charge air temperature.

If cylinder knock occurs in several cylinders simultaneously, another offset will be added to the waste-gate reference, in order to achieve a leaner air/fuel mixture in all cylinders. This process is continuous, and the offset will be restored when the situation normalises.

Air/Fuel ratio control

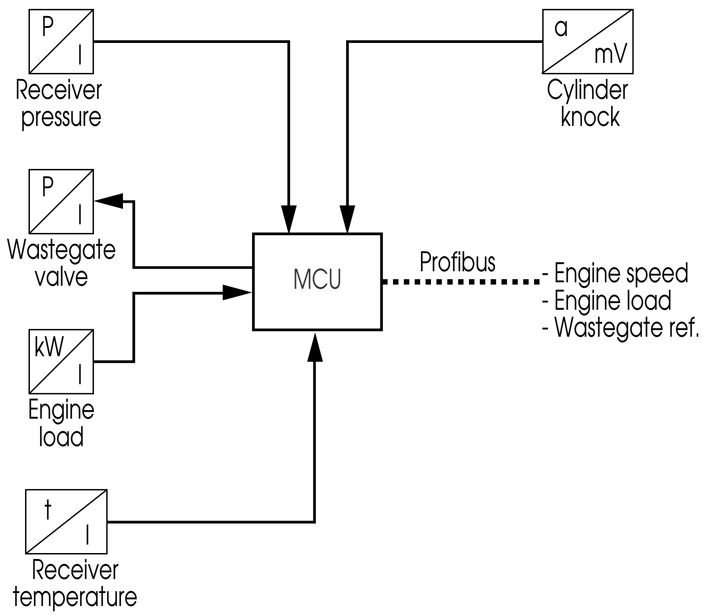

Fig 23-16 3223030408

23.10 Ignition system

23.10.1 General

The ignition system for each cylinder consists of an ignition module, an ignition coil, a high tension extender and a spark plug. Ignition control is calculated and performed by the CCU, see Fig 23-17. The ignition module is described in section 23.10.3. The teflon insulated high tension extender has a 5 kΩ resistor installed in order to reduce the interference generated by the spark.

Ignition system layout

1. Ignition coil
2. Spark plug extension
3. Spark plug
4. CCU
5. Ignition module

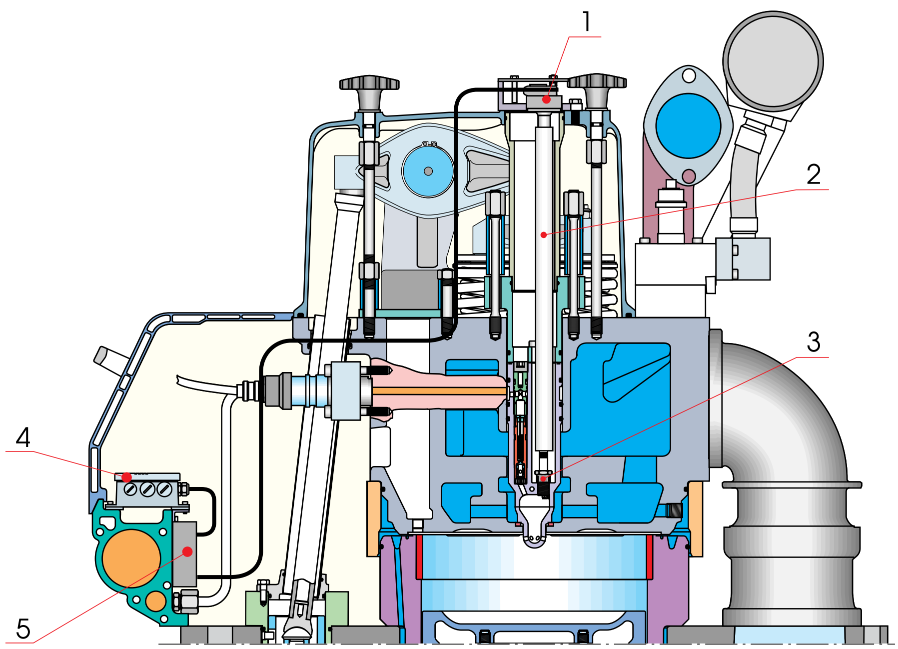

Fig 23-17 3223049701

23.10.2 Ignition control

The reference for ignition timing and the dwell time duration and a separate offset adjustment in timing and duration for each cylinder is determined in the MCU. The ignition timing and dwell time duration changes with engine load.

The ignition timing is defined in degrees with an resolution of 1/10° and the dwell time is defined in µs. These parameters are transmitted to each CCU over the CAN bus. The ignition timing value is the point of time (in degrees before the cylinders top dead center firing) when the ignition spark goes off. The ignition output control signal from CCU to the ignition module is activated (low) during the dwell time period and the start point is derived from the signal from the rotary encoder on the camshaft.

Ignition system

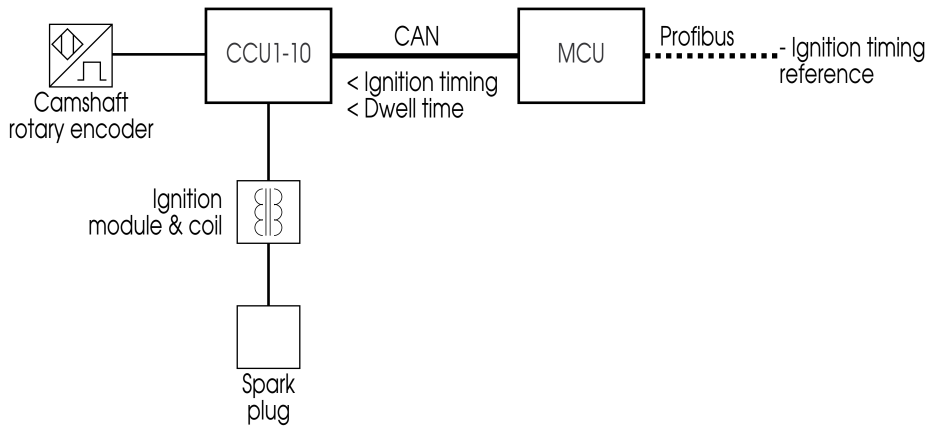

Fig 23-18 3223059601

23.10.3 High voltage circuit

The ignition is of inductive discharge type, and the driver circuitry offers ramp-and-fire operation. Ramp-and-fire means that the primary current must be switched on at a pre-calculated time before the spark event, so that the current will reach the desired level at spark discharge moment. This minimizes power losses in the ignition driver because primary current limiting is not necessary.

The primary current is switched on when the input line “Ignition Control” goes active (low) and will be switched off when the signal goes inactive. If the dwell time exceeds 900 s the primary current will be switched off internally to protect the ignition coil and the coil driver against over current.

During the dwell period energy will be stored in the coil according to $W=LI^2$. When the primary current is switched off the stored energy will be discharged through the secondary winding and transferred to the high tension output and the spark plug via the high tension extender.

Ignition ramp-and-fire operation

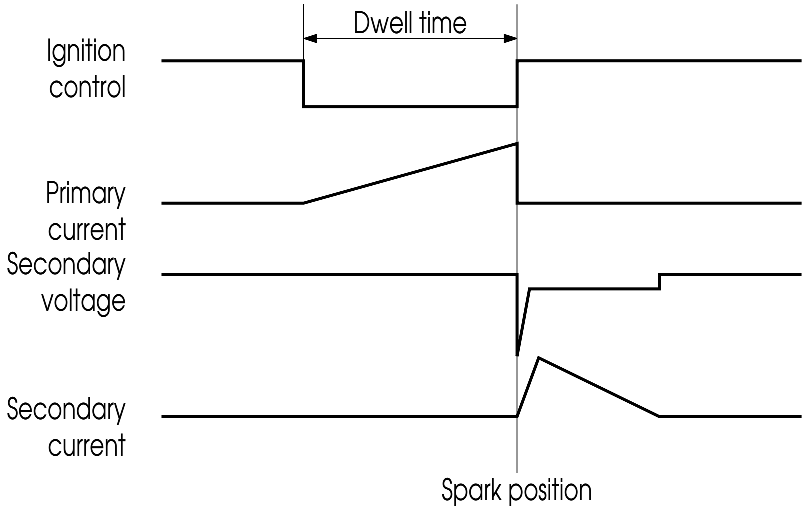

Fig 23-19 3223069601

The physical interface for the high voltage output consists of the coil driver circuitry, ignition coil, high voltage extender and spark plug.

Ignition module driver and high voltage

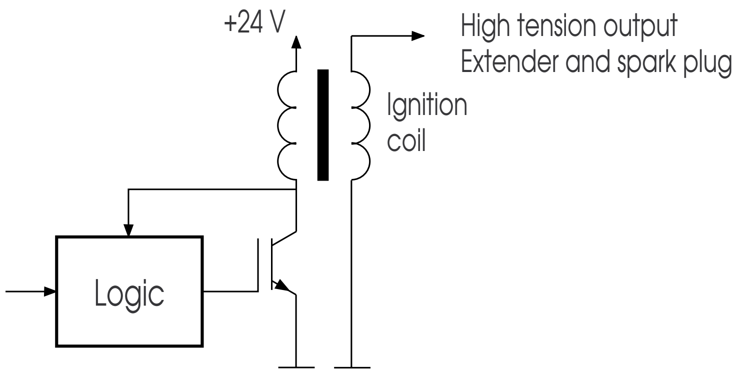

Fig 23-20 3223079601

23.11 Engine speed & load control

The speed and load control together with the synchronizing sequence will be described in the following sections.

23.11.1 General

The internal governor is provided with speed setting functions for synchronising, load sharing under speed control, as well as load control. It also provides fuel limitation and acceleration ramps used at engine start.

Engine speed and load control

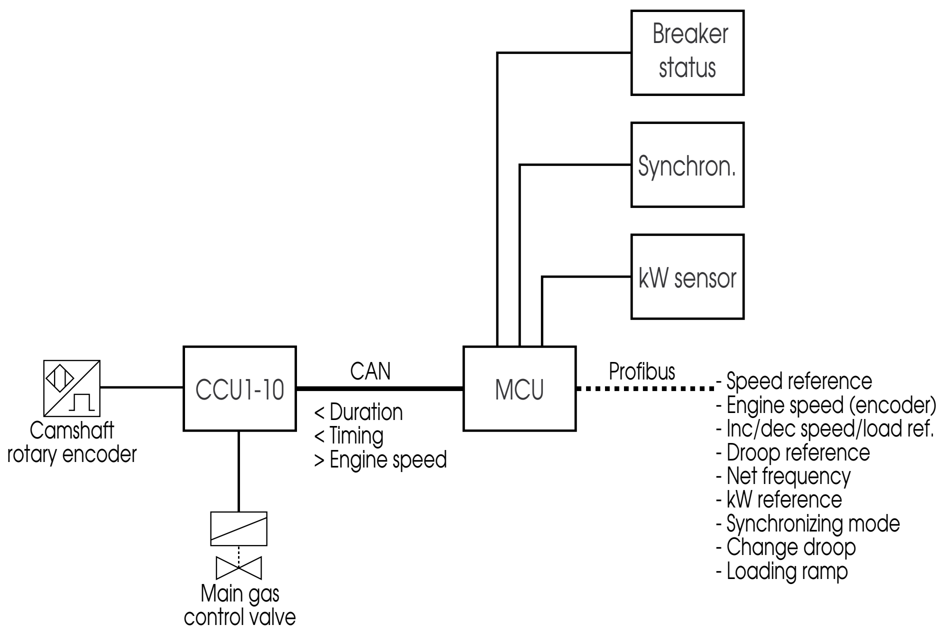

Fig 23-21 3223089601

23.11.2 Engine speed control

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 this controller will accordingly vary, to sustain the reference level. This output will either control the opening duration of the gas valves (gas operating mode) or the diesel fuel rack position (diesel- or backup operating mode). If load control mode is selected, another PID control loop becomes active.

The PID-controller has different sets of dynamic parameters for operation with the generator breaker open (speed dependent mapping) and closed (load dependent mapping) to obtain an optimal stability under all conditions. Some adaptive speed deviation dependent features are also provided, to minimise large speed fluctuations in island mode. To prevent the excessive engine speed increase during accidental opening of the generator breaker, the output of the PID-controller is temporarily set to zero.
When idling, the change-over between idling- and rated speed can either be selected over Profibus or via a binary input. Two different ramp rates are available for switching between idle and rated. The ramp function is stopped if the increase/decrease inputs are activated during the ramp. The speed reference will then be rated.
Two fuel limiters are available. The start fuel limiter is only active in during engine start, up to a speed level of rated - 20 rpm. The start fuel limiter settings are engine speed dependent (8-point table), and the limiter works in combination with a speed reference ramp, also used at engine start. Another fuel limiter limits the max. fuel demand (gas valve opening time) when the generator breaker is closed, to prevent too rich air/fuel ratio.

23.11.3 Synchronizing sequence

For synchronising, the system's speed increase/decrease binary inputs are used. When the engine reaches rated speed, an external device activates the synchronising sequence. Commands from a synchroniser unit activate the two binary inputs "speed increase" and "speed decrease" in WECS. The speed reference can be altered between an allowed min. and max. speed reference level, in steps of 1 rpm (tuneable) when activating these inputs. The internal speed reference is in this way adjusted so that the generator's frequency will match the net frequency. When the two frequencies are matched, the generator breaker closes. An instantaneous increase of the internal speed reference occurs automatically when WECS detects that the generator breaker closes (separate status input) to assure that there occurs on unintentional reverse power of the genset.
When the generator breaker is closed and the engine is operated in droop (speed control mode), the loading of the engine occurs by altering the speed increase/decrease over Profibus, or with the binary speed increase/decrease inputs, The reference changes in steps of 0,1 rpm (tuneable). The change rate is defined according to the increase (or decrease) signal pulse width. Increase commands are used until the load level of this engine is equal to other engines running in parallel. The load level of the engine will after this be according to the consumers connected to the isolated net.

23.11.4 Load sharing

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.
When the engine is operated in speed control mode, load sharing with other engines is normally provided with the use of speed droop. Drop control is a load sharing method, by which parallel running engines share the load by decreasing their speed reference proportionally to an increase in load. The droop value is normally set to 4 %, but the setting is adjustable. Too low droop value means that the load can start oscillating between the engines. Too high droop value means that the plant's frequency decreases steeply with the load level. Load sharing based on droop, means that the power management system must compensate the effect derived from the droop slope. Therefore, this system must operate the speed increase/decrease inputs of WECS (in so called cascade control) to ensure that the net frequency is kept constant regardless of the load level. Speed control with droop is used on plants operating in island mode, but it can also be used when operating against a grid utility. In the latter case, load control is however recommended.

23.11.5 Load control

The load control function is enabled if kW-mode is selected. This mode can only be activated when the generator breaker is closed. Also the grid breaker must be closed, if the plant configuration is such, that kW-mode is only applicable when this breaker closes. The load control mode has most benefits in base load applications where the grid frequency stability is low. The engine load will not fluctuate according to the frequency in the same way as if it would do in speed control mode with droop. In load control mode, the load reference is compared with the actual load of the engine. The difference between these signals constitutes the input to a PID-controller. The regulation output of this controller will accordingly vary, to sustain the reference level. This output will control the opening duration of the gas valves. The PID-controller's dynamic settings have load dependent mapping.
If the frequency deviates outside a fixed window, the control mode will automatically trip back to speed control. The speed reference is updated continuously by the speed control loop also in load control, which means that if a trip occurs, the transfer will basically be bumpless (no load swing). By giving a reset, the load control mode will be restored, providing that all enabling conditions are met.

23.12 Cylinder balancing

An even gas admission duration setting for all gas admission valves will not result in exactly the same gas quantity in all cylinders, due to the geometry of the engine and due to some deviations in the gas valve performance. This slight disparity is handled with the cylinder balancing control. The MCU compares each cylinder's exhaust gas temperature with the average exhaust gas temperature of the entire engine, and adjusts the duration of the individual gas valves with an offset, in order to minimise the deviation. There are limitations for the maximum adjustment available in order to prevent that possible component failures cause a too rich or too lean gas/air mixture. Above an engine load level of approximately 75 % (tuneable) this compensation is disabled, and the duration offset will be determined according to fixed values. The knock control algorithm of WECS will also affect the gas admission duration. The cylinder exhaust gas control is not active in diesel- and backup operating mode.
If the engine is in gas operating mode, and the load level is above approximately 15 % (tuneable) a cylinder knock based control will enable. Light knock in any cylinder will immediately result in a slight reduction of the quantity of gas injected into that cylinder. In order to maintain the same engine load level, the speed/load controller will automatically increase the gas admission into other cylinders. When the situation normalises in the cylinder, the gas admission will slowly be restored to the original setting. This process is continuous, and keeps the cylinders slightly out of knocking conditions. This process will ensure that the efficiency of the engine is at optimal levels.

Cylinder balancing control

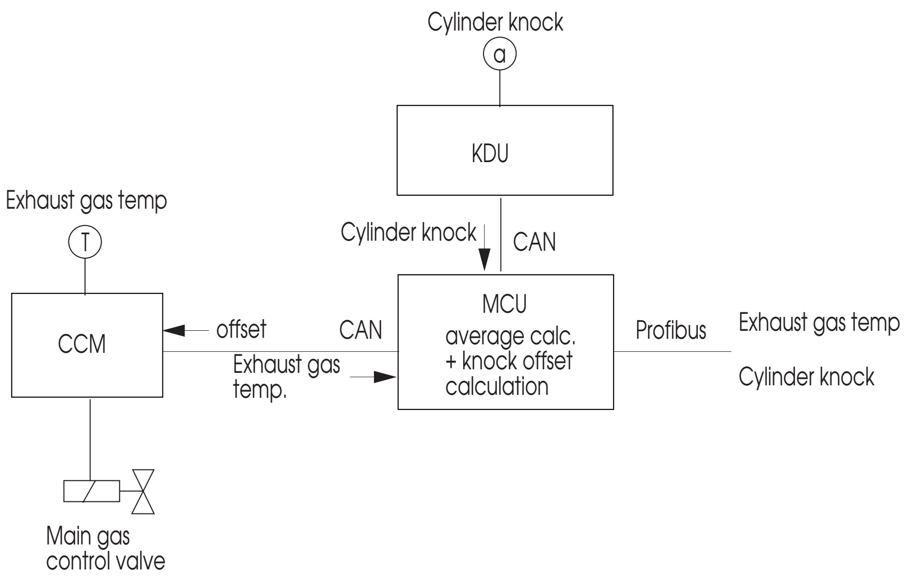

Fig 23-22 32231430408

23.13 Maintenance on the physical connections of the engine control system

Note ! **Each and every one of the maintenance procedures below are to be done only when the engine is in Stop Mode!**

Connectors to be maintained:

- DIN43650, “Hirschmann-type” connectors for all temperature and pressure sensors
- Cannon connectors for all the main gas admission and prechamber control valves
- Method for maintaining screw terminals
- Phoenix connectors in the CCU’s, DCU’s, KDU’s, and SMU’s
- Weiland connectors on the rear side of the MCU
- Row connectors of the MCU rack in the MCU cabinet
- Profibus cable connector of the MCU rack inside the MCU

23.13.1 Maintenance of the DIN43650, “Hirschmann-type” connectors

Locate the DIN43650, “Hirschmann-type” connector which is mounted on the main gas pressure sensor. Locate the holding screw in the top of the connector. Using a suitable sized flat tip screwdriver, loosen and remove the screw holding the connector onto the pressure sensor.

DIN43650, “Hirschmann-type” connector

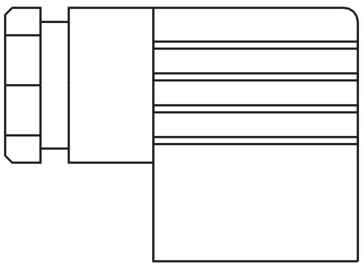

Fig 23-23 3223189723

1 **Remove, by pulling, the connector from the sensor.** Still holding the part of the connector, with the wires leading into it; use the same screwdriver and carefully open the body of the connector itself to expose the four screws inside.

2 **Tighten each of the four screws** with the screwdriver and put the body back together.

3 **Reconnect the connector** to the main gas pressure sensor and drive the holding screw back into place to secure the pressure sensor.

4 **Repeat the following steps** with all the other connectors on the engine.

23.13.2 Maintenance of the Cannon connectors

1 **Localize the Cannon connector of the main gas admission valve.** Check if the locking wire holding the connector ends is tight.

Cannon connector with locking wire

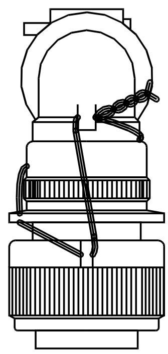

Fig 23-24 3223179723

2 **Pull on the wire.** If it moves, use a pliers to twist the wire just enough to get it tight again.

3 **Repeat the steps 1 and 2** for all the Cannon connectors of the main gas admission and prechamber control valves.

Note! **If the locking wire is broken it has to be replaced with a new one and applied same way as the others.**

Note! **Tighten only by hand. If tools are used, the nut will be damaged.**

23.13.3 Maintenance of screw terminals

Localize the connection boxes for the exhaust gas and cylinder liner temperature sensors in the “hot box” of the engine. Using a suitable sized flat tip screwdriver, open each connection box (one per cylinder). Tighten each of the screw terminals inside the box. Close the cover and tighten the screws.

23.13.4 Maintenance of the Phoenix connectors

Loosen the four Torx screws in the cover of CCU by using a 4 mm Torx key and open the cover.

Phoenix connectors

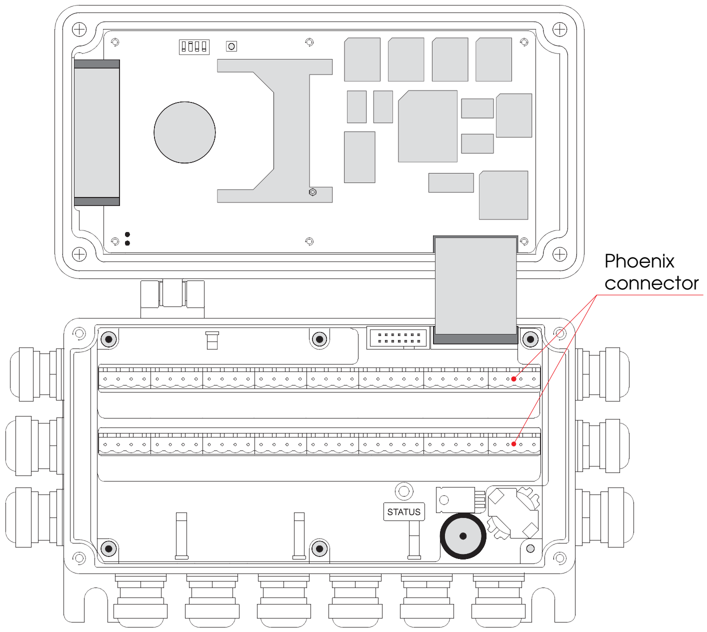

Fig 23-25 3223189723

1 **Use a suitable sized flat tip screw driver** and tighten all the screws of every Phoenix connector in CCU.

2 **Once all of the screws have been tightened,** press down all the Phonix connectors by finger tips. This is because some of them may have risen slightly because of engine vibrations.

3 **Close the cover** and tighten the screws.

4 **Check all other** CCU-, DCU-, KDU-, and SMU boxes in the same way.

23.13.5 Maintenance of the Weiland connectors

Localize the Weiland connectors on the MCU cabinet. Squeeze by hand the fastening lever towards the body of the Weiland connector to ensure that it remains securely connected to the connection block on the back side of the MCU.

Weiland connector

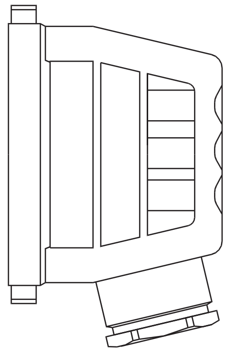

Fig 23-26 3223199723

23.13.6 Maintenance of row connectors and Profibus connector

1 **Open the MCU cover** and press down, one by one all the green row connectors in the MCU rack inside the MCU cabinet.

Just push on them to see if they are all the way in. Do not pull the connectors out, or the wires out of the connectors.

2 **Localize the two plastic knobs** on the Profibus connector block on the left end of the MCU rack. Turn the black plastic knobs clockwise until the screws holds the connector block of the MCU rack. Tighten screws by hand or by pliers.

3 **Close the door of MCU cabinet tightly and lock it.**

23.14 Maintenance of electrical contacts

To prolong the lifetime of electrical contact surfaces and to provide proper electrical connection under all conditions and to maintain a high availability of the WECS system.

The maintenance is carried out by applying contact lubricants to electrical contact surfaces. For best result the contact surface should be cleaned with aerosol electrical contact cleaner before applying the lubricant.

Contact lubricants are specially formulated greases and oils that reduce friction and enhance the electrical performance of current carrying metal interfaces in switches and connectors. They also exhibit a neutral pH thereby avoiding surface corrosion.

Note! **Prior to use read the product information.**

Warning! **To avoid shock or possible fire, disconnect power to any system before applying conductive lubricant. Insure positive and negative contacts remain isolated. Improper use can result in shorting, arcing, or shock.**

Wärtsilä recommends to regulary every 2000 - 4000 running hours or every 6 month maintain the electrical connector contact surfaces with contact lubricant. The contact treatment greases listed below can be ordered from Wärtsilä.

The recommended chemicals are:

- Electrolube SGB20S 20 ml Syringe, part No. 387 022.

  This paste is recommend to be used on the contact surfaces of main electronics connectors and sensor connectors.

  Same active substance as SGB200D but in different consistence, i.e. paste instead of aerosol.
- Electrolube SGB200D 200 ml Aerosol (Flammable), part No. 387 021.

  This spray is recommended to be used on contact surfaces of main electronic (SMU, DCU, RM, MCU and oil mist detector) connectors. Since it is an aerosol there are special requirements of transport handling.
- Chemtronics CW7100 6.5 g Syringe, part No. 387 023.

  This is a heavy duty paste. The electrical conductivity is very high due to the 100 % silver filled grease, see caution below. Should be used on problem sensor and power contact surfaces where SGB grease is not sufficient.

Caution! **Care should be taken since this chemical is very conductive and will cause short-circuit/earth fault if wrongly applied. Must be placed directly on the contact surface and in very small amounts.**