

**WÄRTSILÄ**

**RT-flex82C**

# Operating Manual

“Marine”

**Vessel:**

**Type:**

**Engine No.:**

**Book No.:**

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## **0 Operating Descriptions**

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### **2 Cylinder Liner and Cylinder Cover**

### **3 Crankshaft, Connecting Rod and Piston**

### **4 Engine Control and Control Elements**

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### **6 Scavenge Air System**

### **7 Cylinder Lubrication**

### **8 Piping Systems**

### **9 Engine Monitoring**

**For Particular Attention**

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This manual is put at the disposal of the recipient solely for use in connection with the corresponding type of diesel engine.  
It has always to be treated as confidential.

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Before the operator intends to use the engine or before maintenance work is undertaken, the Operating Instructions or the Maintenance Manual respectively is to be read carefully.

To ensure the best efficiency, reliability and lifetime of the engine and its components, only original spare parts should be used.  
It is to be ensured as well that all equipment and tools for maintenance are in good condition.

The extent of any supplies and services is determined exclusively by the relevant supply contract.

The data, instructions and graphical illustrations etc. in this manual are based on drawings made by **Wärtsilä Switzerland Ltd** and correspond to the actual standard at the time of printing (year of printing is indicated on title page).  
Those specifications and recommendations of the classification societies which are essential for the design have been considered therein. It must be recognized that such data, instructions and graphical illustrations may be subject to changes due to further development, widened experience or any other reason.

This manual is primarily intended for use by the engine operating and maintenance personnel. It must be ensured that it will always be at the disposal of such personnel for the operation of the engines and/or for the required maintenance work.

This manual has been prepared on the assumption that operation and maintenance of the engines concerned will always be carried out by qualified personnel having the special knowledge, training and qualifications needed to handle in a workman-like manner diesel engines of the corresponding size, the associated auxiliary equipment, as well as fuel and other operating media.

Therefore, generally applicable rules, which may also concern such items as protection against danger, are specified in this manual in exceptional cases only. It must be made sure that the operating and maintenance personnel are familiar with the rules concerned.

**This manual has been prepared to the best knowledge and ability of its authors. However, neither Wärtsilä Switzerland Ltd nor their employees assume any liability – under any legal aspect whatsoever, including possible negligence – in connection with this manual, its contents, or modifications to it or in connection with its use.**

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Wärtsilä Switzerland Ltd  
Winterthur  
Switzerland

## General

### Preface

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## 1. Summary

The documentation for this diesel engine type comprises the following books and publications:

### 1.1 Operating Manual

This contains information covering engine operation, the required operating media (oil, water and fuel), as well as a description of the function of specific systems.

### 1.2 Maintenance Manual

This contains, in addition to the maintenance diagrams, information covering specific dismantling and assembly work necessary for engine maintenance. It contains furthermore a masses (weight) table of certain individual parts, a clearance table, a list of rubber / O-rings, tightening values for important screwed connections and a tools list.

### 1.3 Code Book (spare parts catalogue)

In this book all parts are marked with a code number by which they can be ordered from Wärtsilä Switzerland Ltd or the engine supplier. *Such spare parts are to be ordered exclusively from this book.*

### 1.4 Documentation for bought-out items

Separate publications are provided for those items on the engine supplied by outside manufacturers, such as turbocharger, automatic filter, torsional vibration damper, etc. In most cases these can also be used as a spare parts catalogue.

### 1.5 Records and drawings

With the first delivery of the documentation, the setting tables, shop trial documents and surveyor's certificates of the engine concerned as well as schematic diagrams are also supplied.

## 2. Structure of manuals

Generally the manuals have to be regarded as **Basic Manuals**. They describe particularly the standard engine with all cylinder numbers, alternative design executions and special equipment.

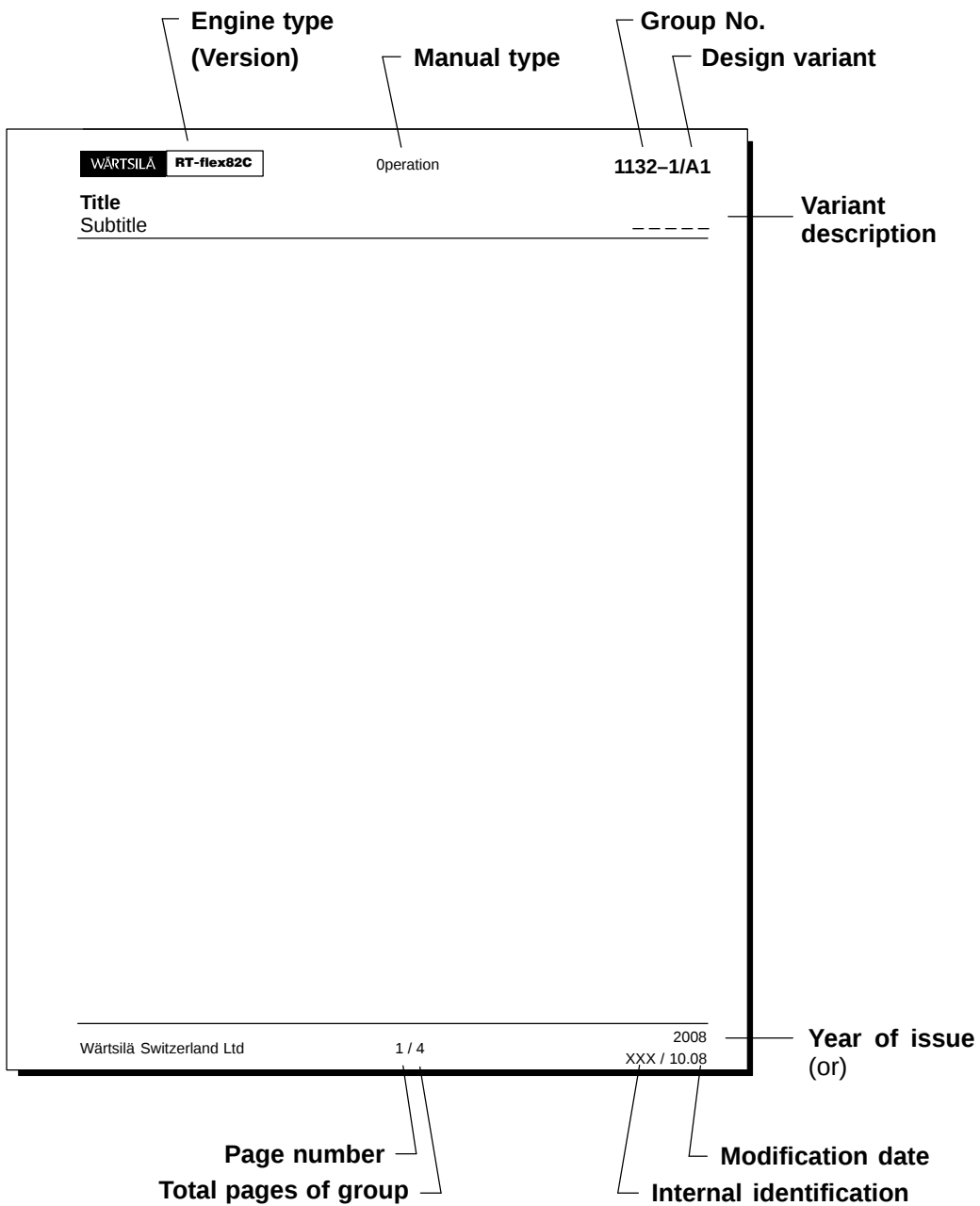
As a rule, in the case of alternative design executions the descriptions have been divided in separate groups and clearly designated by the respective alternative names. This allows on one hand to quickly find with certainty the respective passages, on the other hand it allows the later removal of sheets of not supplied alternatives and special executions.

Further indications can be found under Explanation on the Use of the Operating Manual [0040–1](#).

Preface

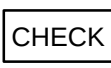
2.1 Structure and page designations

The individual groups with their illustrations are divided according to the design groups whenever possible.



2.2 Symbols

 **Remark:** Refers to important details and recommendations concerning operation and maintenance of the engine.

 Refers to checks which must be carried out for trouble-free operation and during maintenance.

Preface

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**Attention! Risk of injury! or Risk of accident!** Refers to instructions for operation and maintenance of the engine which absolutely must be complied with. In case of non-observance high risk of injury as well as damage to components must be expected.



Refers to activities which must **not** be carried out during operation and maintenance of the engine. In case of non-observance damage to components must be expected.

⇒ Sign for order of actions, activities to be carried out

- Sign for observance of regulations
- Sign for enumerations

### 3. Repeat-order of technical documentation



**Remark:** Corresponding to the continuing development of the engines the documentation is continually being updated.

This means that in a later ordered manual for the same engine, text and designations may no longer coincide in every way with the previous version (see modification date on the relevant pages).

Notwithstanding the foregoing, important information and improvements are brought to the customer's notice by 'Service Bulletins' so that the relevant part of any development should already be known.

When ordering documentation at a later stage for engines which have already been in operation since several years, the following details are basically required:

- Engine type, year of manufacture and engine manufacturer
- Name of vessel or site of installation
- Cylinder or engine number
- Special equipment
- Language of documentation (German or English)
- Form of documentation (printed Manuals or CD-ROM)

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## Guide for Symbols and Abbreviations

### 1. Symbols

These stand for control components (valve units etc.) used for engine control.

| Symbols  | Explanations                                |
|----------|---------------------------------------------|
| <b>A</b> | Control air supply unit                     |
| <b>B</b> | Fuel supply                                 |
| <b>C</b> | Fuel injection                              |
| <b>D</b> | Servo oil supply                            |
| <b>E</b> | Valve unit for start                        |
| <b>F</b> | Exhaust valve drive                         |
| <b>H</b> | Instrument panel                            |
| <b>I</b> | Pressure switches and pressure transmitters |
| <b>K</b> | Local control panel                         |

### 2. Abbreviations

#### 2.1 General

The abbreviations used in the manuals are arranged alphabetically in this guide, however, unit of measures are not listed.



**Remark:** Identical abbreviations e.g. MCR can be distinguished in the corresponding context.

| Abbreviations | Explanations                                                        |
|---------------|---------------------------------------------------------------------|
| AHD           | Ahead                                                               |
| ALM           | Alarm                                                               |
| AST           | Astern                                                              |
| BDC           | <b>B</b> ottom <b>D</b> ead <b>C</b> enter                          |
| BFO           | <b>B</b> unker <b>F</b> uel <b>O</b> il                             |
| BN            | <b>B</b> ase <b>N</b> umber                                         |
| CCAI          | <b>C</b> alculated <b>C</b> arbon <b>A</b> romaticity <b>I</b> ndex |
| CMCR          | <b>C</b> ontract <b>M</b> aximum <b>C</b> ontinuous <b>R</b> ating  |
| COC           | <b>C</b> leveland <b>O</b> pen <b>C</b> up                          |
| HFO           | <b>H</b> eavy <b>F</b> uel <b>O</b> il                              |
| IMO           | <b>I</b> nternational <b>M</b> aritime <b>O</b> rganisation         |
| ISO           | <b>I</b> nternational <b>S</b> tandard <b>O</b> rganisation         |
| JIS           | <b>J</b> apanese <b>I</b> ndustrial <b>S</b> tandards               |
| MCR           | <b>M</b> aximum <b>C</b> ontinuous <b>R</b> ating                   |
| MCR           | <b>M</b> icro <b>C</b> arbon <b>R</b> esidue                        |
| MDO           | <b>M</b> arine <b>D</b> iesel <b>O</b> il                           |
| mep           | <b>m</b> ean <b>e</b> ffective <b>p</b> ressure                     |
| MGO           | <b>M</b> arine <b>G</b> as <b>O</b> il                              |
| PMCC          | <b>P</b> ensky <b>M</b> artens <b>C</b> losed <b>C</b> up method    |

## Guide for Symbols and Abbreviations

| Abbreviations | Explanations                                                                                                                           |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------|
| RCS           | <b>R</b> emote <b>C</b> ontrol <b>S</b> ystem                                                                                          |
| SCR           | <b>S</b> elective <b>C</b> atalytic <b>R</b> eduction                                                                                  |
| SIPWA–TP      | <b>S</b> ulzer <b>I</b> ntegrated <b>P</b> iston ring <b>W</b> ear detecting <b>A</b> rrangement with <b>T</b> rend <b>P</b> rocessing |
| SHD           | <b>S</b> Hut <b>D</b> own                                                                                                              |
| SHF           | <b>S</b> ediment by <b>H</b> ot <b>F</b> iltration                                                                                     |
| SLD           | <b>S</b> Low <b>D</b> own                                                                                                              |
| TDC           | <b>T</b> op <b>D</b> ead <b>C</b> enter                                                                                                |
| WHR           | <b>W</b> aste <b>H</b> eat <b>R</b> ecovery system                                                                                     |

## 2.2 Concerning engine control system WECS–9520

|            |                                                                                                          |
|------------|----------------------------------------------------------------------------------------------------------|
| ALM–20     | <b>A</b> dvanced <b>L</b> ubrication <b>M</b> odule–20                                                   |
| AMS        | <b>A</b> larm and <b>M</b> onitoring <b>S</b> ystem                                                      |
| CAN–Bus    | <b>C</b> ontroller <b>A</b> rea <b>N</b> etwork                                                          |
| CAN M      | CAN <b>M</b> odul bus                                                                                    |
| CAN S      | CAN <b>S</b> ystem bus                                                                                   |
| COM–FN     | <b>C</b> OMon <b>F</b> uNction (engine-related control functions)                                        |
| CYL–FN     | <b>C</b> YLinder <b>F</b> uNction (cylinder-related control functions)                                   |
| DENIS–9520 | <b>D</b> iesel <b>E</b> ngine <b>C</b> oNtrol and <b>O</b> ptImizing <b>S</b> pecification for WECS–9520 |
| ECR        | <b>E</b> ngine <b>C</b> ontrol <b>R</b> oom                                                              |
| FCM–20     | <b>F</b> lex <b>C</b> ontrol <b>M</b> odule–20                                                           |
| FQS        | <b>F</b> uel <b>Q</b> uality <b>S</b> etting                                                             |
| LED        | <b>L</b> ight <b>E</b> mitting <b>D</b> iode                                                             |
| SCS        | <b>S</b> peed <b>C</b> ontrol <b>S</b> ystem                                                             |
| Modbus     | Gould– <b>M</b> odicon <b>F</b> ield <b>b</b> us                                                         |
| OPI        | <b>O</b> Perator <b>I</b> nterface (user interface in control room)                                      |
| PCS        | <b>P</b> ropulsion <b>C</b> ontrol <b>S</b> ystem                                                        |
| RCS        | <b>R</b> emote <b>C</b> ontrol <b>S</b> ystem                                                            |
| SIB        | <b>S</b> hipyard <b>I</b> nterface <b>B</b> ox (engine / remote control interface)                       |
| SSI        | <b>S</b> ynchron <b>S</b> erial <b>I</b> nterface                                                        |
| VEC        | <b>V</b> ariable <b>E</b> xhaust valve <b>C</b> losing                                                   |
| VEO        | <b>V</b> ariable <b>E</b> xhaust valve <b>O</b> pening                                                   |
| VIT        | <b>V</b> ariable <b>I</b> njection <b>T</b> iming                                                        |
| WECS       | <b>W</b> ärtsilä <b>E</b> ngine <b>C</b> ontrol <b>S</b> ystem                                           |
| WECS–9520  | Computerized control system for all flex-specific functions                                              |

## General

### Explanations on the Use of the Operating Manual

---

#### 1. Contents

The **Operating Manual**, called Operation for short, mainly contains descriptions and indications on:

- Servicing of the engine in operation.
- Required operating media (oil, water, air, fuel).
- Explanations of the function of specific components and systems.



**Remark:** The instructions on maintenance and overhauls are found in a separate book, the Maintenance Manual.

#### 2. Where to find what

When looking for group descriptions consult first of all the Table of Contents [0020–1](#). The Subject Index [0030–1](#) is also very useful.

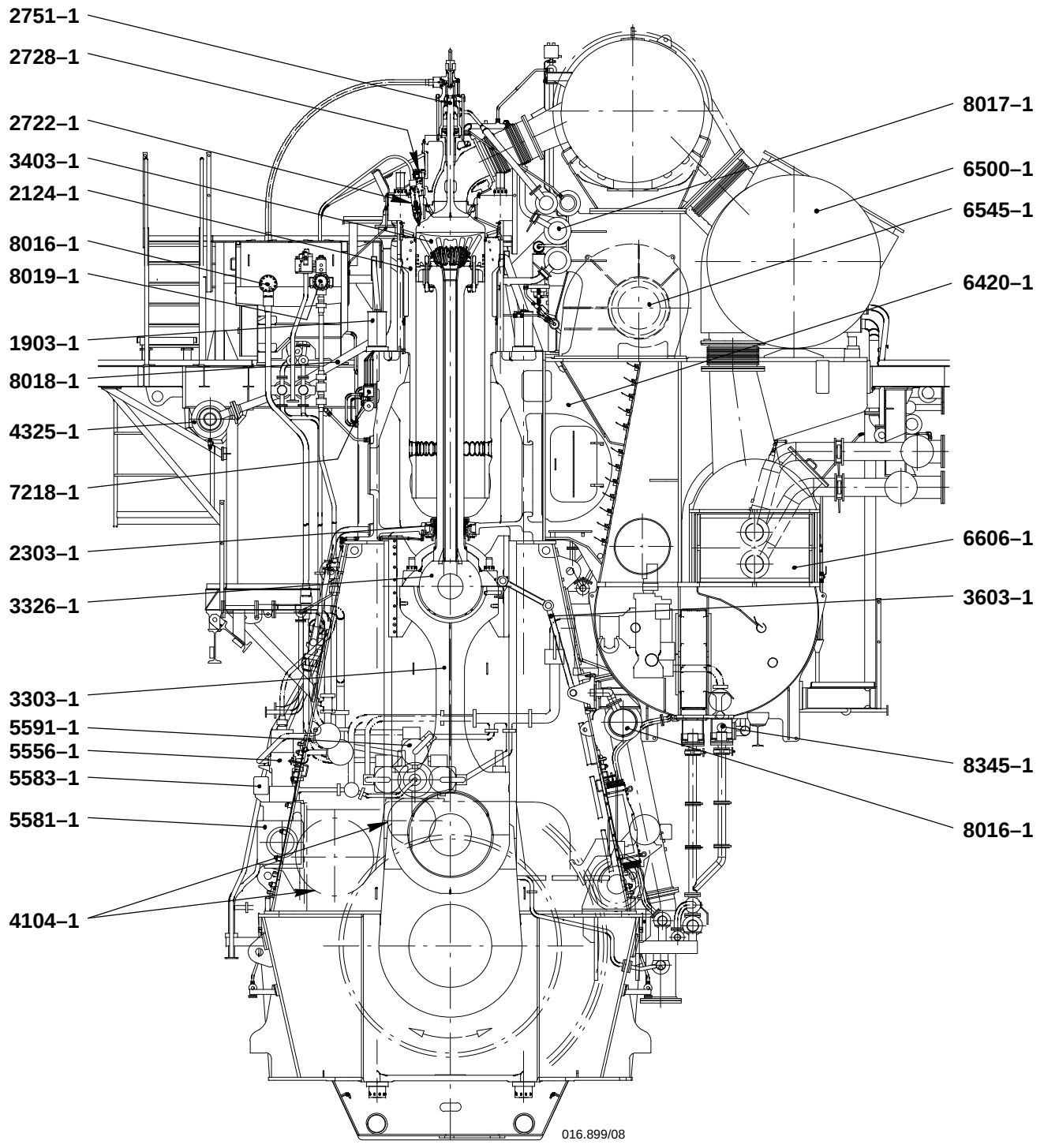
In the cross section and longitudinal section illustrations, important components have been marked with the group number where they can quickly be found with their description. The sections further provide a general view of the design of the engine, which, depending on specific executions, may differ slightly.

*Cross section and longitudinal section see [pages 2 and 3](#).*

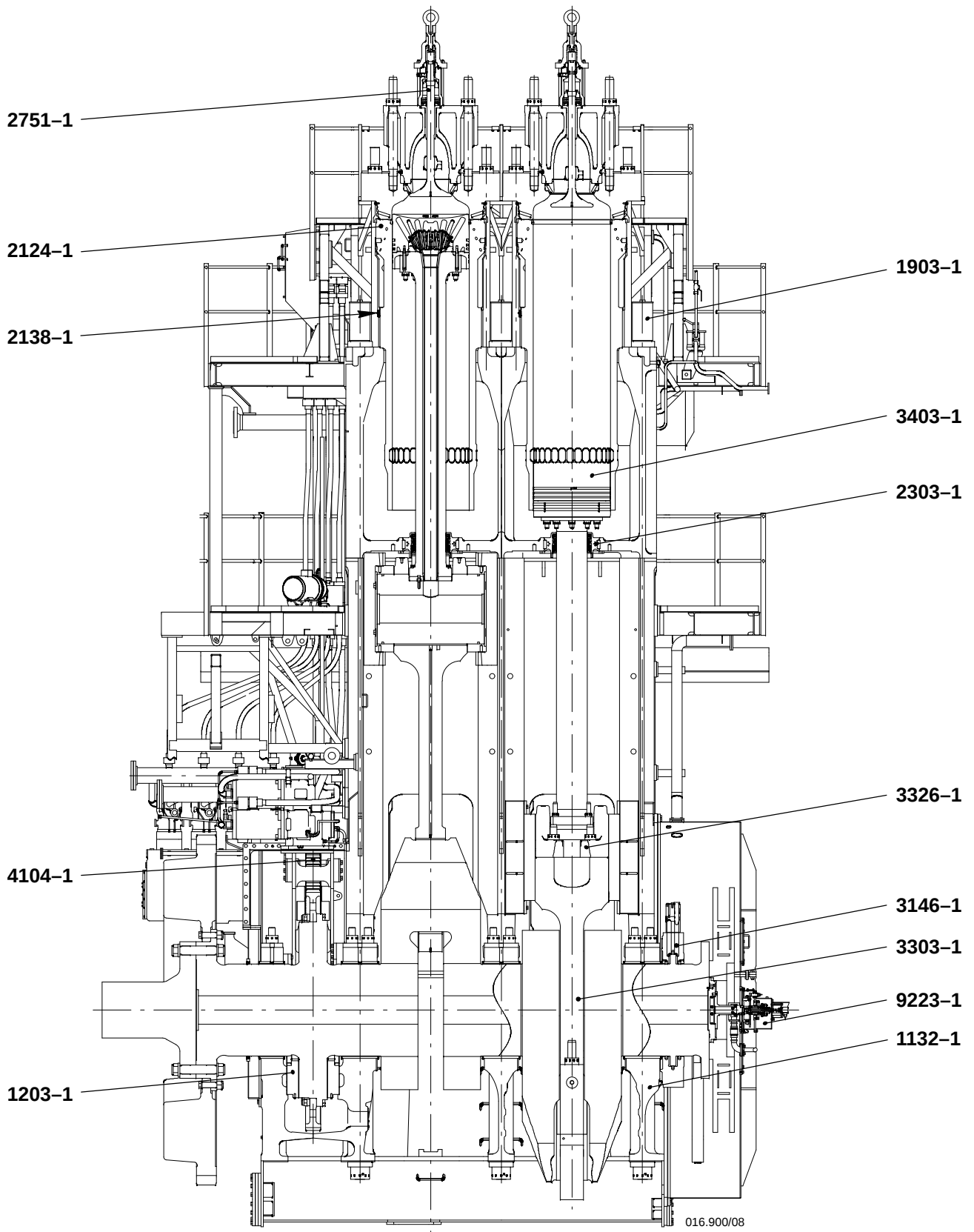
#### 3. Guide for symbols and abbreviations

The symbols and abbreviations used in the Operating Manual are explained in the guide [0035–1](#). Abbreviations used in the illustrations are listed in the corresponding keys.

## Explanations on the Use of the Operating Manual

**Cross Section:**

## Explanations on the Use of the Operating Manual

*Longitudinal Section:*

## General

### Brief Description of the Engine

---

#### 1. General

- The RT-flex engine is a single acting two-stroke diesel engine of crosshead design with exhaust gas turbocharging and uniflow scavenging.
- For direct coupled propeller drive it is reversible.
- The RT-flex concept is based on the Wärtsilä Common Rail, with full electronic control of fuel injection and exhaust valve actuation.
- The engine control is devised in such a way that remote controls of recommended manufacturers which correspond to our specifications can be built on, because the locations of interfaces are exactly defined.
- In case of failure of the remote control the engine can be controlled with emergency control from the local control panel.
- Tie rods bind the bedplate, columns and cylinder jacket together.
- Crankcase and cylinder jacket are separated from each other by a partition which incorporates the sealing gland boxes for the piston rods.
- The thrust bearing and turning gear are situated at the engine driving end.
- The exhaust valve actuation and the electronic injection are controlled by the engine control system WECS–9520.
- Lubricating oil, cooling water, fuel feed and booster pumps as well as air compressors are parts of the engine room installation (ancillary systems).

#### 2. Systems

- The exhaust valves are opened hydraulically by the servo oil system and closed pneumatically. The oil supply is ensured from the bearing oil system through a fine filter. Servo oil pumps in the servo pump unit provides the servo oil rail with the required pressure via three rising pipes.
- The pistons are cooled by bearing oil.
- Fuel pumps in the fuel pump unit deliver fuel under high pressure into the fuel rail via rising pipes and subsequently through the injection control units to each injection valves.
- The injection control units are activated via the servo oil system.
- The cylinders and cylinder covers are fresh water cooled.
- For cooling the scavenge air a single-stage cooler is used with central fresh water cooling (closed circuit).
- The engine is started by compressed air entering into the cylinders via starting valves, controlled by the WECS–9520.

## Brief Description of the Engine

---

- The exhaust gases flow from the cylinders through the exhaust valves into an exhaust gas manifold.
- The turbochargers work on the constant pressure charging principle.
- The scavenge air delivered by the turbochargers flows through air cooler and water separator into the air receiver. It enters the cylinders via air flaps through the scavenge ports when the pistons are nearly at their BDC.
- At low loads independently driven auxiliary blowers supply additional air to the scavenging air space.

**General****Working Principle of the Two-stroke Diesel Engine**

---

**First Stroke: (Compression)**

- Piston in BDC (**B**ottom **D**ead **C**entre).
- Scavenge ports and exhaust valve open.
- Scavenge air flows into the cylinder and presses the exhaust gases through the exhaust valve into the exhaust gas manifold and from there to the turbo-charger.
- Piston moves upwards.

**Point ES:**

- Scavenge ports are being closed by the piston.

**Point AS:**

- Exhaust valve shuts, compression begins.

**Second Stroke: (Ignition – Combustion – Expansion – Exhaustion – Scavenging)**

- At around the TDC (**T**op **D**ead **C**entre) fuel is injected into the cylinder.
- The fuel ignites in the compressed, heated air = ignition. With ignition combustion begins.
- The gases expand and press the piston downwards (working stroke).

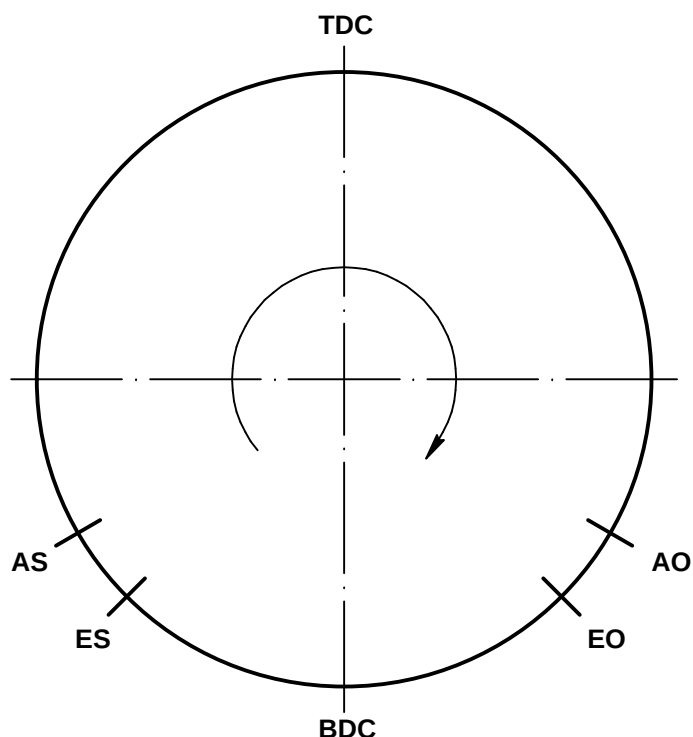
**Point AO:**

- The exhaust valve opens, exhaust gases flow out of the cylinder into the exhaust gas manifold and from there to the turbocharger.

**Point EO:**

- Scavenge ports are being uncovered by the downward moving piston.
- Scavenge air flows into the cylinder and presses the exhaust gases out through the exhaust valve into the exhaust gas manifold and from there to the turbocharger.

(See schematic diagram of Turbocharging [6500–1](#))



**General**Interrelationship between Engine and Propeller

---

**1. General**

There is a defined relationship between the propeller speed and the absorbed power in ships equipped with fixed pitch propellers.

With a given propeller this relationship mainly depends on its rotational speed.

The following formula provides us with an approximation which is adequate for the general consideration of conventional vessels:

$$\frac{P_1}{P_2} = \left( \frac{n_1}{n_2} \right)^3$$

Its graph is called the propeller characteristic.

If an engine is in good condition and properly supplied with air (i.e. turbocharger(s) in good order and the air and exhaust lines have low additional resistance) and the fuel injection quantity is properly adjusted (see setting table), the mean effective pressure developed under service condition according to the specific reading of the load indication corresponds approximately with the mean effective pressure established for this particular position on the test bed.

In the diagram, the propeller characteristic line through the point of CMCR (**Contract Maximum Continuous Rating**), i.e. nominal power at nominal engine speed (100% power at 100% engine speed) is called the nominal propeller characteristic. Engines which are to be employed for the propulsion of vessels with fixed propellers are loaded on the test bed according to this propeller characteristic. However, the power requirement of a new ship with a smooth and clean hull should be less and correspond to the range D.

With increasing resistance, changes in wake flow conditions, due to marine growth and ageing of the vessel's hull, a rough or mechanically damaged propeller, unfavourable sea and weather conditions or operation in shallow water, the propeller will require a higher torque to maintain its speed than it did at the time of sea trial. The mean effective pressure of the engine (and thus the fuel injection quantity) will increase accordingly. In such a case, the operating point will then be located to the left of the original propeller curve which was established during sea trials.

Although cleaning and re-painting will help to reduce the increased resistance of the ship's hull, the original condition can no longer be attained.

Whereas the thermal loading of an engine depends chiefly on the mean effective pressure, the position of the operating point is also important; the farther left it is situated from the propeller curve in the diagram ([page 2](#)), the poorer the air supply to the engine and the more unfavourable the engine's operating conditions will become.

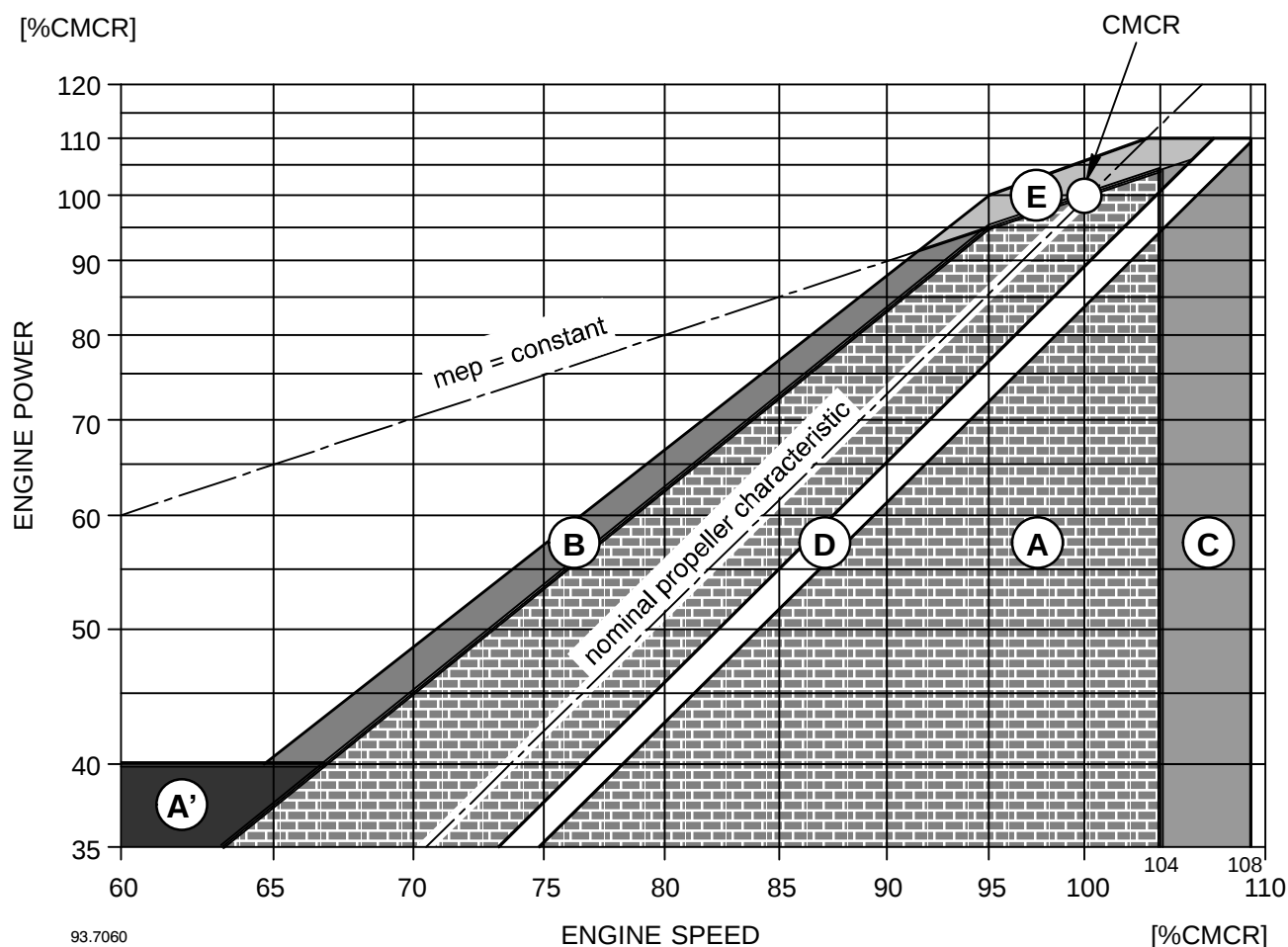
In order to attain optimum working conditions, the operating point of the engine for continuous service should lie in range A on the right side of the nominal propeller characteristic.

**Explanations:**

|      |   |                                           |
|------|---|-------------------------------------------|
| CMCR | = | <b>Contract Maximum Continuous Rating</b> |
| P    | = | <b>Power</b>                              |
| n    | = | <b>speed</b>                              |
| mep  | = | <b>mean effective pressure</b>            |

See also Guide for Symbols and Abbreviations [0035–1](#).

## Interrelationship between Engine and Propeller

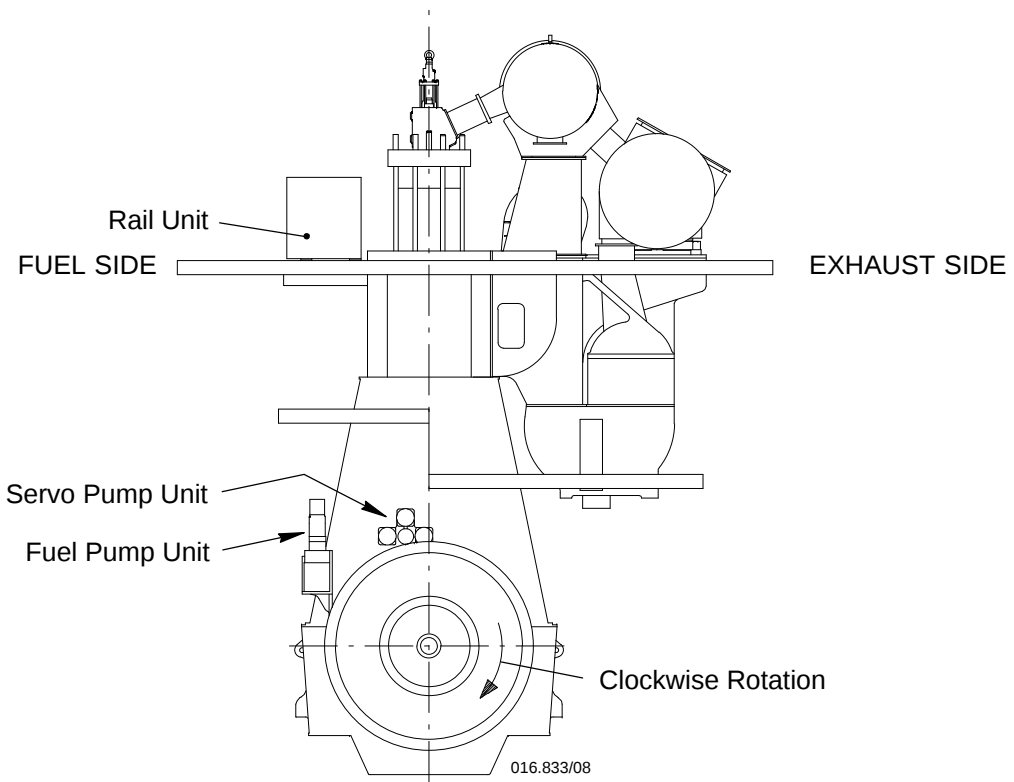
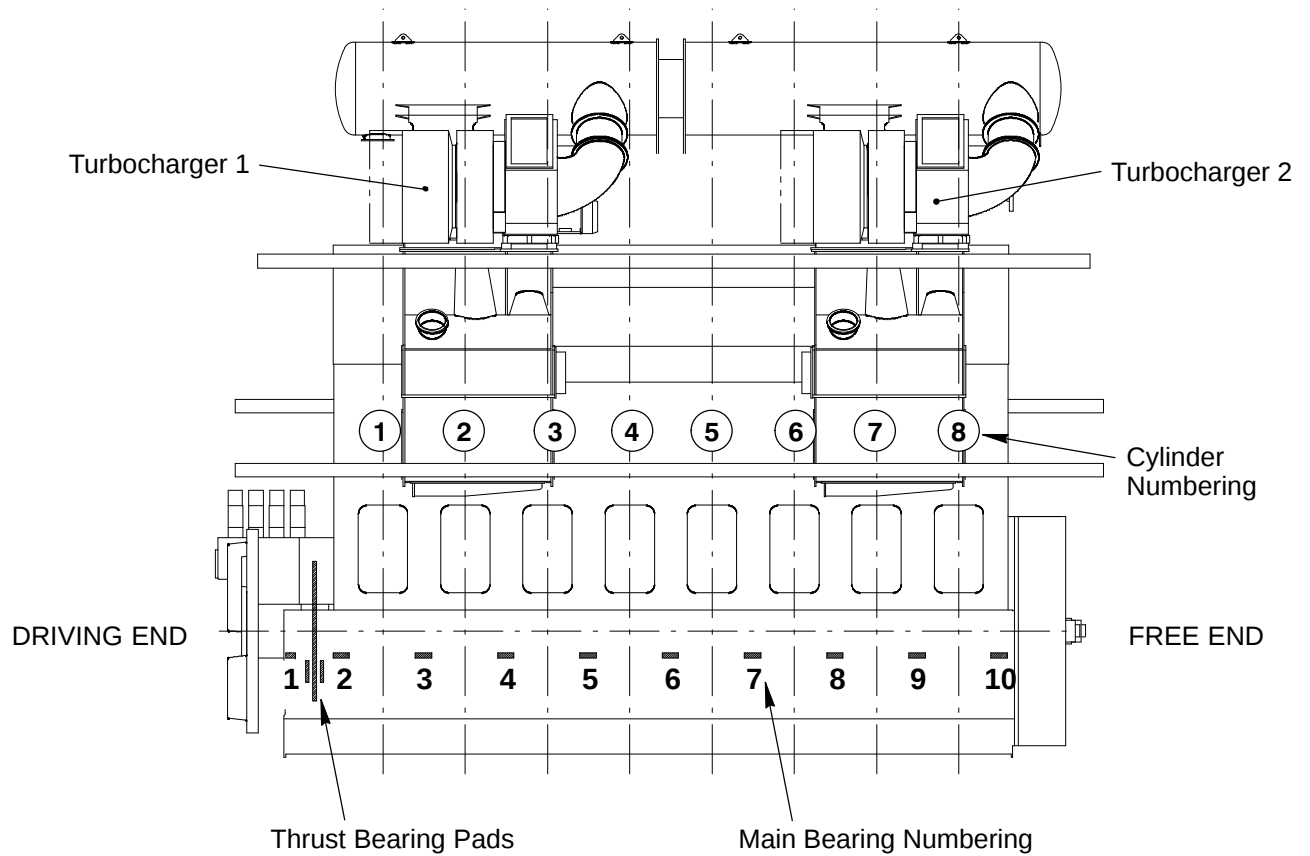


## 2. Load ranges

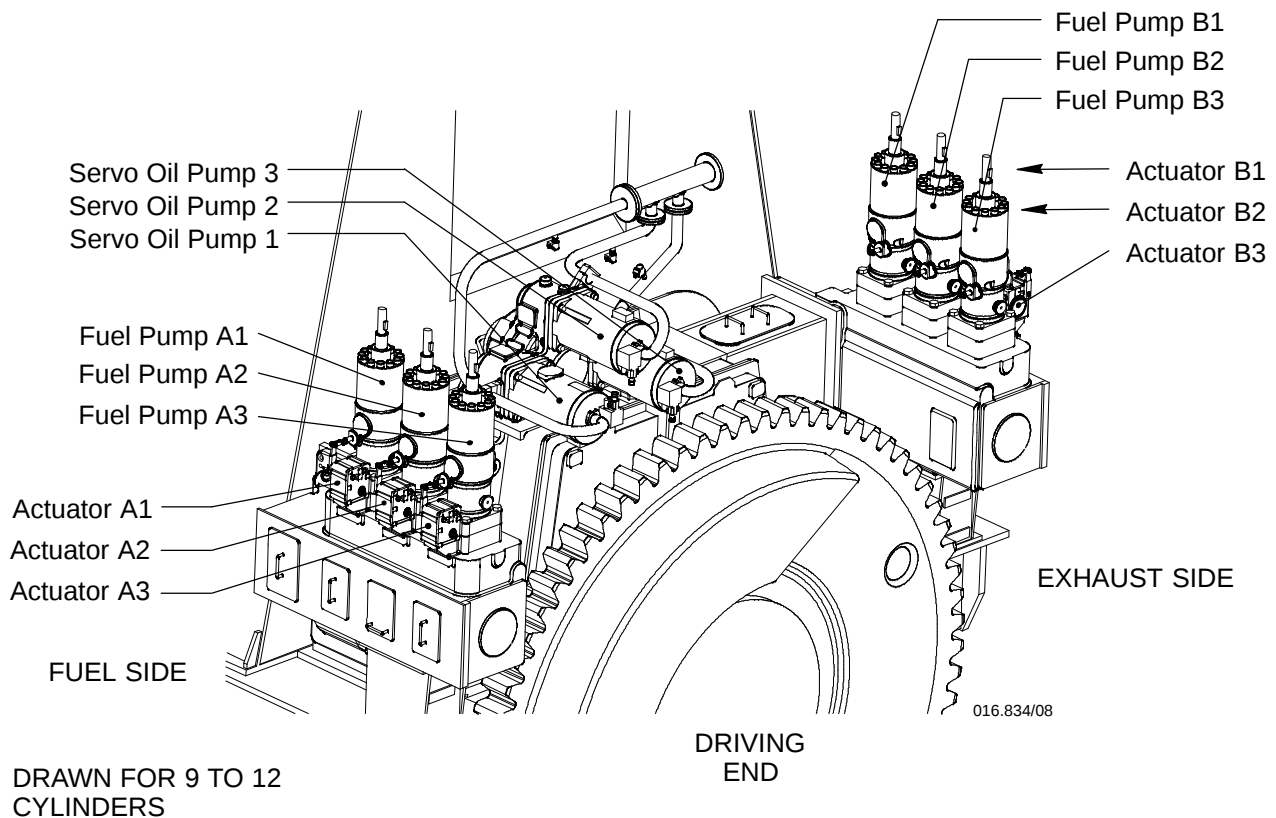
|      |                                                                                                                                                                                                                                                                                                                                                               |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (A)  | The portion on the right of the nominal propeller characteristic is the service range without continuous operating restrictions related to the selected CMCR point.<br>The portion on the left of the nominal propeller characteristic is the service range for transient operating conditions (acceleration) and should be avoided for continuous operation. |
| (A') | Maximum permissible engine power 40% CMCR from approx. 50% up to 67% of CMCR speed.                                                                                                                                                                                                                                                                           |
| (B)  | Service range with operational time limit, follows a characteristic:<br>$P \approx n^{2.45}$ .<br>This characteristic originates from the reference point 95% CMCR power and 95% CMCR speed. With longer operating time in this range, thermal overloading and possible resulting engine damage may be expected.                                              |
| (C)  | Service range with overspeed of 104 to 108% of CMCR speed, only permissible during sea trials to demonstrate the CMCR power in presence of authorized representatives of engine builder. However, the specified torsional vibration limits must not be exceeded.                                                                                              |
| (D)  | Recommended layout range for fixed pitch propeller, valid for the maximum draught, clean hull under contractual weather and sea conditions.                                                                                                                                                                                                                   |
| (E)  | Overload range permissible only for maximum one hour during seatrials in presence of authorized representatives of engine builder.                                                                                                                                                                                                                            |

**General**

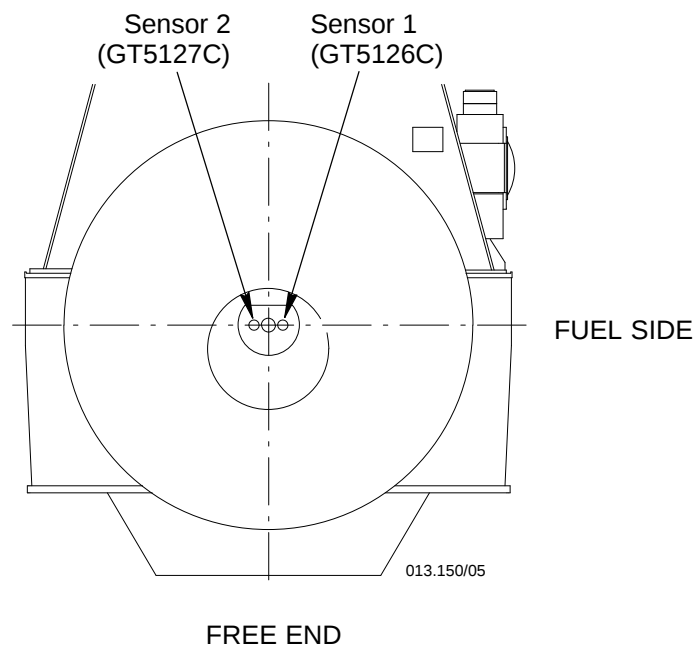
## Engine Numbering and Designations

**General:**

## Engine Numbering and Designations

**flex Parts:**

## Crank Angle Sensors



## Preparation before Taking into Service

### Preparations before Starting after a Short Shut-down (One or More Days)

---

#### 1. Starting position

It is assumed that:

- all components on which overhaul work was carried out have previously been correctly re-assembled and fitted and checked as to their perfect function.
- all devices and tools which were used have been removed from the engine and that no cleaning rags or other items have been left behind.
- The setting of the fuel pumps and the connection of the actuators with the regulating linkage are in order.



**Attention!** Up to point where the venting valves 2.21 and 2.27 must be closed, the shut-off valve for starting air 2.03 remains in position CLOSED (closed by hand), the venting valve 2.21, and the venting valve 2.27 in the starting air main must be open (see Control Diagram [4003–2](#)).

#### 2. Checks and preparations

- ⇒ Check the fluid levels of all the tanks in the engine systems (including the leakage drain tanks).
- ⇒ Check that all the shut-offs for the engine cooling water and lubricating oil systems are in the correct position.
- ⇒ Check that the lubricating device (tool 94844 provided for additional lubrication of the fuel pump drive during overhaul works) is removed and the oil pipe is properly closed by means of the blank flange (see Maintenance Manual 5581–4).
- ⇒ Open the air supply from the shipboard system to the control air supply **A**.
- ⇒ Open the shut-off cock at connection A1 and put air spring venting 4.08 to operating position (see Control Air Supply [4605–1](#)).
- ⇒ Preheat the lubricating oil to about 35 °C (via separating circuit or heating in oil drain tank).
- ⇒ Preheat the cylinder cooling water to min. 60 °C.
- ⇒ Switch on the engine and remote control system WHENS–9520.
  - Switch on all breakers in the power supply box E85.
  - Check that both green indication LETS light up on all FCC–20 modules.
- The FCC–20 modules are able to function if no red LETS light up after the countdown process.
- ⇒ Prepare the servo oil system (see [0130–1](#)).
- ⇒ Start up the pumps for cylinder cooling water, bearing oil and set the pressures to their normal values (see Operating Data Sheet [0250–1](#)).
- ⇒ Switch on control box for automatic filter (see documentation of the automatic filter manufacturer).
- ⇒ Switch on main switch of the servo oil service pumps.
- ⇒ Prepare the cylinder lubricating system (see [0140–1](#)).
- ⇒ Prepare the fuel oil system (see [0120–1](#)).
- ⇒ Ensure that all systems are correctly vented.
- ⇒ After ensuring air spring supply, check whether all exhaust valves are closed.

## Preparations before Starting after a Short Shut-down (One or More Days)

---

- ⇒ Open and shut each exhaust valve 4.01 few times manually in remote control in order to ensure thorough venting of the hydraulic actuators of the exhaust valves (user parameter, function 'Ex. A/M Mc').



**Remark:** The engine can not be started if the exhaust valves are not fully closed.

- ⇒ Open each cylinder cover's indicator valve. With the aid of the turning gear, turn the engine through at least one full revolution to check that all the running gears are in order. Neither water, oil nor fuel may spray out of the indicator valves. If so, depending on the liquid, check cylinder liner, cylinder cover, piston or injection valves.  
With this the cylinder lubrication must be switched on.
- ⇒ Shut indicator valves.
- ⇒ Check to ensure that all the crankcase doors are locked **with all the clamps**.
- ⇒ Check that the fuel pump regulating linkage moves freely.
- ⇒ Check the pressure in the starting air bottles and open their drains until any condensate has been drained.
- ⇒ Open the drain and test valve 2.06 until no more water comes out.
- ⇒ Close venting valves 2.21 and 2.27 and open the main shut-off valves on the starting air bottles 9.01.
- ⇒ Bring the shut-off valve for starting air 2.03 to position AUTOMAT.
- ⇒ Open the shut-off cock at connection A2 (see Control Air Supply [4605-1](#)).
- The pressure gauges on the instrument panel must now show starting air and control air pressure.
- A pressure must also be indicated on the pressure gauges for the control air supply.

The different circuits are:

- Air spring air
- Control air
- Air supply from the board system and back-up supply from the starting air system via the pressure reducing valve 19HA.

Required pressures see Operating Data Sheet [0250-1](#)).

- ⇒ Set the switches on the control panels for the auxiliary blowers to AUTOMAT.
- ⇒ Switch off the servo oil service pump.
- ⇒ Disengage the turning gear and secure the lever.
- ⇒ Open the test valve 2.06 of the shut-off valve for starting air 2.03 for a short time and listen if the valve opens (can be heard distinctly). Close the test valve again.
- ⇒ Press SLOW TURNING button in WHENS-9520 manual control panel on the local control panel ([4618-1](#)). The engine will perform one slow revolution (see also Slow Turning [0220-1](#)).
- ⇒ Depending from where the engine will be started (either bridge, control room or local control panel), the corresponding button in WECS-9520 manual control panel (local control panel) and the corresponding takeover buttons of the remote control must be activated.
- ⇒ Check again to ensure that no personnel are near the flywheel.
- ⇒ Inform readiness to the bridge.

## Preparation before Taking into Service

### Prepare the Fuel Oil System for Operation

---

#### 1. For diesel oil operation

(see [0720-1](#) 'Layout of the fuel oil system')

- ⇒ Set three-way valve 21 in the suction line of low pressure feed pump 23 so that diesel oil flows from daily tank 3 to the pump and to mixing unit 24.
- ⇒ Check to ensure that the shut-off valves before and after engine are open.
- ⇒ Start up pumps 23 and 25.
- ⇒ Drain daily tanks and mixing unit.
- ⇒ Set pressure in fuel oil system using pressure regulating valve 31. When running with diesel oil (and low fuel temperature) a slight over-pressure is sufficient. If later a change-over to heavy fuel oil is required, setting of normal pressure is recommended from the beginning.
- ⇒ Set fuel oil pressure at fuel pump inlet using pressure retaining valve 31a (3.53) (pressure difference before/after pressure retaining valve see Operating Data Sheet [0250-1](#)).

#### 2. For heavy fuel oil operation

(see [0720-1](#) 'Layout of the fuel oil system')



**Remark:** The fuel oil system is not ready for service until the heavy fuel oil before the fuel pumps has reached the required temperature (see Viscosity-Temperature Diagram [0270-2](#)).

The high pressure circuit on the engine must be preheated for at least four to six hours after a prolonged shut-down period (more than 24 hours).

**Before that, the engine may not be started on heavy fuel oil!**

- ⇒ Turn on the heating for heavy fuel oil daily tank 2, mixing unit 24, end-heater 26 and filter 27.
- ⇒ Turn on the heating for the fuel oil system on the engine (fuel rail 13 (3.05), rising pipes 8 (3.29) and the fuel leakage system (see [8019-1](#)).



**Remark:** Check the steam pipings for tightness; any detected leakages must be eliminated before the first commissioning or after maintenance works on the fuel oil system.

- ⇒ Set three-way valve 21 in the suction line of low pressure feed pump 23 so that heavy fuel oil flows from daily tank 2 to pump 23 and to mixing unit 24.
- ⇒ Drain settling, daily tanks and mixing unit.
- ⇒ Check to ensure that the shut-off valves before and after engine are open.
- ⇒ Start up pumps 23 and 25.
- Heat up the heavy fuel oil. This is necessary to bring it to the required viscosity (see Changing Over from Diesel Oil to Heavy Fuel Oil [0270-1](#)).
- ⇒ Set pressure in fuel oil system using pressure regulating valve 31.
- ⇒ Set fuel oil pressure at fuel pump inlet using pressure retaining valve 31a (3.53) (pressure difference before/after pressure retaining valve see Operating Data Sheet [0250-1](#)).

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## Prepare the Fuel Oil System for Operation

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### 3. High pressure circuit on engine

(see Fuel Oil System [8019–1](#)).

- ⇒ Check to ensure that drain valve 22 (3.65) is closed.
- ⇒ Check to ensure that drain screw 23 (3.82) on fuel rail 13 (3.05) at driving end is closed and tightened with a torque of 200 Nm.

### 4. Venting and leak test of fuel oil system on engine

(see [0720–1](#) 'Layout of the fuel oil system' (items in parentheses) and Fuel Oil System [8019–1](#))

#### **Venting:**

The fuel oil system can be vented manually as follows:

- Engine control system WECS–9520 is switched on.
- ⇒ Start low pressure feed pump (23) and booster pump (25).
- When starting booster pump (25) fuel oil circulates through fuel pumps 3 (3.14) and fuel rail 13 (3.05) is filled via rising pipes 8 (3.29).
- ⇒ By means of hand lever on emergency stop valve 26 (fuel shut-down pilot valve 3.08) the fuel rail can be vented via fuel pressure control valve 25 (3.06).

#### **Leak test:**

To carry out a leak test, the high pressure circuit must be kept under pressure by means of servo oil service pump (4.88).

- ⇒ Remove plug 32 (3.39) and the plug on stop valve (3.40) and connect tool 94583 (pipe) between fuel rail 13 (3.05) and servo oil rail (4.11) and open stop valve (3.40).
- ⇒ Switch on bearing oil pump and servo oil service pump (4.88).
- The pressure (70–100 bar) can be read off on pressure gauge of the servo oil service pump.
- ⇒ Carry out leak test.
- ⇒ Close stop valve (3.40).
- ⇒ Remove tool 94583 (pipe). Apply Never-Seez NSBT-8 to the thread and seating surface of plug 32 (3.39) and tighten it with a torque of 300 Nm. Refit and tighten the plug on stop valve (3.40).

**Preparation before Taking into Service**Prepare the Servo Oil System

---

**1. Checks to be carried out on servo oil system**

(see [8016–1](#) 'Servo oil system' )

|       |
|-------|
| CHECK |
|-------|

**Check-list:**

- ⇒ Stop valves 14 (4.37) before and 15 (4.80) after automatic filter 1 (4.20) opened.
- ⇒ Stop valve 27 (3.40) closed and plug fitted on servo oil rail 7 (4.11) at free end.
- ⇒ Drain screw 31 (4.82) tightened with a torque of 200 Nm in servo oil rail 7 (4.11) at driving end (see 8016–1 'Filling and draining of servo oil rail').
- ⇒ Ball valves 21 (3.38) and 22 (3.27) opened to servo oil before and after injection control unit 11 (3.02).

## Preparation before Taking into Service

### Prepare the Cylinder Lubricating System

---

(see Cylinder Lubrication [7218–1](#))

- WECS–9520 engine and remote control system switched on.
- Servo oil service pump 4.88 in operation.

|       |
|-------|
| CHECK |
|-------|

**Check-list:**

- Green LEDs light up on all ALM–20 modules.
- Stop valve 5 (4.30–5) open ([Fig. 'B'](#)).
- Ball valve 5 open after lubricating oil filter 8.17 ([Fig. 'C'](#)).
- Lubricating oil filter 1 (8.17) and measurement tube 4 (8.19) vented ([Fig. 'C'](#)).
- Shut-off valve 6 open to servo oil inlet of lubricating pumps 8.06 ([Fig. 'D'](#)).
- Shut-off valve 7 open to oil inlet of lubricating pumps 8.06 ([Fig. 'D'](#)).
- Relief valve 8 open to accumulator of lubricating pumps 8.06 ([Fig. 'D'](#)).
- Stop valve 7 closed in the lubricating oil pipes to exhaust valve ([Fig. 'I'](#)).



**Remark:** However, stop valve 7 is to be opened during the first commissioning of the engine until conclusion of the sea trial or after an exhaust valve overhaul (see 7218–1 'Additional lubrication of exhaust valve spindle').

- Stop valve 7 closed in the lubricating oil pipes to exhaust valve ([Fig. 'I'](#)).
- Lubricating pumps 8.06 vented (servo and control oil).
- Lubricating pipings to the lubricating quills vented.



**Remark:** Venting must only be carried out in the following cases:

- before first commissioning
- after maintenance works
- after a prolonged shut-down period
- at operating troubles (operating pressure, feed rate).

## Operation under Normal Conditions

### Summary

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#### 1. General

The following groups concern operation of the engine under **normal conditions**. By this we understand that, e.g. all cylinders are working. During manoeuvring, however, not only is the usually normal control of the engine from the control room (or bridge) mentioned, but also the possibility of operation from the local manoeuvring stand.

For operation under abnormal conditions, see [0500–1](#).

Operation in the following sense concerns the complete operation of the engine from the first start at casting off until the final manoeuvre when tying up.

The engine is designed and so equipped that it can also **run pier-to-pier** on heavy fuel oil, i.e. without having to change over to diesel oil.

Fuel also circulates through the fuel pumps when the engine is at a standstill as long as the booster pump is running. Preconditions are that the installation too is laid out to suit, the heavy fuel oil has been correctly treated and it is kept at the correct temperature during the whole period in service, including manoeuvring and 'Stand-by'.

## Operation

### Safety Precautions and Warnings (General Information)

---

#### 1. General

A well maintained engine is a pre-requisite for a troublefree and safe operation. The below mentioned points should always be a guide to the maintenance staff.

#### 2. Illumination

Besides a permanent good illumination hand lamps should be ready at hand in various locations of the engine room.

#### 3. Cleanliness

The engine room as well as the engine itself should always be kept as clean as possible. Special care must be taken to keep the WECS electronic control boxes clean and dry on the rail unit. Any leakages should be attended to as soon as possible. Dust, sand and chemical vapors must be prevented from entering the engine room.

#### 4. Warning

Opening valves and other shut-off devices may allow hot fluids or gases to escape. Therefore open slowly and watch in which direction the medium escapes. Avoid injury.

When removing valves from the cylinder cover, avoid that oils or fuels drip onto the hot piston which could cause an explosion. When disassembling parts of the engine without suitable tools and/or the required care, prestressed springs can expand suddenly and cause injury. Pay attention to the maintenance instructions of the corresponding parts.

#### 5. Fire



**Attention! Special attention has to be paid to the rules of fire fighting.**

Welding work and activities which cause sparks must not be carried out in the engine room before ensuring that no explosive gases, vapors or inflammable fluids are present. If spark generating work must be performed in the engine room make sure that fire extinguishing equipment is readily at hand to fight a fire locally. Components such as turbocharger silencer and WECS electronic control boxes must be protected by suitable covering. When casings and covers are removed before the engine has cooled down, the risk of fire or explosions is increased. Therefore keep the engine closed until it has cooled down.

Care must also be taken when paints or easily inflammable solvents are used in the engine room.

Insulation material saturated with oil or fuel (due to leakages) is also easily ignited and must therefore be replaced.

Cleanliness in the whole engine room, also below the floor plates, reduces the possibility of a fire and the risk of its spreading.

For your personal safety make absolutely sure that in case of a fire alarm no fire extinguishing gases can be automatically released when people are in the engine room. Emergency escapes are to be marked and personnel is to be instructed of what to do in the case of fire.

## Safety Precautions and Warnings (General Information)

---

### 6. Tools

Hand tools should be placed at easily accessible locations and clearly arranged. Special tools and devices shall be placed in the engine room in the vicinity of their usual application in such a way that they can be used without hindrances.

They must be fastened and protected against rust.

### 7. Spare parts

Large spares are to be stored as near as possible to their probable place of fitting, well braced and secured and within the reach of the engine room crane. All the spare parts must be well protected against corrosion, but with a compound requiring little effort for removal. They must also be protected against mechanical damage. The anti-corrosion agent has to be checked periodically and renewed if necessary.

Spare parts removed from the store must be replaced as soon as possible.

### 8. Opening the crankcase doors



If the engine has to be shut-down due to suspected overheated parts of the running gear or bearings, **at least 20 minutes must elapse** before the crankcase doors are unfastened and removed in order to avoid the danger of an explosion.

### 9. Temperature sensing

When commissioning an engine after an overhaul of its running gear a check must be made to find out whether any areas are heating-up abnormally. This check should be made after 10 minutes operation and repeated after about one hour. Following this, the checking should again be made after a short full load run.



***Danger of burning!*** When trying to touch the hot parts it is necessary to pay attention to avoid injury.

### 10. Entering the crankcase, cylinder, exhaust piping or scavenge air receiver

Before entering the spaces of the above parts make sure that:

- starting air to the engine is blocked off and venting valves 2.21 and 2.27 (see Control Diagram 4003-2) are open.
- turning gear is engaged (see Maintenance Manual 0011-1 'Precautionary measures before beginning of maintenance work').



***Attention!*** On ships, please consider that water currents induced by other ships can cause the propeller and the engine with it to rotate. By engaging the turning gear this rotation can be avoided.

### 11. Entering the engine after the use of CO<sub>2</sub>

Where CO<sub>2</sub> has been used to smother a fire within the engine, the relevant spaces must be thoroughly ventilated before entering (risk of suffocation).

## Safety Precautions and Warnings (General Information)

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### 12. Closing up of crankcase doors

The engine may not be put into service until all the **crankcase doors are closed by all the locking latches**. This also applies even if only a short run is to be made, e.g. running in replaced bearings, etc.

### 13. Turning gear

When using the turning gear, the indicator valves in the cylinder covers must be opened. In case the air spring system is not under pressure, the indicator valves may remain closed. If possible, the lubricating oil pump should also be running. However, the oil pressure cannot fully build up when the exhaust valves are open.



**Attention! Check** carefully, that **no personnel as well as components** (tools, devices) are situated in the **danger area** (crankcase, piston underside, propeller shaft etc.).

Also bear in mind that the coupled propeller turns too (danger in surroundings).



**Remark:** If the engine is **standing still** for overhaul, the turning gear must be **engaged** in order to prevent the engine to be turned due to outside influence.

If the engine must be **ready for manoeuvres** the turning gear must not be **engaged**.

**Before starting** the engine, make sure that the turning gear is **disengaged** and the **lever secured** otherwise blocking valve 2.13 (see Control Diagram [4003-2](#)) hinders the start of the engine.

### 14. Measuring and indicating instruments

Calibrate gauge tools before using and at periodical intervals.

### 15. Frost hazard

If there is a possibility that the temperature falls below the freezing point with the engine out of service, measures must be taken that the water in the engine, in the pumps, coolers and piping system cannot freeze. (Draining the systems or heating the engine room).



**Remark:** Further instructions concerning general guidelines for maintenance see Maintenance Manual [0011-1](#) and [0012-1](#).

## Operation under Normal Conditions

### Slow Turning

---

#### 1. General

To ascertain that the running gear turns freely, we recommend, provided no more far reaching specifications have been made by the classification society, to rotate the crankshaft before start-up by at least one full turn. This does not apply if the engine has only been standing still during a manoeuvring interval.

#### 2. Turn by the turning gear

With the turning gear the crankshaft can be rotated especially slowly at about one revolution per 10 minutes. The rotation of the crankshaft as well as the direction of rotation can be noted on the pointer by the flywheel.

#### 3. SLOW TURNING with starting air

The running gear can be turned at approx. 5–10 rpm by releasing a controlled amount of starting air.

In the engine control system WECS–9520 the command SLOW TURNING is provided for this operation. Depending on the active control stand it is initiated:

- by remote control
- at ECR manual control panel in the control room
- at local control panel (see [4618–1](#) 'WECS–9520 Manual control panel').

##### 3.1 Conditions

Beforehand the following conditions must be fulfilled:

- Turning gear disengaged.
- WECS–9520 engine control system switched on.
- Oil pumps operating (bearing oil and crosshead oil).
- Corresponding control stand activated.
- Indicator valves closed.
- Handwheel 2.10 on shut-off valve for starting air 2.03 in position AUTOMAT.
- Shut-off valves on the starting air bottles open.
- Air pressure for air spring correctly set (see Operating Data Sheet [0250–1](#)).
- For slow turning the cylinder lubrication must be switched-on.

##### 3.2 Function

The procedure is similar to starting of the engine. The following designation numbers refer to the Control Diagram [4003–2](#).

- The shut-off valve for starting air 2.03 is opened by the control valve 2.05 and starting air reaches the starting air valves 2.07 in the cylinder covers.
- By FCM–20 modules the 3/2-way solenoid valves before the starting valves are controlled in such a way that the starting valves are opened and shut for short intervals only.
- The slow turning speed of the engine can be optimized in the remote control by varying the timing (open/close) of the starting valves.

## Operation under Normal Conditions

### Starting

#### 1. General

The **condition** for each engine start-up, also for trials and rotation with starting air, is its full **operating condition**, see:

- Preparation before Taking into Service 0110-1
- Prepare the Fuel Oil System for Operation 0120-1
- Prepare the Servo Oil System 0130-1
- Prepare the Cylinder Lubricating System 0140-1

Depending on the possibilities available, the engine can be started:

- from the bridge or control room with remote control
- at backup control box in the control room
- at local control panel on the engine.

#### 2. Starting at control stand in control room

**Additional preparation:**

- ⇒ At WECS-9520 manual control panel (see [4618-1](#)), press button REMOTE AUTOM. CONTROL (Remote Control) for mode transfer to remote control.
- ⇒ At the control room console, press button REMOTE AUTOM. CONTROL (Remote Control) to take over the control.

For further procedure to start on remote control, see the documentation of the remote control manufacturer. As a rule, moving the telegraph from STOP to any other position will automatically release a start.

#### 3. Starting at local control panel

This mode of operation may be chosen e.g. upon failure of the electronic speed control system or the remote control. The operator may under no circumstances leave the local manoeuvring stand. He must regularly observe the speed indication enabling him to immediately adjust the fuel supply when the speed varies to some extent.

**Additional preparation:**

- ⇒ At WECS-9520 manual control panel ([4618-1](#)), press button LOCAL MANUAL CONTROL (Local Control) for mode transfer to local manual control.

**Starting:**

- ⇒ Press button AUX. BLOWER PRESEL.
- ⇒ Press button FUEL CONTROL MODE.
- ⇒ Turn rotary knob for fuel injection quantity to approx. 15% start fuel charge (see display).
- ⇒ Press requested button START AHEAD or START ASTERN until the engine runs.
- ⇒ Slowly adjust rotary switch for fuel injection quantity until the engine runs at the required speed. The corresponding value can be read on display and speed indicator.

Pay attention to the instructions for speed/power increase (see Manoeuvring [0260-1](#)) and to the monitoring data (see Operating Data Sheet [0250-1](#)).



**Remark:** The above mentioned starting procedure may also be carried out on ECR manual control panel.

However, buttons and rotary switch function only in the corresponding mode of operation, i.e. with active control stand (see [4618-1](#) 'WECS-9520 manual control panel').

## Operation

### Normal Running

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#### 1. General

The most favourable operational results are generally achieved by running the engine at constant power. When the engine load and/or speed have to be altered on operational grounds, this should be done slowly, apart from exceptional circumstances.

#### 2. Checks and precautions

|       |
|-------|
| CHECK |
|-------|

During normal running, regular checks have to be made and precautions taken which contribute to trouble-free operation. The most important of these are:

- Regular checks of pressures and temperatures. The limits must be adhered to (see Operating Data Sheet [0250-1](#)).
- The values read off the instruments compared with those given in the acceptance records and taking into account engine speed and/or engine power, provide an excellent yardstick for the engine performance.  
Any deviation must be investigated. The fault can lie with either the engine, the installation or also with the instruments. Where no risk exists, suspect instruments can be exchanged with similar ones. Compare temperatures by feeling the pipes. To make the above mentioned evaluation, among the essential readings are: fuel injection quantity, fuel rail and servo oil rail pressure, engine speed, turbocharger speed, scavenge air pressure, exhaust gas temperature before the turbine. A valuable criterion is also the daily fuel consumption, taking the lower calorific value into consideration.
- Check all shut-off valves in the cooling and lubricating system for correct position.  
The shut-offs for the cooling inlets and outlets on the engine must always be fully open in service. They serve only to cut off individual cylinders from the cooling water system during overhauls.
- When abnormally high or low temperatures are detected at a water outlet the temperature must be brought to the prescribed normal value very gradually. Abrupt temperature changes may cause damage (see also Cylinder Liner [2124-1](#) and Cooling Water System [8017-1](#)).
- The maximum permissible exhaust temperature at turbine inlet must not be exceeded (see Operating Data Sheet [0250-1](#)). The indicated exhaust gas temperatures at cylinder outlet are to be compared with the corresponding values of the acceptance records. Should greater differences between individual cylinders be noted, the cause has to be investigated.
- Check outlet of exhaust gases by observing their colours at the funnel. No dark smoke should escape.
- Maintain the correct scavenge air temperature after the air cooler with the normal water flow (see Operating Data Sheet [0250-1](#)). In principle, a higher scavenge air temperature will result in poorer filling of the cylinder which in return will result in a higher fuel consumption and higher exhaust gas temperatures.
- Check the scavenge air pressure drop through the air cooler. Excessive resistance will lead to a lack of air to the engine.

## Normal Running

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- The fuel oil has to be carefully cleaned before being used. Refer to recommendations in [0720-1](#) 'Fuel treatment' and the separator manufacturer's instructions. Open the drain cocks of all fuel tanks and fuel oil filters regularly for a short period to drain off any water or sludge which may still have collected there. Maintain the correct fuel oil pressure after low pressure feed pump and the inlet to the mixing unit (see Operating Data Sheet [0250-1](#) and [0720-1](#) 'Layout of the fuel oil system'). Adjust the pressure at fuel pump inlet with the pressure retaining valve in the fuel oil return pipe so that the fuel oil circulates within the low pressure circuit of the engine at the normal delivery capacity of the booster pump.
- The heavy fuel oil has to be sufficiently heated to ensure that its viscosity before inlet to the fuel pumps lies within the prescribed limits (see Viscosity-Temperature Diagram [0270-2](#)).
- Now and then determine the cylinder lubricating oil consumption. For normal consumption and how to calculate it, see Measurement of the Cylinder Lubricating Oil Consumption [7218-2](#). Extended service experience will determine the optimum cylinder lubricating oil consumption. Avoid over-lubrication.
- The cooling water pumps should be run at their normal operating point, i.e. the actual delivery head corresponds with the designed value. Thereby the designed delivery rate is obtained and the temperature difference between inlet and outlet will approximately correspond with the desired value (see Operating Data Sheet [0250-1](#)). Should it be considerably higher, the pump concerned must be put in order at the next opportunity.
- Should correct setting of the pressure head of the cylinder cooling water pump require throttling of the flow, this may only be done in the engine outlet manifold. The pressure at the suction side of the pump must be positive in order to prevent any air being drawn in through its stuffing box.
- The vents at the uppermost points of the cooling water spaces must be constantly kept open to permit air to escape.
- Check the level in all water and oil tanks, as well as all the drainage tanks of the leakage piping. Investigate any abnormal changes.
- Observe the cooling water. The cause of any contamination or oiliness has to be investigated and the fault rectified.
- Check periodically the water flow at the sight glasses of condensate collectors 20 and 20a. The butterfly valves 26 and 26a must always be open during operation (see Drainage System and Wash-water Piping System [8345-1](#)).
- Check the pressure drop across the oil filters. Clean them if necessary.
- Check periodically the differential pressure through the automatic filter and the flushing process.
- Bearings which have been overhauled or replaced must be given special attention for some time after being put into service. Observe the precautions for preventing crankcase explosions (see [0460-1](#)).
- Always keep the covers of the rail unit closed with the engine in service.
- Listening to the noise of the engine may reveal any irregularities.

## Normal Running

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- Hand drawn indicator diagrams provide information on the combustion process and pressures within the cylinder (see Indicator Diagrams [0420–1](#)). When the quality of the fuel used changes (diesel oil, heavy fuel oil from various bunkerings), the maximum pressure in the cylinder at service power must be determined at the earliest opportunity and compared with the pressure measured during the corresponding shop trial (speed, power).  
In case considerable firing pressure differences are detected, i.e. too high or too low, they must be adjusted by the electronic FQS in WECS–9520 control system.
- Centrifuge the lubricating oil. Samples should be taken at regular intervals and compared with the values given in Lubricating Oils [0750–1](#).
- Check the dirty oil drain pipes from the piston underside for free passage. An obstruction can be detected by touching the individual drain pipes with the hand (temperature difference). If one has only surrounding temperature, the line must have been blocked by carbon deposits and needs to be cleaned as soon as possible.
- Check periodically the lubricating and fuel oil systems for leakages (see [8016–1](#) 'Servo oil leakage system' and [8019–1](#) 'Fuel leakage system'). Leakages can be localized in the rail unit by opening the corresponding hinged covers and casings. Ascertained leakages must be remedied at the next opportunity.



## Operating Data Sheet

## Pressure and Temperature Ranges at Continuous Service Power MCR

| Medium          | System                                                                 | Location of measurement | Gauge pressure [bar] |         | Temperature [° C] |      |               |
|-----------------|------------------------------------------------------------------------|-------------------------|----------------------|---------|-------------------|------|---------------|
|                 |                                                                        |                         | Min.                 | Max.    | Min.              | Max. | Diff.         |
| Fresh water     | Cylinder cooling                                                       | Inlet                   | 3.0                  | 5.0     | 65                | —    | max.          |
|                 |                                                                        | Outlet each cylinder    | —                    | —       | 80                | 90   | 15            |
|                 | SAC, low temperature circuit LT (single-stage scavenge air cooler)     | Inlet                   | 2.0                  | 4.0     | 25                | 36   | 3)            |
|                 |                                                                        | Outlet                  | —                    | —       | —                 | —    |               |
| Lubricating oil | Servo oil                                                              | Pumps inlet             | 3.5                  | 6.5     | —                 | —    | —             |
|                 | Main bearing                                                           | Inlet                   | 4.5                  | 6.0     | 40                | 50   | —             |
|                 | Piston cooling                                                         | Inlet                   | 4.5                  | 6.0     | 40                | 50   | max.          |
|                 |                                                                        | Outlet                  | —                    | —       | —                 | 80   | 30            |
|                 | Thrust bearing                                                         | Outlet                  | —                    | —       | —                 | 65   | —             |
|                 | Torsional vibration damper (if steel spring damper is used)            | Supply                  | 4.5                  | 6.0     | —                 | —    | —             |
|                 |                                                                        | Housing inlet           | 1.0                  | —       | —                 | —    | —             |
|                 | Integrated axial damper (chamber pressure)                             | Supply                  | 4.5                  | 6.0     | —                 | —    | —             |
|                 |                                                                        | Monitoring              | 1.7                  | —       | —                 | —    | —             |
|                 | Turbocharger bearing (ABB, TPL type) (with <u>internal</u> oil supply) | Inlet                   | 1.0                  | 2.5     | —                 | —    | —             |
|                 |                                                                        | Housing outlet          | —                    | —       | —                 | 110  | —             |
|                 | Turbocharger bearing (ABB, TPL type) (with <u>external</u> oil supply) | Inlet                   | 1.3                  | 2.5     | —                 | —    | —             |
|                 |                                                                        | Housing outlet          | —                    | —       | —                 | 120  | —             |
|                 | Turbocharger bearing (MHI, MET type)                                   | Inlet                   | 0.7                  | 1.5     | —                 | —    | —             |
|                 |                                                                        | Housing outlet          | —                    | —       | —                 | 85   | —             |
| Fuel oil        | Supply unit (fuel pump)                                                | Inlet                   | 7.0 1)               | 10 2)   | —                 | 150  | —             |
|                 | After pressure retaining valve (fuel pump)                             | Return                  | 3.0                  | 5.0     | —                 | —    | —             |
| Scavenge air    | Scavenge air cooler                                                    | after cooler            |                      |         | 25                | 70   | —             |
|                 | Intake from engine room (pressure drop)                                | Air filter / silencer   | max. 10 mbar         |         | —                 | —    | —             |
|                 | Intake from outboard (pressure drop)                                   | Ducting and filter      | max. 20 mbar         |         | —                 | —    | —             |
|                 | Scavenge air cooler (SAC) (pressure drop)                              | new SAC                 | max. 30 mbar         |         | —                 | —    | —             |
|                 |                                                                        | fouled SAC              | max. 50 mbar         |         | —                 | —    | —             |
| Air             | Starting air                                                           | Engine inlet            | 12                   | 25 / 30 | —                 | —    | —             |
|                 | Control air                                                            | Engine inlet            | 6.0                  | 7.5     | —                 | —    | —             |
|                 |                                                                        |                         | normal 6.5           |         | —                 | —    | —             |
|                 | Air spring of exhaust valve                                            | Main distributor        | 6.0                  | 7.5     | —                 | —    | —             |
|                 |                                                                        |                         | normal 6.5           |         | —                 | —    | —             |
| Exhaust gas     | Receiver                                                               | after cylinder          | —                    | —       | —                 | 515  | Deviation ±50 |
|                 |                                                                        | Turbocharger inlet      | —                    | —       | —                 | 515  | —             |
|                 | Manifold after turbocharger                                            | new                     | max. 30 mbar         |         | —                 | —    | —             |
|                 |                                                                        | fouled                  | max. 50 mbar         |         | —                 | —    | —             |

**Remarks to pressure and temperature ranges:**

- Limits for alarm, slow-down and shut-down; see group [0250–2](#).
- Pressure measured approx. 6 m above crankshaft centre line.

- 1) At 100% engine load.
- 2) At stand-by condition; during commissioning of the fuel oil system, the fuel oil pressure at the inlet of the fuel pumps is adjusted to 10 bar.
- 3) The water flow has to be within the specified limits (scavenge air cooler specification).

## Operating Data Sheet

## Alarms and Safeguards at Continuous Service Power

| Medium Performance                              | Physical unit                                      | Location                        | Signal No.<br>1)  | Function<br>2) | Kind of signal<br>3) | Setting value<br>[bar / °C] | Function time delay<br>[sec] |
|-------------------------------------------------|----------------------------------------------------|---------------------------------|-------------------|----------------|----------------------|-----------------------------|------------------------------|
| Cylinder cooling water                          | Pressure                                           | Engine inlet                    | PT1101A           | ALM            | L                    | 3 bar                       | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | L                    | 2.8 bar                     | 60                           |
|                                                 |                                                    |                                 | PS1101S           | SHD            | L                    | 2.5 bar                     | 60                           |
|                                                 | Temperature                                        | Engine inlet                    | TE1111A           | ALM            | L                    | 65 °C                       | 0                            |
|                                                 |                                                    | Outlet each cylinder            | TE1121-32A        | ALM            | H                    | 90 °C                       | 0                            |
| LT circuit<br>Single-stage SAC      Fresh water | Pressure                                           | Cooler inlet                    | PT1361A           | ALM            | L                    | 2 bar                       | 0                            |
|                                                 | Temperature                                        | Cooler inlet                    | TE1371A           | ALM            | L                    | 25 °C                       | 0                            |
|                                                 |                                                    | Cooler outlet                   | TE1381-83A        | ALM            | H                    | 70 °C                       | 0                            |
| Lubricating oil<br>Bearing and piston cooling   | Pressure                                           | Engine inlet                    | PT2001A           | ALM            | L                    | 4.5 bar                     | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | L                    | 4.3 bar                     | 60                           |
|                                                 |                                                    |                                 | PS2002S           | SHD            | LL                   | 3.8 bar                     | 10                           |
|                                                 | Temperature                                        | Engine inlet                    | TE2011A           | ALM            | H                    | 50 °C                       | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 55 °C                       | 60                           |
| Servo oil<br>(for cylinder lubrication)         | Pressure                                           | Lubricating pump<br>Inlet FE/DE | PT2041-42A        | ALM            | L                    | 40 bar                      | 3                            |
|                                                 |                                                    |                                 |                   |                | H                    | 70 bar                      | 3                            |
|                                                 | Pressure<br>(leakage)                              | Lubricating pump<br>Inlet FE/DE | PT2046-47A        | ALM            | H                    | 10 bar                      | 0                            |
|                                                 |                                                    |                                 |                   |                |                      |                             |                              |
|                                                 | Pressure                                           | Servo oil pump<br>Inlet         | PT2051A           | ALM            | L                    | 3.8 bar                     | —                            |
| Servo oil                                       | Failure                                            | Automatic filter                | XS2053A           | ALM            | F                    | —                           | 0                            |
|                                                 |                                                    |                                 |                   |                |                      |                             |                              |
|                                                 | Flow                                               | Servo oil pump                  | FS2061-63A<br>11) | ALM            | L                    | no flow                     | 0                            |
| Oil leakage monitoring                          | Level                                              | Supply unit 7)                  | LS2055C           | ALM            | H                    | max.                        | 0                            |
|                                                 |                                                    | Rail unit 7)                    | LS2076-77A        | ALM            | H                    | no flow                     | 0                            |
|                                                 |                                                    | FE/DE                           |                   |                |                      |                             |                              |
| Thrust bearing oil                              | Temperature                                        | Thrust bearing<br>Pads AHEAD    | TE4521A           | ALM            | H                    | 75 °C                       | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 80 °C                       | 60                           |
|                                                 |                                                    |                                 | TS4521S           | SHD            | H                    | 85 °C                       | 60                           |
| Oil mist                                        | Concentration                                      | Crankcase                       | AS2401A           | ALM            | H                    | —                           | 0                            |
|                                                 |                                                    |                                 | AS2401S           | SLD            | H                    | —                           | 60                           |
|                                                 | Failure                                            | Detection unit                  | XS2411A           | ALM            | F                    | —                           | 0                            |
| Piston cooling oil                              | Temperature                                        | Outlet each cylinder            | TE2501-12A        | ALM            | H                    | 80 °C                       | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 85 °C                       | 60                           |
|                                                 | Diff. pressure                                     | Inlet each cylinder             | PS2541-52S        | SHD            | H                    | 0.4 bar                     | 15                           |
|                                                 | Flow                                               | Inlet each cylinder             | FS2521-32S        | SHD            | L                    | no flow                     | 15                           |
| Turbocharger oil<br>(ABB, TPL type)             | Pressure                                           | Inlet                           | PT2611-13A        | ALM            | L                    | 1 bar                       | 5                            |
|                                                 |                                                    |                                 |                   | SLD            | L                    | 0.8 bar                     | 60                           |
|                                                 |                                                    |                                 | PS2611-13S        | SHD            | L                    | 0.6 bar                     | 5                            |
|                                                 | Temperature                                        | Housing outlet                  | TE2601-03A        | ALM            | H                    | 110 °C                      | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 120 °C                      | 60                           |
|                                                 | Pressure<br>(with external<br>oil supply)          | Inlet                           | PT2611-13A        | ALM            | L                    | 1.3 bar                     | 5                            |
|                                                 |                                                    |                                 |                   | SLD            | L                    | 1.1 bar                     | 60                           |
|                                                 | Temperature                                        | Housing outlet                  | TE2601-03A        | ALM            | H                    | 120 °C                      | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 130 °C                      | 60                           |
|                                                 | Additional requirement with external<br>oil supply | Inlet                           | TE2621A           | ALM            | H                    | 80 °C                       | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 85 °C                       | 60                           |
| Turbocharger oil<br>(MHI, MET type)             | Pressure                                           | Inlet                           | PT2611-13A        | ALM            | L                    | 0.7 bar                     | 5                            |
|                                                 |                                                    |                                 |                   | SLD            | L                    | 0.6 bar                     | 60                           |
|                                                 |                                                    |                                 | PS2611-13S        | SHD            | L                    | 0.4 bar                     | 5                            |
|                                                 | Temperature                                        | Housing outlet                  | TE2601-03A        | ALM            | H                    | 85 °C                       | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 95 °C                       | 60                           |
|                                                 |                                                    | Inlet                           | TE2621A           | ALM            | H                    | 60 °C                       | 0                            |
|                                                 |                                                    |                                 |                   | SLD            | H                    | 65 °C                       | 60                           |

## Alarms and Safeguards at Continuous Service Power

| Medium Performance                                        | Physical unit  | Location                               | Signal No.<br>1)  | Function<br>2) | Kind of signal<br>3) | Setting value<br>[bar / °C] | Function time delay<br>[sec] |
|-----------------------------------------------------------|----------------|----------------------------------------|-------------------|----------------|----------------------|-----------------------------|------------------------------|
| Geislinger damper oil 5)                                  | Pressure       | Casing inlet                           | PT2711A           | ALM            | L                    | 1 bar                       | 0                            |
| Axial damper oil                                          | Pressure       | Chamber aft side                       | PT2721A           | ALM            | L                    | 1.7 bar                     | 60                           |
|                                                           |                | Chamber fore side                      | PT2722A           | ALM            | L                    | 1.7 bar                     | 60                           |
| Cylinder lubricating oil                                  | Diff. pressure | Filter                                 | PS3121A           | ALM            | H                    | 0.3 bar                     | 0                            |
| Fuel oil<br>(see Viscosity-Temperature Diagram<br>0270–2) | Temperature 4) | before supply unit                     | TE3411A           | ALM            | H                    | 50–160 °C                   | 0                            |
|                                                           |                |                                        |                   | ALM            | L                    | 20–130 °C                   | 0                            |
|                                                           | Pressure       | before supply unit                     | PT3421A           | ALM            | L                    | 7 bar                       | 0                            |
|                                                           | Viscosity 4)   | before supply unit                     | 5)                | ALM            | H                    | 17 cSt                      | 0                            |
|                                                           |                |                                        |                   | ALM            | L                    | 12 cSt                      | 0                            |
|                                                           | Temperature    | Fuel pump Outlet                       | TE3431–36A        | ALM            | D                    | –30 °C<br>12)               | 30                           |
| Fuel leakage monitoring                                   | Level          | Rail/supply unit 7)                    | 7)                | ALM            | H                    | max.                        | 0                            |
| Exhaust gas                                               | Temperature    | after each cylinder                    | TE3701–12A<br>10) | ALM            | H                    | 515 °C                      | 0                            |
|                                                           |                |                                        |                   | ALM            | D                    | ±50 °C                      | 0                            |
|                                                           |                |                                        |                   | SLD            | H                    | 530 °C                      | 60                           |
|                                                           |                |                                        |                   | SLD            | D                    | ±70 °C                      | 60                           |
|                                                           | Temperature    | before TC 6)                           | TE3721–23A<br>10) | ALM            | H                    | 515 °C                      | 0                            |
|                                                           |                | after TC 6)                            | TE3731–33A<br>10) | ALM            | H                    | 530 °C                      | 60                           |
| Scavenge air                                              | Temperature    | Scavenge air receiver after cooler     | TE4031–33A        | ALM            | L                    | 25 °C                       | 0                            |
|                                                           |                |                                        |                   | ALM            | H                    | 60 °C                       | 0                            |
|                                                           |                |                                        |                   | SLD            | H                    | 70 °C                       | 60                           |
|                                                           | Temperature    | each piston underside (fire detection) | TE4081–92A        | ALM            | H                    | 80 °C                       | 0                            |
| Condensate                                                | Level          | Water separator                        | LS4071–73A        | ALM            | H                    | max.                        | 0                            |
|                                                           |                |                                        |                   | SLD            | H                    | max.                        | 60                           |
|                                                           |                | before water separator                 | LS4075–77A        | ALM            | H                    | max.                        | 0                            |
|                                                           |                |                                        |                   | SLD            | H                    | max.                        | 60                           |
| Starting air                                              | Pressure       | Engine inlet                           | PT4301C           | ALM            | L                    | 12 bar                      | 0                            |
| Air spring air 8)                                         | Pressure       | Distributor                            | PT4341A           | ALM            | H                    | 7.5 bar                     | 0                            |
|                                                           |                |                                        |                   | ALM            | L                    | 5.5 bar                     | 0                            |
|                                                           |                |                                        |                   | SLD            | L                    | 5 bar                       | 60                           |
|                                                           |                |                                        | PS4341S           | SHD            | LL                   | 4.5 bar                     | 0                            |
| Leakage oil from air spring air                           | Level          | Exhaust valve air spring               | LS4351A           | ALM            | H                    | max.                        | 0                            |
| Control air normal supply 8)                              | Pressure       | Engine inlet                           | PT4401A           | ALM            | L                    | 6 bar                       | 0                            |
|                                                           |                |                                        | PT4411A           | ALM            | L                    | 5.5 bar                     | 0                            |
| safety supply 9)                                          | Pressure       | Engine inlet                           | PT4421A           | ALM            | L                    | 5 bar                       | 0                            |
| Fuel pump actuator                                        | Failure        | E98.1                                  | XS5046A           | ALM            | F                    | –                           | 0                            |
|                                                           |                | E98.2                                  | XS5047A           | ALM            | F                    | –                           | 0                            |
| WECS–9520 control system                                  | Power failure  | Power supply box E85                   | XS5056A           | ALM            | F                    | –                           | 0                            |
| Cylinder lubricating system                               | Power failure  | Power supply box E85                   | XS5058A           | ALM            | F                    | –                           | 0                            |
| Engine performance data overspeed                         | Speed          | Crankshaft                             | ST5111–12S        | SHD            | H                    | 110%                        | 0                            |

## Alarms and Safeguards at Continuous Service Power

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### **Remarks to alarms and safeguards:**

- 1) Signal number indicates interface to remote control (see [4003-3](#)).
- 2) Function:  
SLD = Slow down  
SHD = Shut down  
ALM = Alarm
- 3) Kind of signal:  
D = Deviation  
F = Failure  
H = High  
L = Low  
LL = Very Low
- 4) Alternative execution.
- 5) Not included in standard engine scope of supply.
- 6) Other abbreviations:  
TC = Turbocharger  
SAC = Scavenge Air Cooler
- 7) Location of measurements and signal numbers see [8016-1](#) 'Servo oil leakage system' and [8019-1](#) 'Fuel leakage system'.
- 8) Supply from board system for control and air spring air via pressure reducing valve 23HA.
- 9) Supply from starting air pipe before shut-off valve (from starting air bottles 9.01) for control and air spring air via pressure reducing valve 19HA.
- 10) Signal designation changes after amplifier (on engine) from **TExxxx**A to **T~~I~~xxxx**A.
- 11) Alarm is effective only above 30% engine power.
- 12) Deviation from median (acts as 'no flow' detection).

## Operation

### Manoeuvring

---

#### 1. General

Correct manoeuvring and the resulting increase in engine load up to service power, as well as decrease in load from the service power, is very important with the usual high engine powers of today. Experience has shown that changing the load too quickly in the upper power ranges can result in increased wear and fouling, especially of the piston rings and cylinder liners.

Slow load changes allow the piston rings to adapt themselves to the new running conditions and therefore ensure optimum sealing.

On the other hand, there must always be sufficient power available within a short time to ensure safe manoeuvring in ports and waterways.

#### 2. Manoeuvring

We generally understand manoeuvring as the operation of leaving port until release to SEA SPEED and from the port approach until FINISHED WITH ENGINE. In particular the speed and direction changes as well as, in the wider sense, any such alterations during normal service.

The manoeuvring range is the speed range up to and including the manoeuvring speeds FULL AHEAD and FULL ASTERN. This range is usually divided into four manoeuvring stages with correspondingly allocated speeds.



**Remark:** Depending on torsional vibration situation, a barred speed range might exist.

Normally the FULL manoeuvring speed for engines driving fixed pitch propellers corresponds to about 70% of the nominal speed which in turn represents about 35% of the nominal power. This means that, with the vessel sailing straight ahead, about 2/3 of the nominal ship's speed will be reached. In principle, a fully operational engine can be manoeuvred within the above mentioned manoeuvring range already provided with the start fuel limiter and scavenge air limiter without any time or performance restrictions.

Should the engine be accelerated quickly to FULL manoeuvring speed when the vessel is at a standstill, the momentary engine load will be higher until the vessel has reached sea-speed.

Manoeuvring can be done from the bridge (provided bridge control is installed), from the manoeuvring console in the control room or at the local control panel on the engine.

Special precautions have to be taken when manoeuvring at the local control panel.

Either heavy fuel oil or diesel oil can be used during manoeuvring, however, heavy fuel oil should be preferred (see 0270–1 'General'). The fuel used must have been suitably treated (see Fuel Treatment, Fuel Oil System 0720–1).

The Operational data given in 0250–1 basically also apply during manoeuvring.

When manoeuvring on heavy fuel oil, the fuel has to be heated up enough to maintain its viscosity at inlet to the fuel pumps within the range given in Viscosity-Temperature Diagram 0270–2. The heating of the fuel oil system is to be kept on. The temperature of the cooling media should be kept as close as possible to the upper limits given for normal service (see Operating Data Sheet 0250–1).

Manoeuvring

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**2.1 Reversing under normal operation, at control room manoeuvring console**

As various makes of remote controls can be connected to the engine controls we do not describe here the operation from the manoeuvring stand in the control room. For this operation the documentation of the remote control makers must be utilized.

**2.2 Reversing at local control panel**

(see also Local Control Panel [4618–1](#) and [4003–1](#) 'Engine local control')

***Transfer and takeover from REMOTE AUTO. CONTROL (Remote Control) to LOCAL MANUAL CONTROL (Local Control):***

- ⇒ At the control room console, press button LOCAL MANUAL CONTROL (Local Control) for mode transfer to local manual control.
- ⇒ At WECS–9520 manual control panel (see [4618–1](#)), press button LOCAL MANUAL CONTROL to take over the control.
- ⇒ Press button FUEL CONTROL MODE.

This mode of operation should, therefore, **only** be practised for a longer period of time **when the circumstances demand it**, e.g. until the defect in the speed control system or until other faults in the remote control can be remedied.

In installations with controllable pitch propellers or with clutch couplings, some additional precautions have to be taken and it is essential that there is good communication between the bridge and the local manoeuvring stand.



**Remark:** Since the speed is no longer being maintained by the speed control system, an engineer must be continuously stationed at the local manoeuvring stand so that he can intervene immediately if necessary.

***Reversing:***

- ⇒ Turn rotary knob to 15% fuel injection quantity (see display).
- ⇒ Press requested button START AHEAD or START ASTERN until the engine runs in the correct direction.



**Remark:** On ships under way this procedure may under certain circumstances take rather a long time (several minutes), as the propeller is "dragged" in the "wrong" sense of rotation.

The above mentioned reversing procedure can also be carried out on ECR manual control panel.

However, buttons and rotary switch function only in the corresponding mode of operation, i.e. with active control stand (see [4618–1](#) 'WECS–9520 Manual control panel').

## Manoeuvring

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### 3. Increasing power after release to SEA SPEED and decreasing

For the reasons given at the beginning, the engine load should only be increased and decreased over a certain time span, usually 40–50 minutes, between full manoeuvring and service power. However, this time span may not be less than 30 minutes when increasing the load and 15 minutes when decreasing it.

This increase and decrease in load is carried out by manual operation of corresponding devices on the local manoeuvring stand:

Exceptions to the above mentioned time limitations on speed and power reductions are critical alarm conditions in the engine room which demand a quicker reduction, or when a shut-down or automatic slow-down system is activated.

### 4. Emergency manoeuvre

In the event of emergency manoeuvre, all the restrictions specified under sections 2 and 3 are lifted, i.e. the full power of the engine can be called on when necessary, because the safety of the vessel has first priority.

## Operation

### Changing Over from Diesel Oil to Heavy Fuel Oil and Vice Versa

---

#### 1. General

Continuous operation with heavy fuel oil is recommended for engines and plants provided for running on heavy fuel oil. Changing over from heavy fuel oil to diesel oil operation may only be undertaken when absolutely necessary for example by:

- Flushing the engine before maintenance works
- Heating plant switched off in the drydock
- Environmental requirements

To ensure safe changing over, consider the following items:

#### 2. Recommended viscosity at inlet to fuel pumps

The temperature necessary to ensure that the required viscosity of the fuel before inlet to the fuel pumps is reached can be seen on Viscosity-Temperature Diagram [0270–2](#). This temperature is hereafter referred to as the 'required preheating temperature'.

The preheating of the fuel is controlled by a viscosimeter.



**Remark:** During engine standstill fuel oil circulates through the fuel pumps on the supply unit but not through the fuel rail; changing over is thus not possible!

##### 2.1 Changing over from diesel oil to heavy fuel oil (see schematic diagram [0720–1](#)).

###### *Plant side:*

After changing over the three-way valve 21 the result is a mixture of diesel oil and heavy fuel oil in the mixing unit 24. The viscosimeter controls the end-heater 26 in such a way that the required viscosity (preheating temperature) of the mixture is maintained. This preheating should be done only **slowly** (temperature rise max. 15°C/min.). Sudden temperature changes can lead to seizing of the fuel pump plungers.

The heating for the fuel filter 27 as well as for the fuel delivery and return pipes should be kept on, at least until the 'required preheating temperature' (read off at the thermometer before inlet to the fuel pumps) is reached.

Check fuel pressure after low pressure feed pump and at fuel pump inlet (see Operating Data Sheet [0250–1](#)).

###### *Engine side:*

- The trace heating on the engine (supply unit and fuel rail) must be turned on at the latest when changing over from diesel oil to heavy fuel oil in the plant. All covers of the rail unit must be closed.
- If the engine room is completely cold the trace heating shall be turned on about one hour before changing over.
- Before stopping the engine, changing over must be completely finished, avoiding a mixture of diesel oil and heavy fuel oil in the fuel rail which may cause viscosity problems during the next start.

It is recommended not to exceed 75% CMCR load during changing over and until the required preheating temperature has been reached.

## Changing Over from Diesel Oil to Heavy Fuel Oil and Vice Versa

---

### 2.2 Changing over from heavy fuel oil to diesel oil

#### *Plant side:*

To change over from normal heavy fuel oil service to diesel oil, the three way valve 21 has first of all to be repositioned accordingly. This results in a mixture of heavy fuel and diesel oil in the mixing unit 24. The viscosity of the circulating mixture at a certain temperature drops quickly corresponding to the increasing share of diesel oil. After a short period the heating can be shut off.

#### *Engine side:*

- The trace heating on the engine (supply unit and fuel rail) must be shut off at the same time when changing over from heavy fuel oil to diesel oil in the plant.
- A complete change over takes appropriately longer if the engine is running at low load.



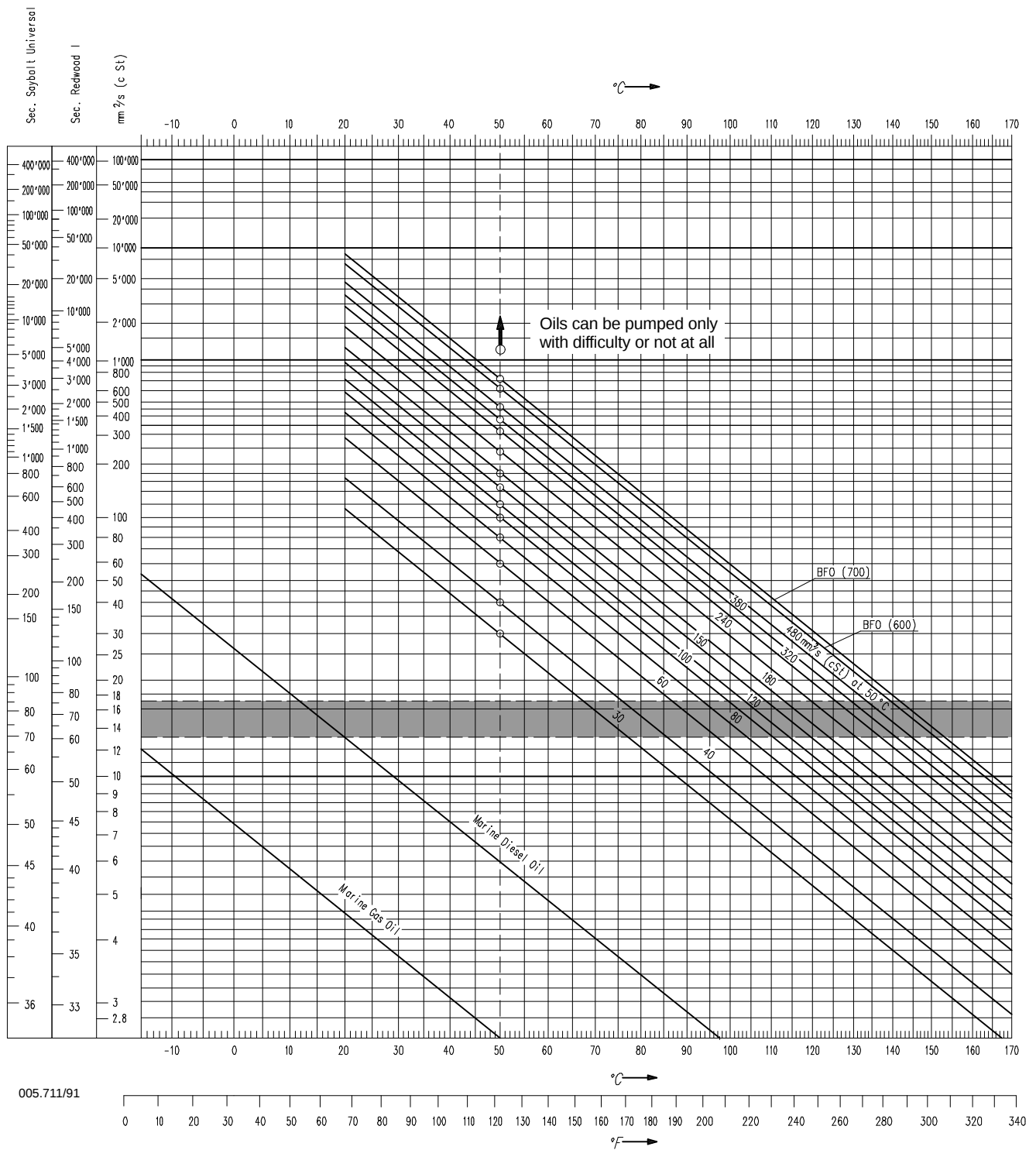
**Attention!** Running on diesel oil and with turned on trace heating is extremely dangerous for the engine!

- Before stopping the engine, changing over must be completely finished, avoiding a mixture of diesel oil and heavy fuel oil in the fuel rail which may cause viscosity problems during the next start.

It is recommended to change over from heavy fuel oil to diesel oil operation at less than 50% CMCR power.

## Viscosity - Temperature Diagram

Typical Values of Petroleum Fuel Oils



 Recommended viscosity before fuel pumps

**Example:**

To obtain the recommended viscosity before fuel pumps a fuel oil of 150 mm<sup>2</sup>/s (cSt) at 50 °C must be heated to 108–120 °C.

## Operation

### Operation at Low Load

---

#### 1. General

Pay attention to the following details:

- Checks and precautions in [0240–1](#).
- Trace heating of the fuel oil system in operation.
- Temperature of cooling medium within the normal range (see Operating Data Sheet [0250–1](#)).
- Careful treatment of the fuel oil (see Fuel Treatment, Fuel Oil System [0720–1](#)).
- The cylinder lubricating oil quantity is automatically adapted to the lower load. The lubricating oil quantities are regulated by the WECS–9520 control system in accordance with engine load.

#### 2. WECS–9520 Injection control

At low load the WECS–9520 control system automatically cuts out one of the three injection valves per cylinder. At very low load two of the three injection valves are cut out.

This ensures optimal atomization and combustion, reducing smoke emission and fuel consumption.

To spread the thermal load evenly in the combustion chamber, the WECS–9520 control system changes the cutting out of the three injection valves in regular intervals.

There is no time restriction on operation at low load due to optimized combustion in this range.

## Operation

### Operation at Overload

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#### 1. General

Normally, overload (110% of CMCR power) is only run during sea trials, in the presence of an authorized representative of the engine builder.

Running on overload, however, is to be limited to maximum one hour per day (see also Interrelationship between Engine and Propeller [0070–1](#)).

When running on overload, the engine must be monitored particularly carefully. Upon any indication of irregularities, the load (power) has to be reduced.

**The load indication (fuel injection quantity) and the exhaust gas temperature before turbine serve to indicate the measure of engine load** (see Operating Data Sheet [0250–1](#) and Acceptance Records).

The coolant temperatures have to be kept within their normal ranges.

In normal service the full load position of the load indication (fuel injection quantity) may not be exceeded (see Acceptance Records).

The maximum permissible position of the load indication (fuel injection quantity) is to be found in the acceptance records. It may not be exceeded. The change of adjustments is only permissible in order to demonstrate the CMCR power, during sea trials with overspeed of 104 to 108% of CMCR speed.

When running into strong head winds, in heavy seas, with heavy growth on the ship's hull and in shallow water, the ship resistance increases. Without any alteration to the speed setting the governor will maintain the engine speed; the position shown on the load indication (fuel injection quantity) will increase.

## Shutting Down

### General

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#### 1. Unloading

Whenever circumstances permit, we recommend that the load be reduced slowly, see Manoeuvring [0260–1](#).

#### 2. Stopping

##### ***From control room by remote control: (normal case)***

As various remote control makes can be connected to the engine controls we do not describe here the operation from the manoeuvring stand in the control room. For this the documentation of the remote control makers must be utilized.

Normally it is sufficient to move the telegraph to position STOP.

##### ***From control room by backup control box:***

- The engine is shut down by the engine control system WECS–9520 after reducing the engine speed/power and pressing the STOP button at the ECR manual control panel.

##### ***From local control panel: (see Control Diagram [4003–2](#) and Local Control Panel [4618–1](#))***

- The engine is shut down by the engine control system WECS–9520 after reducing the engine speed/power and pressing the STOP button at the WECS–9520 manual control panel.



**Remark:** However, the buttons function only in the corresponding mode of operation, i.e. with active control stand.

#### 2.1 In case of emergency

- The engine can be stopped immediately by pressure releasing in the fuel rail via the fuel shut-down valve 3.07 by pressing the EMERGENCY STOP button in the control room (control console) or on the local control panel. At the same time the fuel pump actuators move the regulating (thooted) racks in the fuel pumps to position '0'.

#### 2.2 Further possible ways of stopping the engine

The engine can also be brought to a standstill by the following measure:

- Switch off electric power to WECS–9520 in the supply box E85.



**Remark:** This option should be carried out as an ultimate emergency measure only!

## Shutting Down

### Measures to be Taken after Stopping

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#### 1. Measures for shorter service breaks (days to a few weeks)

##### 1.1 Engine manoeuvrable

Where the engine must still be capable of being manoeuvred after it has been stopped, pay attention to the following points:

- WECS–9520 engine control system must remain switched on.
- All the pumps for cooling water, lubricating oil and fuel have to be kept running.
- Control air must be available and the starting air bottles should be replenished.
- Maintain cylinder cooling water at the preheating temperature, and the lubricating oil is not to be cooled down.
- The fuel must be held at the required temperature according to Viscosity-Temperature Diagram [0270–2](#).

##### 1.2 Engine not manoeuvrable

- After the engine has been stopped, the cooling water and lubricating oil pumps should be left running for at least a further 20 minutes in order to allow the temperatures to equalize. These media should not be cooled down below their normal inlet temperatures. The sea-water pump can, therefore, usually be stopped immediately.
- Should the engine have been shut down during operation with heavy fuel oil, then the circulation must be maintained via the injection pumps and the fuel oil system must remain in operation.
- The heating of the fuel oil pipework at the engine must be switched on. Should this measure not be required, then the engine operation must be changed to diesel oil before shutting down the engine (see [0270–1](#) 'Changing over from heavy fuel oil to diesel oil' and Measures to be taken before Putting Out of Service for Extended Period [0620–1](#)).
- The low pressure feed pump and booster pump can be stopped, if the engine has been shut down while operating with diesel oil (see [0720–1](#) 'Layout of the fuel oil system').
- The starting air supply has to be closed after stopping the engine, i.e. **close the shut-off valves on the starting air bottles**, turn the handwheel 2.10 to position CLOSED (closed by hand) at the shut-off valve for starting air 2.03 and drain it by using the venting valves 2.21 and 2.27 (see Control Diagram [4003–2](#)).
- The indicator valves in the cylinder covers are to be opened.
- The turning gear can be engaged.



**Remark:** Follow all the safety regulations when carrying out repair work or any overhauls which are due (see Maintenance Manual [0011–1](#) and [0012–1](#)). Release pressure from the fuel oil system if necessary.

## Measures to be Taken after Stopping

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### **Post-lubrication of the cylinders:**

- Post-lubrication starts automatically during slow-down of the engine (speed below 8%).
- ⇒ Close the shut-off valve on the control air supply (supply of air from the board system).



**Remark:** Before venting the air spring system, the lubricating oil pump must always be switched off.

- Where possible, keep the cooling water warm in order to prevent the engine from cooling down too much. The cooling water pump is, therefore, kept running unless required to be stopped for maintenance work.
- ⇒ At relatively frequent intervals, turn the engine through by several revolutions with the indicator valves open, using the turning gear (possibly done daily in damp climates). Do this with the lubricating oil pump and servo oil service pump running and switching on the cylinder lubrication at the same time. After completing this procedure, ensure that the piston comes to rest in a different position each time.
- ⇒ Repair all the defects detected in service (leaks, etc.).

## **2. Measures for service interruptions over a longer period (weeks or months)**

Refer to section 1.2 above and to Measures to be taken before Putting Out of Service for Extended Period [0620-1](#).

## Special Measures in Operation

### Running-in of New Cylinder Liners and Piston Rings

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#### Overview

|    |                                          |     |
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| 1. | General .....                            | 1/3 |
| 2. | Fuel .....                               | 1/3 |
| 3. | Cylinder lubricating oil .....           | 2/3 |
| 4. | Cylinder lubricating oil feed rate ..... | 2/3 |
| 5. | Running-in programme .....               | 3/3 |

#### 1. General

After the fitting of new cylinder liners or even only after replacing piston rings, these must be run-in. The purpose of running-in is to achieve a good sealing of the rings as soon as possible.

Under no circumstances must any seizures occur on the running surfaces of cylinder liner and piston rings.

It is of the utmost importance that spare cylinder liners are purchased from recognized reliable manufacturers who apply modern material and machining technologies.

##### 1.1 Preparations and checks to be carried out before starting the engine

⇒ Carry out all starting preparations according to [0110–1](#).

Furthermore, check the following points:

- Condition of piston rings, cylinder liners from piston underside and if there are any signs of condensation or leakages (if the engine has not been started for some time).
- Scavenge air receiver and piston underside for contamination.
- Water separator in clean condition.
- Scavenge air receiver drains open and that high level alarm functions properly.
- Required cylinder lubricating oil feed rate set according to section 4.

⇒ Switch off VIT (user parameter, function 'VIT OFF' in remote control).

##### 1.2 Remarks on running-in

- The engine has to be run-in according to the guidelines of the running-in programme ([section 5](#)).
- The load-up programme should not be completed faster than recommended.
- It is necessary to occasionally inspect the condition of the running surfaces of the piston rings and the cylinder liner to assess the status of running-in.
- The stability and the level of the cylinder cooling water temperature must be checked frequently (no fluctuations in temperature are permitted), (see Cylinder Liner [2124–1](#)).
- For running-in of single cylinders their load can be reduced temporarily by function 'Inj. correction factor' (see [4002–3](#) 'Maintenance settings').

#### 2. Fuel

For running-in the same fuel (HFO), correctly treated and properly preheated, should be utilized as for normal operation.

## Running-in of New Cylinder Liners and Piston Rings

---

### 3. Cylinder lubricating oil

Under normal operating condition as well as for running-in, a well cleaning, high-alkaline (BN) cylinder lubricating oil should be applied (see [0750–1](#) 'Cylinder lubricating oil') for the use of heavy fuel oils with high sulphur content.

### 4. Cylinder lubricating oil feed rate

#### 4.1 Increasing the feed rate

During the running-in phase the lubricating oil feed rate to the respective cylinder must be raised, i.e. adjusted to 1.4 g/kWh (see [7218–1](#) 'Adjusting the feed rate of lubricating oil').

#### 4.2 Reducing the feed rate

Based on nominal power, the lubricating oil feed rate can be reduced as follows:

- to 1.2 g/kWh after about 15 running hours
- to 1.0 g/kWh after 50 running hours
- to 0.9 g/kWh after 200 running hours and after inspections of the piston rings and cylinder liners.

Due to regular checks of the piston rings and cylinder liners in the course of the next 500–1000 operating hours, the feed rate can be reduced in small steps until the required feed rate of 0.7 g/kWh is reached according to the running-in programme.

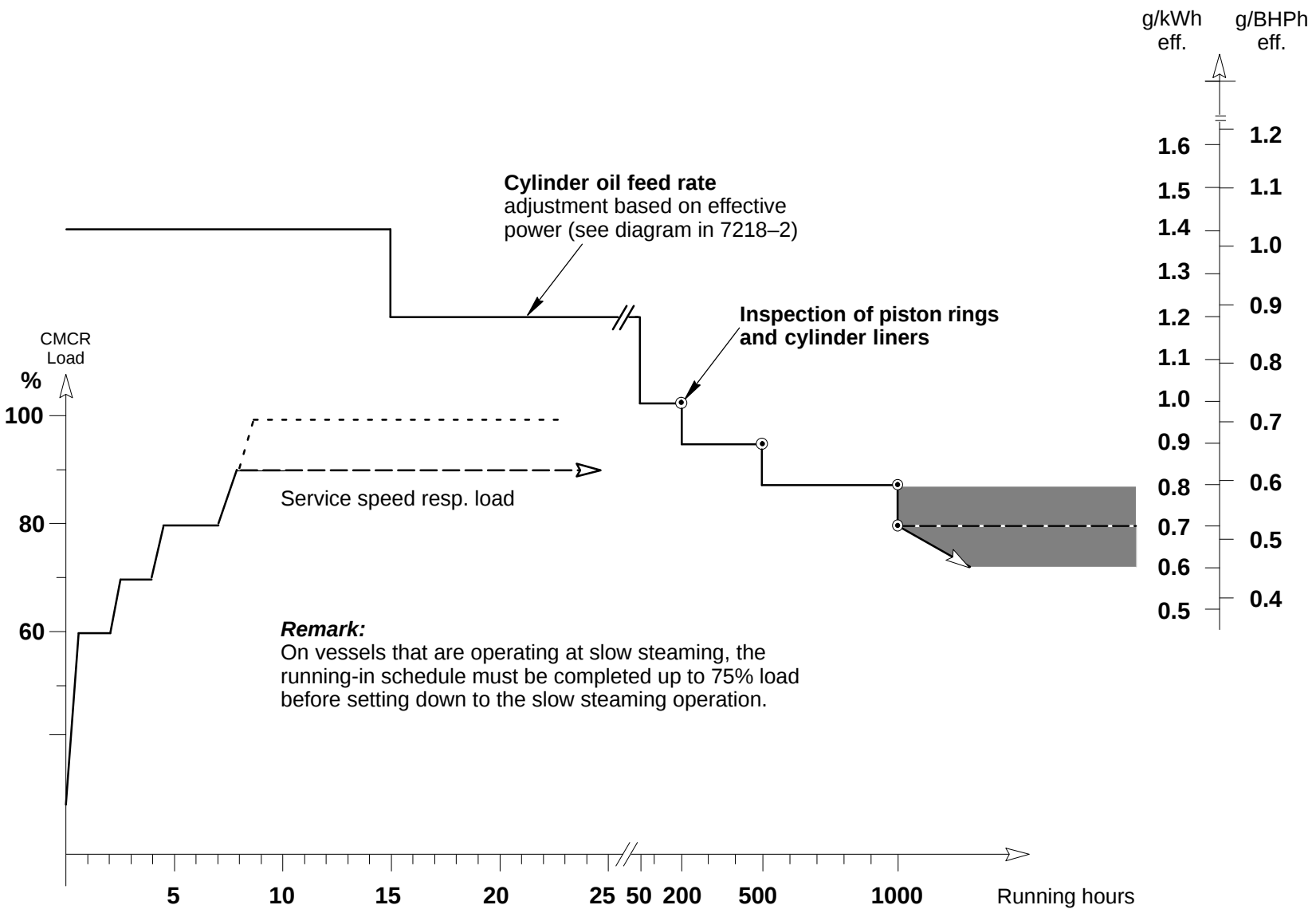
A reduction below the recommended value after 1000 running hours can be envisaged after confirmation that satisfactory conditions have been achieved at this stage. The reduction should be in steps of approximately 0.1 g/kWh, with periods of 500 to 1000 running hours between each step. Any decision to reduce the feed rate should be based on the inspection results of the running surface of the piston rings and cylinder liner through the scavenge ports.

The final feed rate for normal service depends mainly on:

- Operating conditions of engine
- Sulphur content of heavy fuel oil
- Maintenance condition
- Operational considerations (cylinder lubricating oil costs versus cylinder liner replacement and maintenance costs)
- Selection of lubricating oil
- Oil analysis of piston underside drain

# Running-in of New Cylinder Liners and Piston Rings

## 5. Running-in programme





## Special Measures in Operation

### Indicator Diagrams

#### 1. General

Indicator diagrams shall only be drawn with a suitable, well working indicator at constant power and speed, and in case of marine engines in calm sea and deep water.

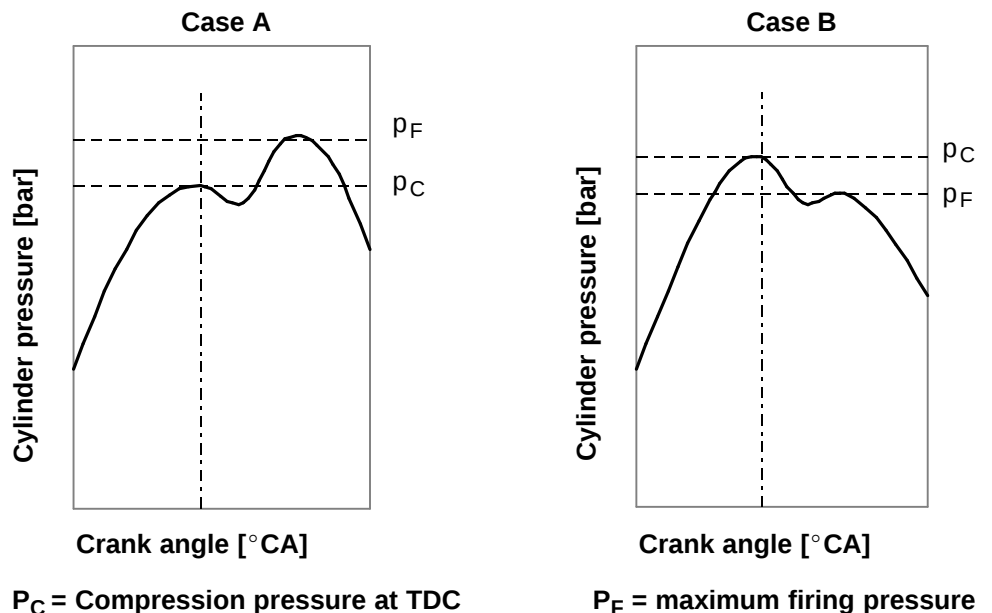
For the interpretation of the indicator diagrams note the respective cylinder number, engine speed, the positions of the load indicator and VIT.

#### 2. Definition of cylinder pressures

Higher compression ratio and fuel injection delay have been introduced to reduce the  $\text{NO}_x$  value for engines in compliance with the IMO rules.

In general the ratio of the maximum firing pressure to the compression pressure is within the range of 0.90 to 1.25 at 100% load.

Depending on the engine rating and the corresponding IMO tuning, the diagram curves can **vary within the two following cases**:

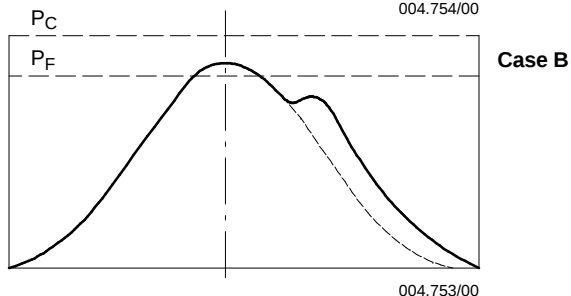
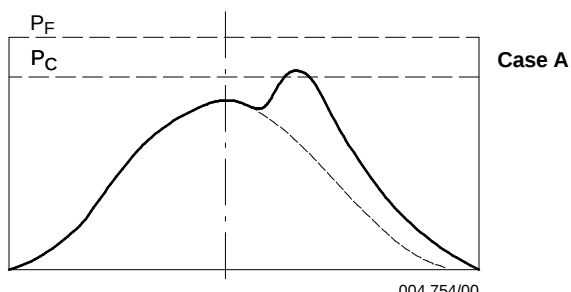
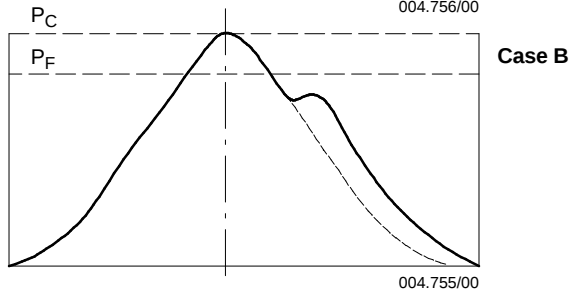
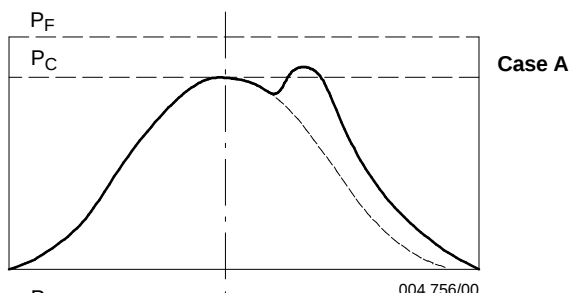
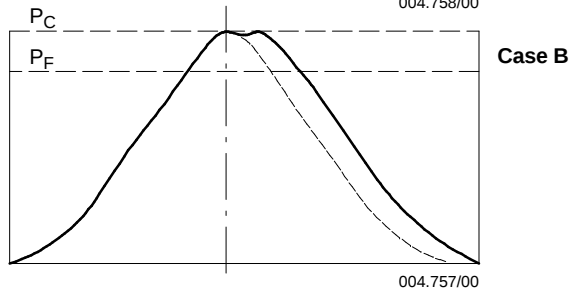
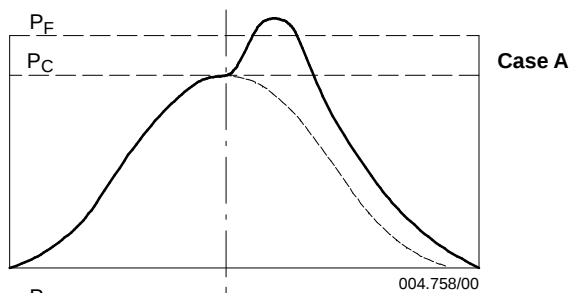


#### 3. Interpretation of indicator diagrams and corresponding engine adjustments



**Remark:** The diagrams which have been drawn during the acceptance trial should be taken as reference. For reference values on compression and maximum firing pressures for the corresponding load and speed refer to the trial reports and performance curves.

## Indicator Diagrams



### 3.1 Maximum firing pressure too high at correct compression pressure

#### Possible causes:

- Ignition (start of injection) too early for the fuel type in use.

The correction of the ignition pressure must be carried out by adjusting the FQS to "later" (see user parameters [4002-3](#)).

A correction at the FQS may only be effected if **all** cylinders show the same pressure deviation.

### 3.2 Maximum firing pressure too low at correct compression pressure

#### Possible causes:

- Poor combustion: Nozzle tip with trumpets or worn out.  
⇒ Check the injection nozzles.
- Ignition (start of injection) too late for the fuel type in use.

The correction of the ignition pressure must be carried out by adjusting the FQS to "earlier" (see user parameters [4002-3](#)).

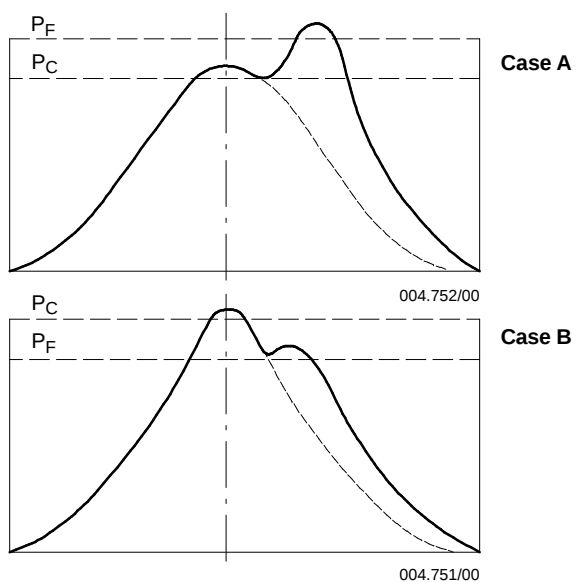
A correction at the FQS may only be effected if **all** cylinders show the same pressure deviation.

### 3.3 Compression and maximum firing pressure too low

#### Possible causes:

- Actual load lower than assumed.
- Exhaust valve leaking.  
⇒ Check exhaust valve.
- Scavenge air pressure too low.  
⇒ Clean turbocharger or scavenge air cooler.
- Suction temperature too high.
- VEC timing wrong i.e. exhaust valve closing time too late (parameter in WECS-9520).

## Indicator Diagrams

**3.4 Compression pressure and maximum firing pressure too high*****Possible cause:***

- Engine overloaded.
- VEC timing wrong.



## Special Measures in Operation

### Measures against Fouling and Fires in the Scavenge Air Spaces

---

#### 1. General

The principle cause of fouling is blow down of combustion products between piston and cylinder into the scavenge air spaces. The fouling will be greater if there is incomplete combustion of the fuel injected (smoky exhaust).

#### 2. Causes and measures

##### 2.1 Causes of poor combustion

- The injection valves are not working correctly (trumpets at the nozzle tip).
- The fuel is too cold particularly at low load.
- Operation with a temporary shortage of air during extreme variations in engine loading and with the scavenge air pressure-dependent fuel limiter (smoke limiter) in the governor set too high.
- Overloading, insufficient supply of air due to restricted engine room ventilation, fouling of the silencer and diffuser on the air side of the turbocharger, fouling of the wire mesh and nozzle ring before turbocharger, fouling of the exhaust gas boiler, the air cooler and water separator, the air flaps in the scavenge air receiver and of the scavenge ports.

##### 2.2 Causes of blow-by of combustion products

- Worn, sticking or broken piston rings.
- Worn cylinder liner.
- Individual cylinder lubricating quills are not working.
- Damage to the running surface of the cylinder liners.

If one or more of these operating conditions prevail, residues, mainly consisting of incompletely burned fuel and cylinder lubricating oil, will accumulate at the following points:

- Between piston ring and piston ring groove.
- On the piston skirt.
- In the scavenge ports.
- On the bottom of the cylinder jacket (piston underside).

##### 2.3 Causes of fires

- With blow-by, hot combustion gases and sparks which have bypassed the piston rings between piston and cylinder liner running surface, enter the space on the piston underside.
- Leaky sealing rings in the piston rod gland as well as blocked drain pipes from the piston underside will lead to an accumulation of system and cylinder lubricating oil and therefore to a major fire risk.



**Remark:** Periodically check the bottom of the cylinder jacket and if necessary clean it.

## Measures against Fouling and Fires in the Scavenge Air Spaces

---

### 2.4 Indications of a fire

- Sounding of the respective temperature alarms.
- A considerable rise in the exhaust gas temperatures of the cylinder concerned and a rise in piston underside temperature.
- Under certain conditions the turbocharger may start surging.

### 2.5 Fire fighting measures

We recommend the following:

- Reduction of engine power.
- Cutting out the fuel injection of the cylinder concerned (user parameter Inj. CUT OFF in remote control).
- Increase feed rate of lubricating oil to maximum so that lubrication is ensured despite the increased temperature (see [7218–1](#) 'Adjusting the feed rate of lubricating oil').
- Where the plant specifies a fire extinguishing system (carbon dioxide CO<sub>2</sub>) the containers can be joined to the connections which have been provided on the receiver. The respective shut-off valve must be absolutely leakproof.
- Should for any reason a fire be feared then shut down the engine and fill the scavenge space with CO<sub>2</sub> gas.



**Remark:** Pay attention to paragraph 11 in [0210–1](#) 'Entering the engine after the use of CO<sub>2</sub>'.

- If steam is used as a fire extinguishing medium, measures against corrosion have to be taken.

A fire should have died down after 5 to 15 minutes. This can be verified by checking the exhaust gas temperatures and the temperatures of the doors to the piston underside space.

Afterwards the engine must be stopped whenever possible and the cause of the fire investigated.

CHECK

The following checks should be carried out:

- Cylinder liner running surface, piston and piston rings.
- Air flaps in the receiver (to be replaced if necessary).
- Possible leakages.
- Piston rod gland as far as possible.
- Injection nozzles.
- After a careful check, or if necessary repair, the engine can slowly be put back on load with injection restarted and lubricating oil feed rate reset.

Should a stoppage of the engine not be feasible and the fire have died down, the lubricating oil feed rate can be reset, the injection again cut in and the load slowly increased.



**Remark:** Avoid running for hours with considerably increased cylinder lubrication.

## Measures against Fouling and Fires in the Scavenge Air Spaces

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### 2.6 Preventive measures

As can be seen from the causes, good engine maintenance goes a long way to safeguarding against fires in the scavenge air spaces. The following measures have a particularly favourable influence:

- Use of correctly spraying injection nozzles and keeping the air and gas passages clean (regular inspection and cleaning).
- The permanent drain of dirty oil from the piston underside must always be assured.
- To prevent accumulation of dirt, check the dirty oil drain pipes from the piston underside for free passage. An obstruction can be detected by touching the individual drain pipes with the hand (temperature difference). If one has only surrounding temperature, the line must have been blocked by carbon deposits and needs to be cleaned as soon as possible.

## Special Measures in Operation

### Instructions Concerning the Prevention of Crankcase Explosions

---

#### 1. General

Investigations into the causes of crankcase explosions with diesel engines have shown that they can only occur under particular conditions and, therefore, are extremely rare.

The oil mist in the crankcase is inflammable over a very narrow range of concentration only. There must always be an extraneous cause to set off ignition such as hot engine components. Only under these circumstances and the presence of a critical mixture ratio of oil mist and air can an explosion occur.

Engines are equipped, as standard, with an oil mist detector (see Oil Mist Detector [9314–1](#)), which continuously monitors the intensity of oil mist in the crankcase and triggers an alarm if the mist exceeds a limit of admissible intensity.

Good engine maintenance and deliberate action in cases of an alarm rule out explosions to a large degree.

#### 2. Measures to be taken in case of an alarm

- ⇒ **Get a way from the engine, risk of explosion!**
- ⇒ Reduce engine speed (power) immediately.
- ⇒ As soon as conditions allow, stop the engine.
- ⇒ Find cause and remedy as far as possible (see Operating Troubles [0840–1](#)).



**Attention!** Should the engine be shut down because of a suspected heating-up of a running gear, then neither the doors nor the checking covers of the crankcase may be opened immediately. The heated areas must cool during **at least 20 minutes**, to prevent ignition by access to fresh air. Till the heated parts have cooled the danger of an explosion is still possible. To prevent accidents no person may therefore stand in the vicinity of the explosion flaps of the crankcase doors. Where no fire extinguishing plant is connected or not in use, a portable fire extinguisher must be kept ready when the crankcase doors are opened later.

## Operation under Abnormal Conditions

### General Information

---

#### 1. General

In the following descriptions "Operation under Abnormal Conditions", measures are given which must be taken when engine parts develop defects which cannot be immediately rectified but where the engine must continue to be operated, or where its operation must be resumed as soon as possible.

#### 2. Reduced power output

In emergency cases where the engine must run with one or more cylinders out of operation, turbochargers out of service or reduced coolant flows etc., the engine power must be reduced in order to prevent thermal overloading.

The full load position of the load indication (fuel injection quantity) or the maximum exhaust gas temperature before the turbine (see Operating Data Sheet [0250–1](#)) may under no circumstances be exceeded. If necessary the engine speed and power have to be reduced under observation of any barred speed range where critical speeds exist.

In addition, the exhaust smoke must be checked and continuously observed as the engine must not be operated with dark exhaust and under soot generating conditions. Speed and power must be reduced until the exhaust smoke has reached acceptable levels.

#### 3. Taking cylinders out of operation

When individual cylinders have been taken out of operation the turbocharger can run into 'surging'. This makes itself known by a loud sound. Surging can be detected visually at the pressure gauge as large fluctuations in the scavenge air pressure.

Should the 'surging' occur at short intervals or even continuously, the speed has to be suitably reduced.



**Remark:** Should individual cylinders be out of operation, it is possible (particularly with engines having few cylinders) that the engine comes to rest in a position from which it cannot be restarted, since none of the intact pistons lies within a starting range. In such cases, the engine should be started for a short moment in the opposite direction in order to bring the crankshaft to another position. The possibility has to be taken into account that the engine will not reverse so well and corresponding precautions have to be taken together with the bridge.

**Operation under Abnormal Conditions****Operation with Injection Cut Out (One or More Cylinders)****1. Measures**

If the injection of one or more cylinders has to be cut out, the following measures must be taken:

- ⇒ Cutting out injection of cylinder concerned with user parameter Inj. CUT OFF in remote control.



**Remark:** Where the reason for cutting out is a defect in the injection system (injection control unit, injection pipe to the injection valves, etc.) only the injection of the cylinder concerned needs to be cut out. If possible the exhaust valve shall always remain in operation.



**Attention!** For safety reasons the plugs must be disconnected from the pre-control valves (rail valves) of the corresponding cylinder (see Fig. 'A').

Should the engine be kept running with the injection cut out for an extended period, the lubricating oil feed rate for the respective cylinder must be reduced to the minimum (see 7218–1 'Adjusting the feed rate of lubricating oil').

For a later restoring, the previous settings must be noted.

**2. Restarting of injection**

Replace defective injection control unit at the first opportunity (see Injection Control Unit 5564–1 in the Maintenance Manual).



**Risk of injury!** Always use gloves when working on hot components and wear safety goggles!

**2.1 Exchange of defective injection control unit****Procedure:**

- ⇒ Stop the engine.
- ⇒ Close heating pipings.
- ⇒ Switch off fuel booster pump 3.15 and bearing oil pump.
- ⇒ Carefully loosen drain screw 5 by approx. two turns for pressure relief of servo oil rail 2 (see Fig. 'B').
- ⇒ Carefully loosen drain screw 6 by approx. two turns for pressure relief of fuel rail 1, ensuring that the latter is pressureless (see Fig. 'B').
- ⇒ Replace the defective injection control unit.
- ⇒ Close drain screw 5 and tighten it with a torque of 200 Nm.
- ⇒ Close drain screw 6 and tighten it with a torque of 200 Nm.

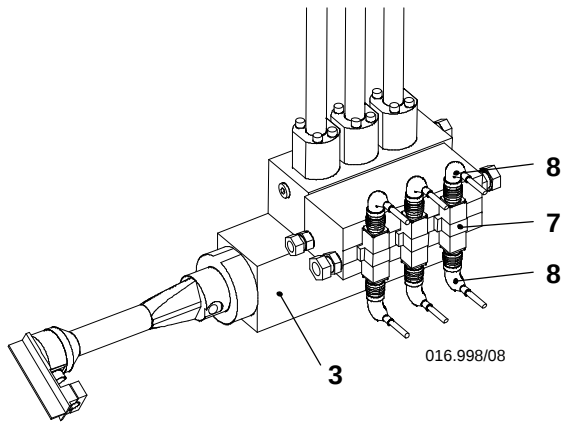
**CHECK**

Switch on fuel booster pump 3.15, bearing oil pump, servo oil service pump 4.88 and carry out a leakage check.

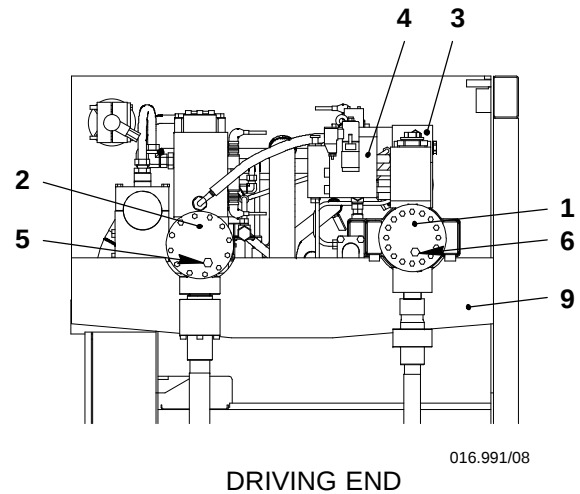
- ⇒ Switch off servo oil service pump 4.88.
- ⇒ Reopen heating pipes.
- ⇒ Adjust the lubricating oil feed rate for the respective cylinder to the previous settings (see 7218–1 'Adjusting the feed rate of lubricating oil').
- ⇒ Cutting in injection of the cylinder concerned with user parameter Inj. RUN in remote control.
- ⇒ Reconnect plugs 8 to pre-control valves 7 (rail valves).

## Operation with Injection Cut Out (One or More Cylinders)

**A**



**B**



**Key to Illustrations:**

|            |                                 |
|------------|---------------------------------|
| <b>'A'</b> | <b>Injection control unit</b>   |
| <b>'B'</b> | <b>Rail unit at driving end</b> |

- |                                    |                                       |
|------------------------------------|---------------------------------------|
| 1 Fuel rail 3.05                   | 6 Drain screw 3.82                    |
| 2 Servo oil rail 4.11              | 7 Pre-control valve (rail valve) 3.76 |
| 3 Injection control unit 3.02      | 8 Plug                                |
| 4 Fuel pressure control valve 3.06 | 9 Rail unit                           |
| 5 Drain screw 4.82                 |                                       |

### 2.2 Exchange of defective injection pipe

Replace defective injection pipe at the first opportunity (see Fuel Pressure Piping [8733-1](#) in the Maintenance Manual).



**Remark:** A defective, leaking injection pipe can be localized by means of the drain screws at the flange (see [8019-1](#) 'Fuel leakage system').

As a temporary measure the affected injection pipe can be isolated by removing both plugs from the corresponding pre-control valve (rail valve) on the injection control unit. Injection will take place through the remaining injection pipe, however, this prolongs the injection time releasing an alarm 'Inj. time too long'.

**Procedure:**

- ⇒ Stop the engine.
- ⇒ Replace defective injection pipe.

## Operation under Abnormal Conditions

### Faults in High Pressure Fuel System

#### Overview

|    |                                                  |     |
|----|--------------------------------------------------|-----|
| 1. | Defective fuel pump .....                        | 1/6 |
| 2. | Defective actuator .....                         | 1/6 |
| 3. | Defective injection control unit .....           | 3/6 |
| 4. | Defective fuel pressure control valve 3.06 ..... | 6/6 |

## 1. Defective fuel pump

### 1.1 Identification

- Higher regulating positions (actuator) of the fuel pumps at the same output compared with the acceptance report.
- Abnormal noises such as knocking, scraping and ringing.
- Alarm indication by level switch LS3426A (see [8019–1](#) 'Fuel leakage system').

### 1.2 Causes

- Pump plunger seized, spring broken, regulating sleeve blocked.
- Roller blocked, damage to cam, roller guide seized.
- Breakage of a rising pipe.
- Blocked (regulating) toothed rack.

### 1.3 Measures

- ⇒ Stop the engine.
- ⇒ Cut out the corresponding fuel pump (see Cutting Out and Cutting In of the Fuel Pump [5556–2](#)).
- ⇒ Replace defective parts at the first opportunity (see Fuel Pump [5556–1](#) and Fuel Pump Unit [5581–1](#) in the Maintenance Manual).

## 2. Defective actuator

### 2.1 Identification

- If an actuator fails, its regulating output remains in position. The toothed rack does not react to load changes.
- At higher fuel consumption, the intact actuators take over the control of fuel quantity regulation.
- At lower fuel consumption, fuel pressure control valve 3.06 takes over the fuel pressure regulating function.



**Remark:** If all actuators fail, their regulating outputs remain in position. The toothed racks do not react to load changes. Fuel quantity regulation is not possible at higher fuel consumption. Fuel pressure control valve 3.06 takes over the fuel pressure regulating function at lower fuel consumption. The fuel quantity flowed off is led into the fuel return.

Operation with this regulating functions should be avoided if possible or be maintained only few hours, reduce rail pressure (see 2.3 'Measures' and [5562–1](#) 'Fuel pressure control valve 3.06').

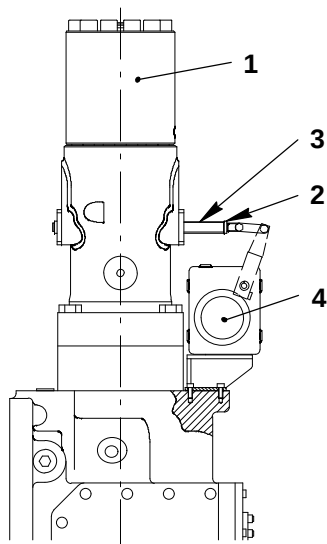
At an overpressure in the fuel rail (failure or malfunction of fuel pressure control valve 3.06), fuel overpressure safety valve 3.52 opens and an alarm is triggered by level switch LS3446A.

## Faults in HP Fuel System

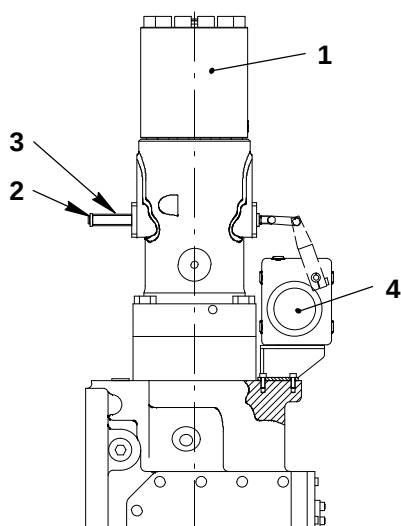
## 2.2 Causes

- Actuator blocked.
- Electrical interference (cable coupling defective, parting of a cable etc.).

## 2.3 Measures

**A**

017.005/08

**B**

017.005/08

**Failure of one actuator:**

- ⇒ Fit spacer 3 (tool 94555) on toothed rack 2 in position '0' to fuel pump with regard to the faulty actuator.
- ⇒ Replace defective actuator at the first opportunity (see Fuel Pump Actuator 5583-1 in the Maintenance Manual).
- ⇒ Check control signals from WECS-9520 and electric cables, if necessary replace them.
- ⇒ Ensure that the regulating linkage moves freely.
- Spacer 3 (tool 94555) can also be fitted in position 'max.' depending on the preferential output (i.e. mainly at full load). Fuel pressure regulation via fuel pressure control valve 3.06 should be avoided if possible.
- ⇒ Turn knurled screw at fuel pressure control valve 3.06 (see 5562-1) counter-clockwise till the stop.

**Failure of all actuators:**

- ⇒ Fit spacer 3 (tool 94555) on regulating rack 2 in position '0' at half of fuel pumps, and in position 'max.' at other half (Fig. 'A' and 'B').
- If higher load is required more pumps can be set to position 'max.' instead of '0'.
- ⇒ Turn knurled screw at fuel pressure control valve 3.06 (see 5562-1) counter-clockwise till the stop.

**Key to Illustrations:** 'A' Spacer in position '0'  
 'B' Spacer 'max.'

1 Fuel pump 3.14  
 2 Regulating rack

3 Spacer (tool 94555)  
 4 Actuator 3.21

## Faults in HP Fuel System

**3. Defective injection control unit****3.1 Identification**

- Alarm indication in WECS-9520 (remote control).
- The fuel injection is cut off automatically (Inj. CUT OFF) on the corresponding cylinder, and a SLOW DOWN will be released.
- Leakage at the injection control unit.
- Alarm indication by level switch LS3446A due to leakage at the injection pipes (see [8019-1](#) 'Fuel leakage system').

**3.2 Causes**

- Fuel quantity sensor defective.
- Fuel quantity piston at the stop (caused by pre-control valve failure).
- Pre-control valve (rail valve) defective.
- Crack in the injection control unit.
- Injection control valve seized.
- Fuel quantity piston seized.
- Breakage of a injection pipe.

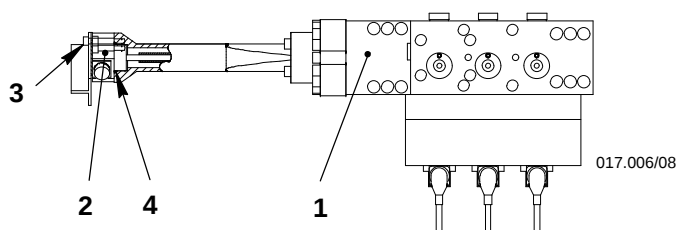
**3.3 Measures****Fuel quantity sensor:**

**Remark:** The engine does not have to be stopped.  
Operation is possible also with a faulty fuel quantity sensor.

**Replacing defective fuel quantity sensor:**

- ⇒ Remove plug. Do not loose O-ring inside the socket!
- ⇒ Loosen and remove screws 3.
- ⇒ Remove fuel quantity sensor 2.
- ⇒ Oil O-ring 4 and fit new fuel quantity sensor.
- ⇒ Apply Never-Seez NSBT-8 to screws 3 and tighten them with a torque of 20 Nm.
- ⇒ Insert plug in the correct position. *Important:* Plug must be tight!

**C**

**Key to Illustration: 'C'**

- 1 Injection control unit 3.02
- 2 Fuel quantity sensor 3.03
- 3 Screw
- 4 O-ring

Faults in HP Fuel System

---

**Fuel quantity piston:**

- ⇒ If the fuel quantity piston is at the stop, manually relieve fuel rail pressure shortly at the fuel shut-down valve (EM. STOP) ZV7061S. This valve is arranged in the rail unit at the driving end.
- If the fuel quantity piston sticks in a position, i.e. in most cases this is not a seizure of the piston but a hydraulic locking caused by a rail valve stuck in position 'Inject'.
- See section **Injection control unit**, if the measure taken is unsuccessful.

**Pre-control valve (rail valve):**

- The defective pre-control valve can also be replaced during operation.

**Procedure:**

- ⇒ Cutting out injection of cylinder concerned with user parameter Inj. CUT OFF in remote control.



**Risk of injury!** Always use gloves when working on hot components! Always wear safety goggles.

**Attention!** Closing sequence of ball valves at fuel injection unit must strictly be observed as follows:

Ball valve 1 (servo oil inlet) must be closed prior to ball valve 2 (servo oil outlet) (see Fig. 'D').

- ⇒ Close ball valve 1 before injection control unit 5.
- ⇒ Close ball valve 2 after injection control unit 5.
- ⇒ Remove cable 8.
- ⇒ Loosen screws 7 and remove them together with the pre-control valve 6.
- ⇒ Take care that the three O-rings are put in the new pre-control valve and the surfaces are clean.
- ⇒ Fit the pre-control valve, apply Never-Seez NSBT-8 to the four screws 7 and tighten them with a torque of 2.5 Nm (see Fig. 'D' and Injection Control Unit 5564–1 in the Maintenance Manual).

|       |
|-------|
| CHECK |
|-------|

**Important!** Pay attention that the bore positions correspond.

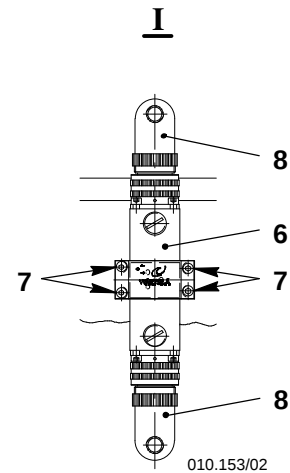
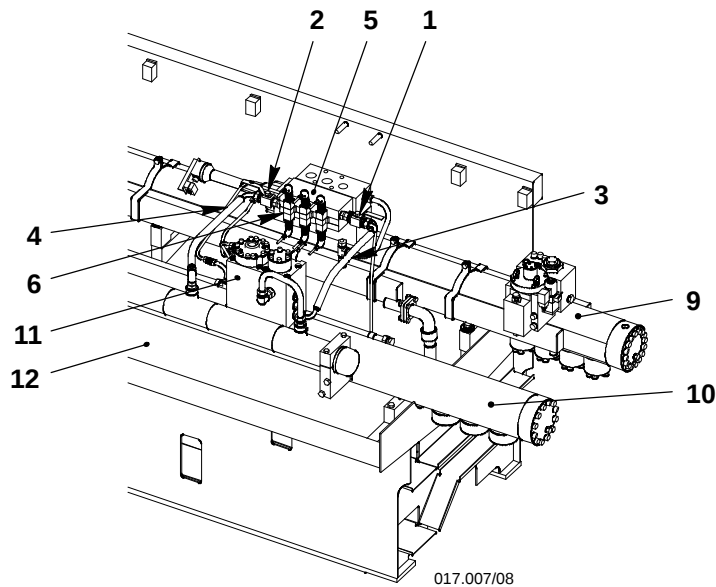


**Attention!** Opening sequence of ball valves at fuel injection unit must strictly be observed as follows:

Ball valve 2 (servo oil outlet) must be opened prior to ball valve 1 (servo oil inlet).

- ⇒ Open ball valves 2 and then 1.
- ⇒ Reconnect cable 8. Important: Plug must be tight!
- ⇒ Cutting in the injection of the cylinder concerned with user parameter Inj. RUN in remote control.

## Faults in HP Fuel System

**D****Key to Illustration: 'D' Injection control unit**

- |                                       |                                    |
|---------------------------------------|------------------------------------|
| 1 Ball valve 3.38                     | 7 Screw                            |
| 2 Ball valve 3.27                     | 8 Cable                            |
| 3 Flexible hose (inlet)               | 9 Fuel rail 3.05                   |
| 4 Flexible hose (outlet)              | 10 Servo oil rail 4.11             |
| 5 Injection control unit 3.02         | 11 Exhaust valve control unit 4.10 |
| 6 Pre-control valve (rail valve) 3.76 | 12 Rail unit                       |

**Injection control unit:**

The injection must be cut off as an immediate measure in case of:

- injection control unit cracked
- injection control valve or fuel quantity piston seized

See [0510-1 'Measures'](#).



**Remark:** With injection cut off (Inj. CUT OFF) the engine can only be operated at reduced load.

- ⇒ Replace defective injection control unit at the first opportunity (see [0510-1 'Restarting of the injection'](#) and Injection Control Unit [5564-1](#) in the Maintenance Manual).

**Injection pipe:**

- ⇒ Cut out the injection to the injection valves at a breakage of a injection pipe (see [0510-1 'Measures'](#)).
- ⇒ Replace defective injection pipe at the first opportunity (see [0510-1 'Exchange of a defective injection pipe'](#) and Fuel Pressure Piping [8733-1](#) in the Maintenance Manual).

**Exchange of defective rising pipe:**

- ⇒ Stop the engine.
- ⇒ Switch off fuel booster pump 3.15.
- ⇒ Replace defective rising pipe (see [8752-1](#) in the Maintenance Manual).

## Faults in HP Fuel System

#### 4. Defective fuel pressure control valve 3.06

##### 4.1 Identification

- Engine load drops or engine stops.
- Fuel rail pressure too low (alarm).
- Regulating shaft position higher than normal or on maximum.
- 'Whistling' noises with running engine.

##### 4.2 Causes

- Retaining pressure set too low (knurled screw 4 not at the lower stop).
- Defective fuel pressure control valve 2.
- Fuel pressure control valve has opened or is leaky.



**Remark:** If the knurled screw is at the lower stop and nevertheless fuel oil drains off the fuel pressure control valve, there is an indication of an internal leakage.

##### 4.3 Measures

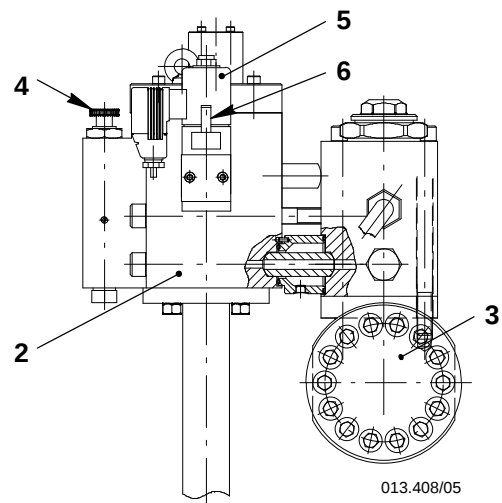
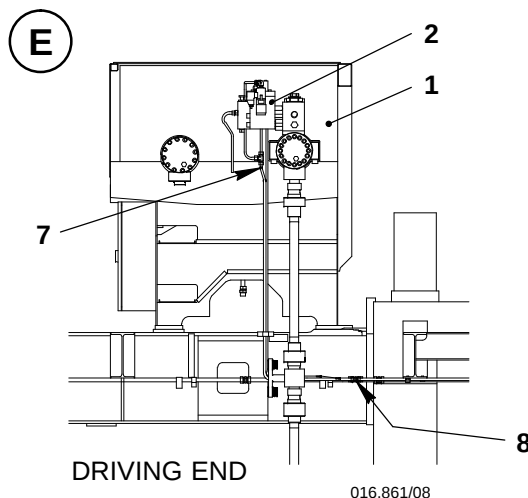
- ⇒ Turn knurled screw 4 to the lower stop.
- ⇒ Overhaul or replace defective fuel pressure control valve 2 at the first opportunity.
- ⇒ Check oil supply to fuel pressure control valve, clean filter in the inlet.



**Attention!** Replacing of the fuel pressure control valve can only be carried out at engine standstill!

The oil supply from bearing oil system 7 and fuel rail 3 must be pressureless.

- ⇒ Switch off fuel booster pump 3.15 and bearing oil pump.
- ⇒ Relieve pressure with hand lever 6 on fuel shut-down pilot valve 5.



##### Key to Illustration: 'E'

- 1 Rail unit
- 2 Fuel pressure control valve 3.06
- 3 Fuel rail 3.05
- 4 Knurled screw

- 5 Fuel shut-down pilot valve 3.08
- 6 Hand lever
- 7 Oil supply from bearing oil system
- 8 Non-return valve 3.67

## Operation under Abnormal Conditions

### Operation with Exhaust Valve Control Unit Cut Out

#### 1. General

As a rule, in the event of a defect in an exhaust valve control unit, in the exhaust valve control unit, on the hydraulic piping or on an exhaust valve, the fault must be corrected **immediately**.

Should this not be possible because the engine has to be put back in service, the following measures have to be taken at the cylinder concerned.

#### 2. Emergency operation with exhaust valve closed

##### 2.1 Cut out an exhaust valve control unit

At malfunctions of the exhaust valve, especially if the closing or opening time deviates strongly.

The exhaust valve remains **closed** in the following emergency operation.

- ⇒ Cut out the injection (see 0510–1 'Measures').
- ⇒ Set the exhaust valve control unit for the cylinder concerned to MAN. CLOSE with user parameter EXH. VALVE AUTO / MAN. in remote control.



**Attention!** For safety reasons plugs 6 must be disconnected from pre-control valve (rail valve) 5 of the corresponding cylinder.

##### 2.2 Operation with cut out exhaust valve control unit

After taking the above measures the engine can be put back in service.



**Remark:** With one or more cut out exhaust valve control unit(s), the engine can only be operated at reduced load.

Generally the remarks in 0500–1 have to be observed. Furthermore the exhaust gas temperature after cylinders may on no cylinder exceed the **maximum limit of 515 °C**.

##### 2.3 Re-starting of exhaust valve control unit

Replace defective exhaust valve control unit or HP piping at the first opportunity (see Exhaust Valve Control Unit 5612–1 and Hydraulic Piping for Exhaust Valve Drive 8460–1 in the Maintenance Manual).

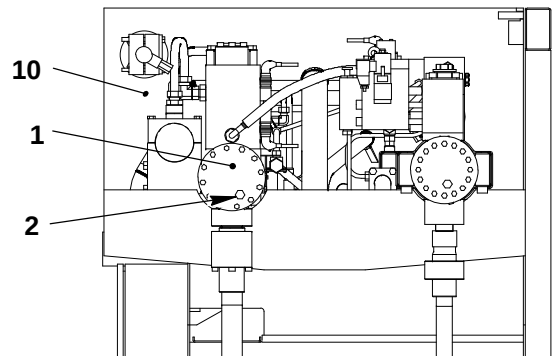
#### **Exchange of defective exhaust valve control unit or hydraulic piping:**

- ⇒ Stop the engine.
- ⇒ Switch off bearing oil pump.
- ⇒ Open drain screw 2 by about two turns for pressure relief in the servo oil rail 1 (see Fig. 'A').
- ⇒ Loosen screws 9 on flange 7 of actuator pipe 4 in order to drain the latter via oil leakage pipe 12 on cover 8 of exhaust valve control unit 3.
- ⇒ The defective exhaust valve control unit or the hydraulic piping can now be replaced (see 5612–1 and 8460–1 in the Maintenance Manual).
- ⇒ Close drain screw 2 and tighten it with a torque of 200 Nm.
- ⇒ Switch on bearing oil pump.
- ⇒ Cut in the injection (see 0510–1).
- ⇒ Set the exhaust valve control unit for the cylinder concerned to AUTO with user parameter EXH. VALVE AUTO / MAN. in remote control.
- ⇒ Reconnect plugs 6 to pre-control valve (rail valve) 5.

Carry out a visual leakage test.

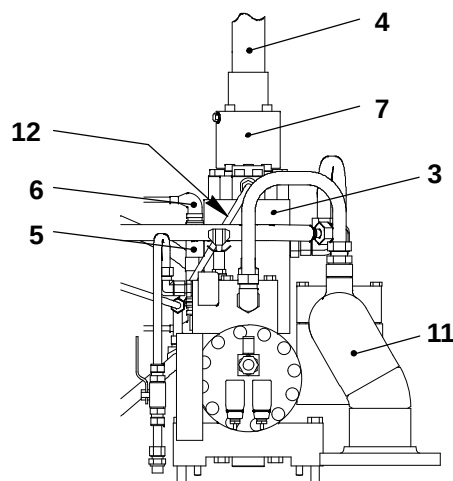
|       |
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## Operation with Exhaust Valve Control Unit Cut Out

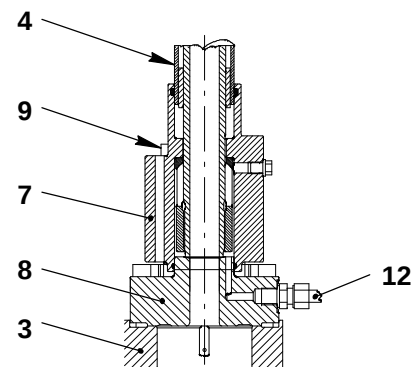
**A**

016.991/08

DRIVING END

**B**

016.928/08



016.926/08

**Key to Illustration:**

|            |                                   |
|------------|-----------------------------------|
| <b>'A'</b> | <b>Servo oil rail</b>             |
| <b>'B'</b> | <b>Exhaust valve control unit</b> |

- |   |                                     |    |                              |
|---|-------------------------------------|----|------------------------------|
| 1 | Servo oil rail 4.11                 | 7  | Flange                       |
| 2 | Drain screw 4.82                    | 8  | Cover                        |
| 3 | Exhaust valve control unit 4.10     | 9  | Screw                        |
| 4 | Actuator pipe 4.66                  | 10 | Rail unit                    |
| 5 | Pre-control valve (rail valve) 4.76 | 11 | Servo oil return piping 4.63 |
| 6 | Plug                                | 12 | Oil leakage pipe             |

---

Operation with Exhaust Valve Control Unit Cut Out

---

**3. Emergency operation with exhaust valve opened**

This mode of operation is only required in case of water leakages into the combustion chamber (see also [0545-1](#)).

**3.1 Putting an exhaust valve out of service**

- ⇒ Stop the engine.
- ⇒ Switch off bearing oil pump.
- ⇒ Loosen and remove damper 1 located on top of upper housing 2 (see Fig. C).
- ⇒ Close venting cock 4.08 in the control air supply **A**. Thereby the air piping to the exhaust valves is vented and the exhaust valve remains open.
- ⇒ Fit thrust pin 4 (tool 94259) with oiled thread (see Fig. 'D').



**Remark:** Take care that shim rings 3 do not get lost. These should remain in place when the thrust pin is fitted.

For safety reasons the thrust pin must also be fitted if an exhaust valve is jammed in the open position.



**Attention!** For safety reasons the plugs must be disconnected from the pre-control valve (rail valve) of the corresponding cylinder.

- ⇒ Put back air spring venting 4.08 to operating position after fitting the thrust pin.
- ⇒ Switch on again bearing oil pump.
- ⇒ Remove control signal plug 5 from the starting valve.



**Remark:** Concerning the reduction in engine load, the same conditions apply as under paragraph [2.2](#).

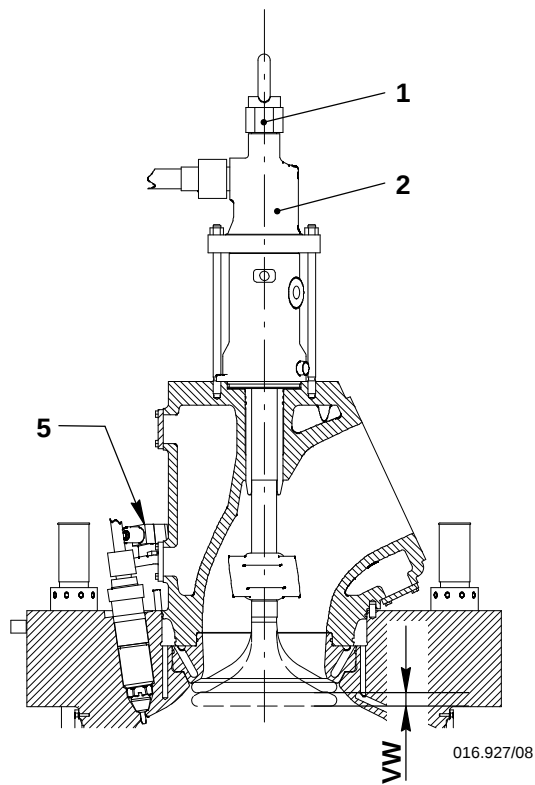
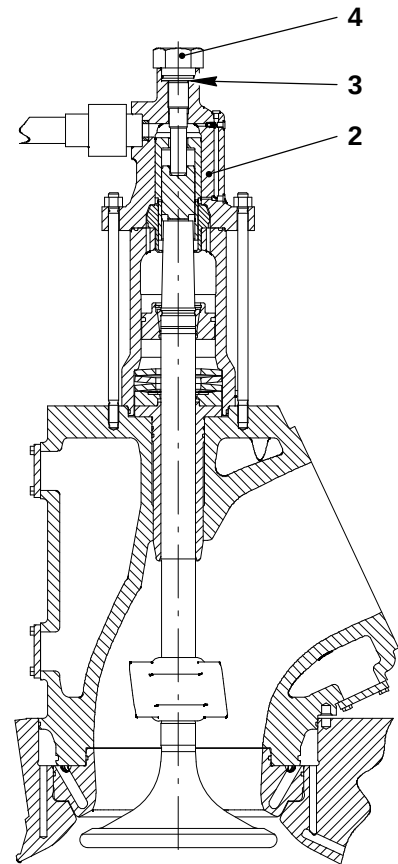
**3.2 Re-starting of exhaust valve control unit**

**Attention!** After termination of the emergency operation with open exhaust valve, the seating faces of the valve seat and head must be checked for perfect condition (no hard dirt deposits). Seating faces with heavy deposits must be overhauled according to [2751-3](#) and [2751-4](#) in the Maintenance Manual.

After the defect has been corrected, the following must be carried out:

- ⇒ Switch off bearing oil pump.
- ⇒ Close venting cock 4.08 in the control air supply **A**. Thereby the air piping to the exhaust valves is vented and the exhaust valve remains open.
- ⇒ Loosen and remove thrust pin 4 (tool 94259). Take care that shim rings 3 do not get lost (see Fig. 'D').
- ⇒ Fit damper 1 with oiled thread (see Fig. 'D').
- ⇒ Cut in the injection (see [0510-1](#)).
- ⇒ Turn venting cock 4.08 back to operating position.
- ⇒ Switch on again bearing oil pump.
- ⇒ Reconnect the plugs to the pre-control valve (rail valve).
- ⇒ Reconnect the control signal plug 5 to the starting valve.

## Operation with Exhaust Valve Control Unit Cut Out

**C****D**

**Key to Illustrations:** 'C' Exhaust valve  
 'D' Thrust pin fitted

- 1 Damper
- 2 Upper housing
- 3 Shim ring
- 4 Thrust pin (tool 94259)

- 5 Control signal plug

VW Maximum exhaust valve stroke

## Operation under Abnormal Conditions

### Faults in Servo Oil System

---

#### 1. Defective automatic filter

##### 1.1 Identification

- Alarm indication in ship alarm system and in control box of automatic filter (XS2053A).
- Differential pressure too high.
- Flushing intervals getting shorter.

##### 1.2 Causes

- Filter elements clogged.
- Failure in the control or power supply.
- Limiting values of the system oil reached or exceeded (see [0750–1](#) 'Attention limits for selected system oil parameters').

##### 1.3 Measures

- ⇒ If the automatic filter is clogged, switch over to bypass, the engine remains in operation.
- ⇒ Clean clogged filter elements manually.
- ⇒ Examine reason of the clogging.
- ⇒ Remedy faults (see documentation of automatic filter supplier).
- ⇒ Check the condition of the system oil (see [0750–1](#) 'Taking oil samples').
- ⇒ If no flushing cycle is released, investigate reason (no control air, rotating motor, position switch or pneumatic flushing valve defective).

#### 2. Defective servo oil pump

##### 2.1 Identification

- Flow sensors FS2061A – FS2063A indicate a pump failure, i.e. an alarm is triggered in alarm and monitoring system ('Servo oil pump n. flow').

##### 2.2 Causes

- Servo oil pump blocked, shaft at shorable overload protection broken (see Servo Pump Unit [5591–1](#)).
- Failure of the actuators CV7221C – CV7223C.
- Failure of control current (cable coupling defective).

##### 2.3 Measures

In case of a single pump failure, engine operation can be maintained over the entire load range.

- ⇒ Replace defective servo oil pump at the first opportunity (see 8016–1 'Filling and draining of servo oil system' and Servo Pump Unit 5591–1 in the Maintenance Manual).



**Attention!** The operating mode with a pump out of order must not be considered as permanent. If another pump fails the engine will no longer be operative!

Faults in Servo Oil System

---

**3. Defective exhaust valve control unit****3.1 Identification**

- Alarm indication in WECS–9520 (remote control 'Exh. valve late/not opening').
- The fuel injection is cut off automatically (Inj. CUT OFF) on the corresponding cylinder, and a SLOW DOWN will be released.
- Alarm indication by level switches LS2076A or LS2077A due to leakages at the HP pipings to the exhaust valves (see [8016–1](#) 'Servo oil leakage system').

**3.2 Causes**

- Pre-control valve (rail valve) defective.
- Piston or slide rod in exhaust valve control unit seized.
- Breakage of a HP piping to the exhaust valve.

***Pre-control valve (rail valve):***

Replace defective pre-control valve at the first opportunity.

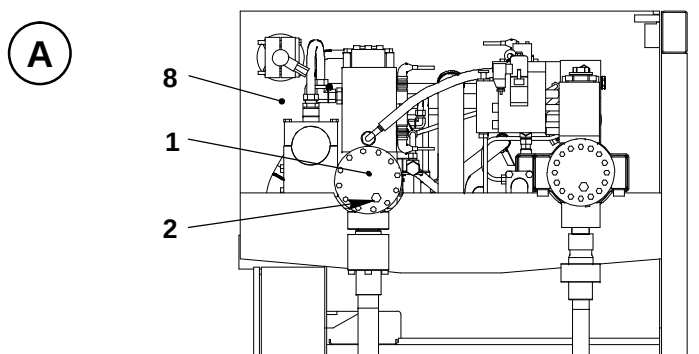
- ⇒ Stop the engine.
- ⇒ Switch off bearing oil pump.
- ⇒ Open drain screw 2 by about two turns for pressure relief in the servo oil rail 1 (see [Fig. 'A'](#)).
- ⇒ Remove cable 7.
- ⇒ Loosen screws 6 and remove them together with pre-control valve 5.
- ⇒ Take care that the three O-rings are put in the new pre-control valve and the surfaces are clean.
- ⇒ Fit the pre-control valve with four screws 6 and tighten the latter with a torque of 2.5 Nm (see [Fig. 'B'](#) and Exhaust Valve Control Unit [5612–1](#) in the Maintenance Manual).

|       |
|-------|
| CHECK |
|-------|

**Important!** Pay attention that the bore positions correspond.

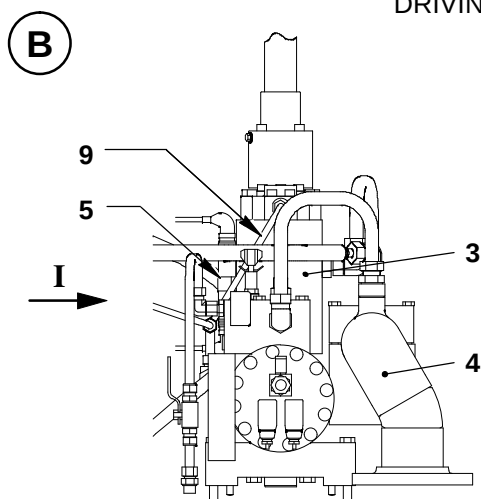
- ⇒ Close drain screw 2 and tighten them with a torque of 200 Nm.
- ⇒ Reconnect cable 7. *Important:* Plug must be tight!

## Faults in Servo Oil System

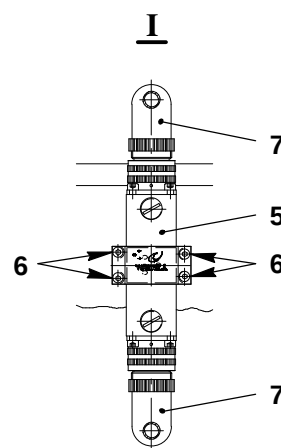


DRIVING END

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**Key to Illustrations:** 'A' Servo oil rail  
'B' Exhaust valve control unit

- |                                       |                    |
|---------------------------------------|--------------------|
| 1 Servo oil rail 4.11                 | 6 Screw            |
| 2 Drain screw 4.82                    | 7 Cable            |
| 3 Exhaust valve control unit 4.10     | 8 Rail unit        |
| 4 Servo oil return piping 4.63        | 9 Oil leakage pipe |
| 5 Pre-control valve (rail valve) 4.76 |                    |

**Defective exhaust valve control unit:**

The exhaust valve control unit should be shut off as an immediate measure in case of:

- Piston or slide rod in exhaust valve control unit seized.

See [0520-1](#) 'Emergency operation with exhaust valve closed'.



**Remark:** With one or more cut out exhaust valve control unit(s), the engine can only be operated at reduced load.

- ⇒ Replace defective exhaust valve control unit at the first opportunity (see [0520-1](#) 'Restarting of exhaust valve control unit' and [5612-1](#) in the Maintenance Manual).

**Hydraulic piping to exhaust valve:**

- ⇒ Cut out the injection of the cylinder concerned at a breakage of a hydraulic piping to the exhaust valve (see [0510-1](#) 'Measures').
- ⇒ Replace defective hydraulic piping at the first opportunity (see [0520-1](#) 'Exchange of a defective hydraulic piping' and [8460-1](#) in Maintenance Manual).

## Operation under Abnormal Conditions

### Operation with Running Gear Partially or Totally Removed

---

#### 1. General

Should the engine have to be put back into operation after a defect in the running gear of a cylinder, which cannot be immediately remedied, then, depending on the type of defect, the following measures must be taken:



**Remark:** The engine can only be operated at reduced load.

Generally the remarks in 0500–1 have to be observed. Furthermore the exhaust gas temperature after cylinders may on no cylinder exceed the **maximum limit of 515 °C**.

#### 2. Piston removed

##### **Breakdown cases:**

- Piston cracked or leaking
- Serious damage to piston and/or cylinder liner
- Damage to piston rod gland and/or piston rod

##### 2.1 Measures

The exhaust valve remains **closed** in the following emergency operation.

- ⇒ Cut out the injection (see 0510–1 'Measures').
- ⇒ Cut out the exhaust valve control unit (see 0520–1 'Emergency operation with exhaust valve closed').
- ⇒ Remove control air pipe 7 from inlet bend 6 (Fig. 'A').
- ⇒ Remove inlet bend 6 from starting air pipe 5 and fit blank flange 8 (tool 94831).
- ⇒ Remove control signal plug 11 from the starting valve.
- ⇒ Fit cover plate 8 (tool 94345d) in place of the piston rod gland.
- ⇒ Mount cover and lifting plate 9 (tool 94324) with base 10 (tool 94324b) onto the crosshead.
- ⇒ If necessary, close cooling water feed and return piping of the relevant cylinder.

#### 3. Piston, crosshead and connecting rod removed

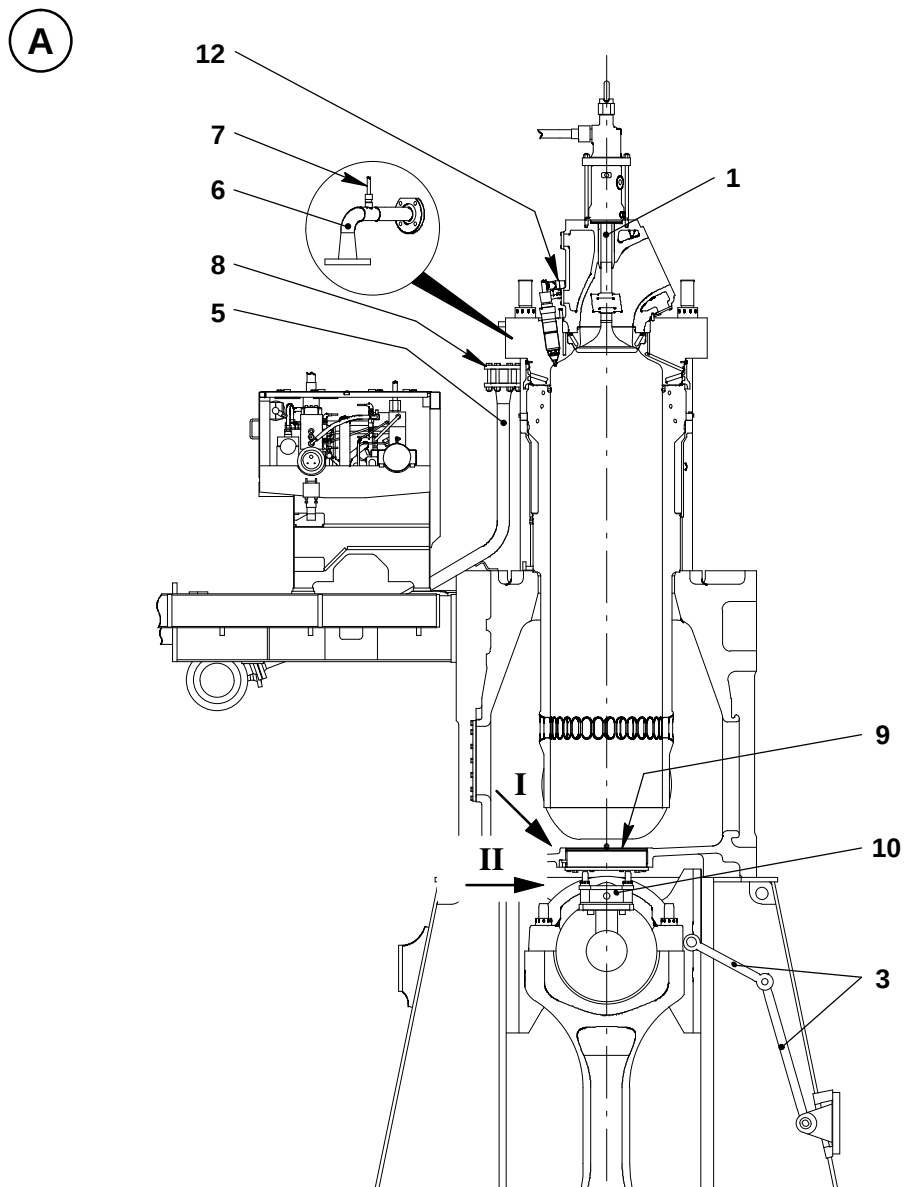
##### **Breakdown cases:**

- Defects to crosshead or guide shoes
- Connecting rod bearing badly damaged
- Defects on crosshead pin or on connecting rod

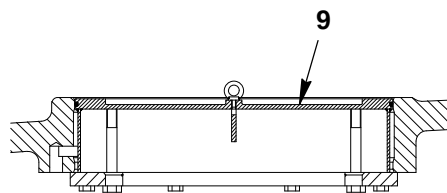
##### 3.1 Measures

- ⇒ With the exception of mounting cover and lifting plate 9 (tool 94324) with base 10 (tool 94324b) onto the crosshead pin, all measures under section 2.1 must be carried out (see Fig. 'B').
- ⇒ Furthermore blank off the oil supply for piston cooling at 'OS' and for the crosshead lubrication outside the engine.
- ⇒ Remove the toggle lever 3.

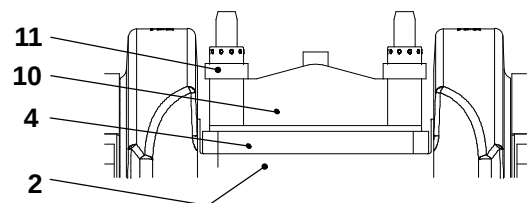
# Operation with Running Gear Partially or Totally Removed



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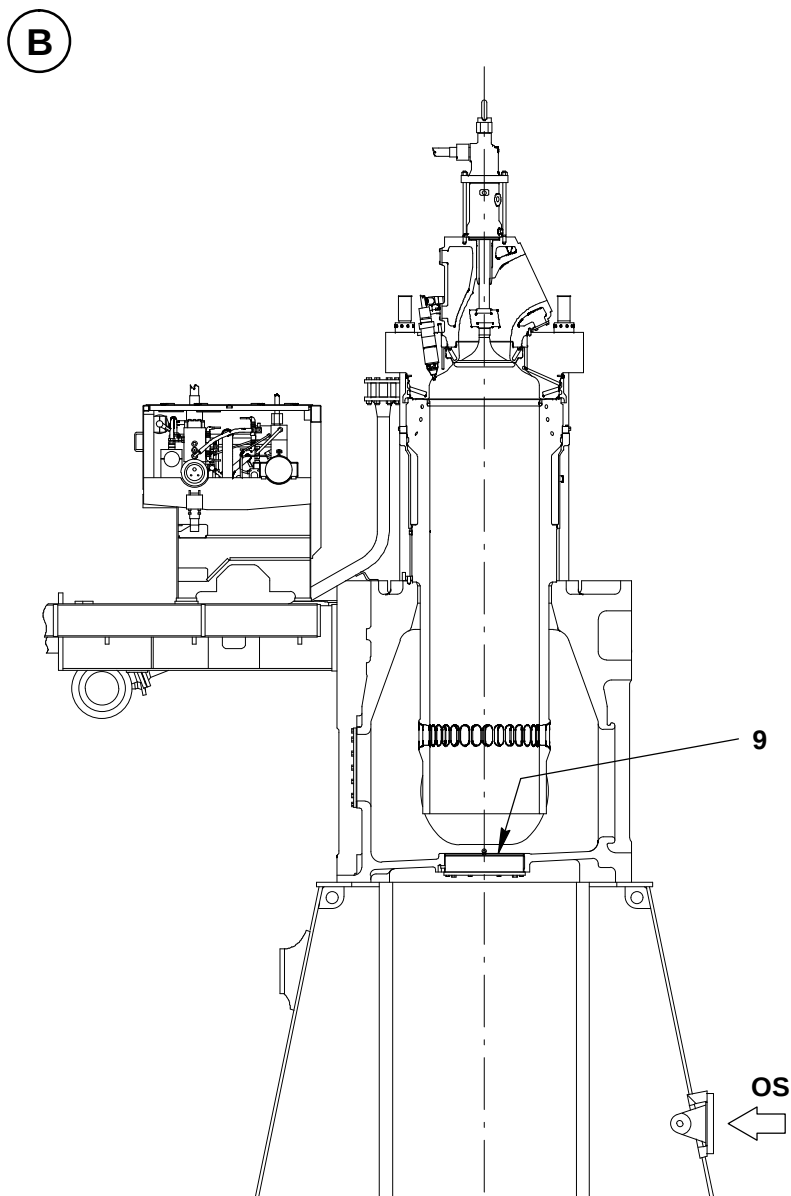
I

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II

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## Operation with Running Gear Partially or Totally Removed



016.925/08

**Key to Illustrations:** 'A' Piston removed  
'B' Piston, crosshead and connecting rod removed

- 1 Exhaust valve
- 2 Crosshead
- 3 Toggle lever
- 4 Compression shim
- 5 Starting pipe
- 6 Inlet bend
- 7 Control air pipe

- 8 Blank flange (tool 94831)
- 9 Cover plate (tool 94345d)
- 10 Cover and lifting plate (tool 94324)
- 11 Base (tool 94324b)
- 12 Control signal plug

OS Oil supply



## Operation under Abnormal Conditions

### Operation with Water Leakage into the Combustion Chamber

---

#### 1. General

As a rule in the event of a water leakage into the combustion chamber (crack in the cylinder cover or liner) the part in question must be changed **immediately**.

#### 2. Measures

Should this not be possible but the engine has to be put back in service as soon as possible, the following measures have to be taken at the cylinder concerned:

- ⇒ Close the valves to the cooling water inlet and outlet from the affected cylinder (disconnect from the cooling system) and drain the cooling water via the drain piping.
- ⇒ Operation with injection cut out (see 0510-1).
- ⇒ Operation with exhaust valve control unit cut out (see 0520-1 'Emergency operation with exhaust valve opened').



**Remark:** If the cooling of the cylinder concerned is shut, there is a risk of overheating the combustion chamber by compression heat. Therefore the exhaust valve must be opened to prevent damage to further components.

After taking the above measures the engine can no longer be operated at full load. Generally the remarks on 0500-1 have to be observed. Furthermore the exhaust gas temperature after cylinder may **not exceed the maximum limit of 515 °C on any cylinder**.

This emergency operation may not be regarded as continuous. The defective cylinder cover or cylinder liner must be replaced as soon as possible.

After termination of this emergency operation, the measures for re-starting must be observed (see 0520-1).

## Operation under Abnormal Conditions

### Scavenge Air Cooler Out of Service / Failure of Auxiliary Blowers

---

#### 1. Scavenge air cooler out of service

When a scavenge air cooler is defective, water can enter the scavenge air receiver and escape through the condensate collector of the cooler drain. An alarm is triggered by the corresponding level switch.



**Remark:** Should the escape of water be observed in the condensate collector of the cooler **at engine standstill** and running water pumps, a check for a cooler defect must be made as soon as possible.

Where this is the case, we recommend that the following measures be taken:

- Where operation permits, replace the defective cooler with the spare one as soon as possible.
  - Shutting down and draining the defective cooler (only possible with dual-arrangement of coolers and turbochargers).
- ⇒ The individual cooling water supply and return pipes of the defective cooler have to be closed off and the vent and drain cocks opened and left open.
- Leakage water entering the receiver flows away through the condensate drain pipes of the scavenge air cooler and water separator into the collecting pipe.
  - When running in this mode, the scavenge air temperature will rise and thus the exhaust gas temperature as well.
  - Therefore, the engine may only be loaded such that the normal scavenge air temperature (measured after the scavenge air cooler) at service output is not exceeded. The scavenge air temperature has to be continuously and carefully monitored.
  - Should the scavenge air temperature rise too high, the engine speed must be correspondingly reduced (maximum permissible scavenge air temperature after cooler, see Alarms and Safeguards [0250-2](#)).



**Remark:** In these cases the engine can be operated only at about 25% load. In case of emergency individual, defective cooler pipes may be blanked off (see Maintenance Manual [6606-1](#) 'Locating and sealing of leaking cooler tubes in service').

#### 2. Failure of auxiliary blowers

Should **one** of the auxiliary blowers fail the engine can be started and operated. At partial load more smoky exhaust must be expected.

When **both** auxiliary blowers fail the engine cannot be started.

## Operation under Abnormal Conditions

### Defective Remote Control

---

#### 1. General

Should a fault have occurred in the remote control, rendering engine control from the control room impossible, then the engine can be run at the local control panel.

Detailed descriptions are given in the groups:

- Starting [0230–1](#)
- Manoeuvring [0260–1](#)
- Shutting Down [0310–1](#)
- Measures to be Taken after Stopping [0320–1](#)
- [4003–1](#) 'Engine local control'
- Local Control Panel [4618–1](#)



**Attention!** This form of engine operation should only be used when absolutely necessary. The engineer may not leave the manoeuvring stand. The engine speed must be observed frequently so that immediate action can be taken if large deviations in speed occur.

## Operation under Abnormal Conditions

### Defect in Speed Control System

---

#### 1. General

As a rule, a defect in the speed control system should be remedied as soon as possible (see documentation of the manufacturer). Should this not be possible, the engine can be controlled at the local control panel.

In case the 'fuel command' signal from the speed control system to WECS–9520 is lost with running engine, the latter will keep in operation, however with the last known fuel command and an alarm will sound.

Detailed descriptions are given in the groups:

- Starting [0230–1](#)
- Manoeuvring [0260–1](#)
- Shutting Down [0310–1](#)
- Measures to be Taken after Stopping [0320–1](#)
- [4003–1](#) 'Engine local control'
- Local Control Panel [4618–1](#)



**Attention!** This form of engine operation should only be used when absolutely necessary. The engineer may not leave the manoeuvring stand. The engine speed must be observed frequently so that immediate action can be taken if large deviations in speed occur.

## Operation under Abnormal Conditions

### Turbocharger Out of Service

#### 1. General

Upon failure of a turbocharger the engine must be shut down as quickly as possible to avoid worse damage.

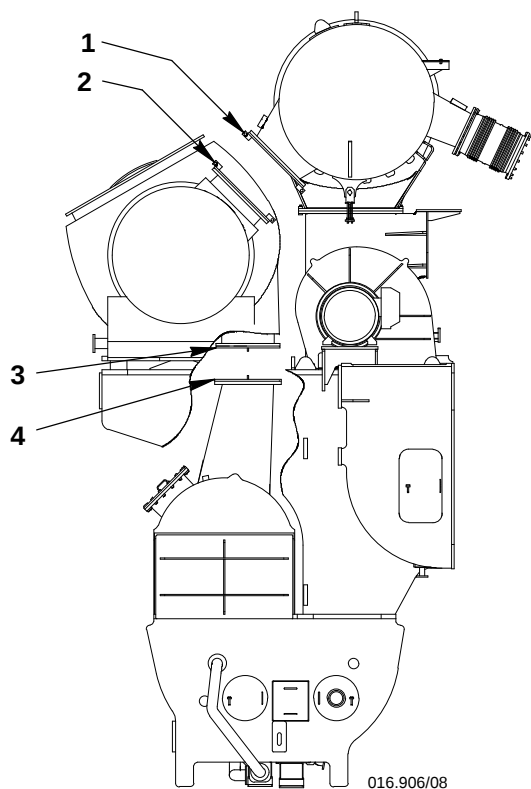
Should repair or replacement of a turbocharger not be immediately possible, then the engine can be run in 'Emergency Operation' at reduced load and after the measures below have been taken.

In the mentioned 'Emergency Operation' the engine should basically run only as long as absolutely necessary. (For further instructions see 0500-1 'Reduced power output').

The loads (outputs) given are guidance values. Depending on the condition of the engine they may have to be further reduced.

#### 2. Breakdown case 1

(Part failure of turbocharger on engines equipped with several turbochargers)



#### Operable output relative to CMCR:

| Number of turbochargers |             | Operable output in % |
|-------------------------|-------------|----------------------|
| fitted on engine        | broken down | P                    |
| 2                       | 1           | approx. 50           |
| 3                       | 1           | approx. 66           |
| 3                       | 2           | approx. 33           |

#### Measures:

- ⇒ Remove expansion joint between the defective turbocharger and exhaust manifold and fit blind flanges 1 and 2 (tools 94653).
- ⇒ Remove expansion joint between the defective turbocharger air outlet and diffuser, and fit blind flanges 3 (tool 94655) and 4 (tool 94653). (Fit blind flange 3 only if the air is drawn in through a suction duct).
- ⇒ Check oil supply (pressure) of the other turbochargers. If the pressure has dropped, the supply must be plugged to the defective turbocharger (when restarting turbocharger be sure to reopen lubricating oil supply).
- ⇒ Block the rotor of the defective turbocharger as described in the turbocharger manual.

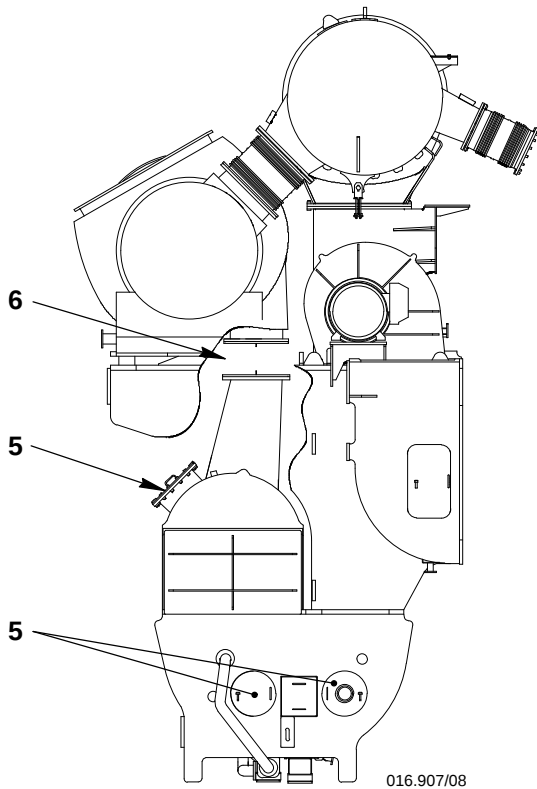


**Remark:** Scavenge air pressure, turbocharger speed and firing pressures must never exceed the values of normal operation.

## Turbocharger Out of Service

**3. Breakdown case 2**

(Failure of all turbochargers on engines without exhaust bypass piping)

**Operable output relative to CMCR:**

Approx. 10 to 15%, depending on the output of the auxiliary blowers.

**Measures:**

- ⇒ Block the rotors of the defective turbochargers as described in the turbocharger manual.
- ⇒ In case of lube oil loss the supply must be plugged (when restarting turbochargers be sure to reopen lubricating oil supply).
- ⇒ Open all covers 5 on the receiver.
  - Expansion joints 6 can be removed additionally on the air outlet.
  - Auxiliary blowers must run during operation.



**Remark:** Exhaust gas temperature before turbocharger must not be higher than at normal operation. Black thick smoky exhaust must be avoided.

## Special Measures before and after Operation

### Preparations before Starting after a Prolonged Shut-down Period or an Overhaul

---

#### 1. General

After the engine has been shut down for a few days, the same preparations have to be made as required before starting (see Preparation before Taking into Service [0110–1](#)).

#### 2. Special Measures

- A function check of the engine control has to be carried out according to Control System Checking [4003–1](#).
- If bearings or parts of the running gear have been replaced or removed for checking, then the lubricating oil supply must be checked at normal oil pressure (see Operating Data Sheet [0250–1](#)). Check visually through open running gear doors whether sufficient oil flows out of every bearing point.
- In the course of the following operating period it is recommended to watch these parts for abnormal heating. For this check stop the engine after its start, at first in short intervals, later in longer intervals, and compare the temperature of the respective parts with the one of those parts which had not been freshly fitted (see [0210–1](#) 'Temperature sensing').
- With regard to running-in new pistons, piston rings and cylinder liners, see [0410–1](#).
- After draining servo oil rail 7 (4.11), check whether drain screw 31 (4.82) is tightened with a torque of 200 Nm in servo oil rail 7 (4.11) at driving end (see [8016–1](#) 'Filling and draining of servo oil rail').
- Check to ensure that there is free passage for the scavenge air and exhaust gas.
- If the cooling water for the scavenge air cooler has been drained, refill and vent the system.
- Close drains in the exhaust gas manifold and on the exhaust gas pipe if these have been opened.
- Analyze the lubricating oil quality (see Lubricating Oils [0750–1](#)) after a prolonged shut-down period (several months).

## Special Measures before and after Operation

### Measures to be taken before Putting Out of Service for Extended Period

#### 1. Precautions

In the event of the engine being put out of service for an extended period (several weeks), the following precautions have to be taken:



**Remark:** It is recommended to run the engine on diesel oil instead of heavy fuel oil for some time before shutting it down. This should be done particularly when it is intended to work on parts of the fuel system during the shut-down period (see Changing Over from Diesel Oil to Heavy Fuel Oil and Vice Versa [0270-1](#)).

- ⇒ Close stop valves on the starting air receivers.
- ⇒ Bring handwheel 2.10 on shut-off valve for starting air 2.03 to position CLOSED (closed by hand) and open venting valves 2.21 and 2.27.
- ⇒ Engage turning gear.
- ⇒ Check on the pressure gauges whether no pressure is indicated.
- The water and oil pumps should be kept running for **at least 20 minutes** after the engine has been stopped so that the cooled engine parts are brought to as even a temperature as possible. However, the engine **must not be cooled down too much**.
- ⇒ Close off the air supplies to control air supply unit **A** on the engine and to automatic filter 4.20 in the plant.



**Remark:** Before venting the air spring system, the lubricating oil pump must always be switched off.

- ⇒ Open the indicator valves on the cylinder covers.
- Post-lubrication starts automatically during slow-down of the engine (speed below 8%).
- ⇒ Close the stop valves on the fuel tanks.
- ⇒ Open the drains of the exhaust gas manifold and on the exhaust gas pipe.
- For the scavenge air coolers, **the measures recommended by the cooler manufacturers** should be followed. When such is not available, we recommend that the coolers be completely drained or the cooling water pump run daily for about 30 minutes with the flow quantity regulating valves in the same position as for normal running conditions.
- Keep cylinder cooling water approximately at room temperature (watch for frost risks).
- Cover the silencer of the turbocharger airtight with a plastic sheet in order to prevent air circulation through the engine (risk of condensed water formation).
- With the indicator valves open and switched cylinder lubrication on, turn the engine by a minimum of two full turns with the turning gear, at intervals which should not be too long (weekly in dry and daily in damp climates). At the same time start up the oil pump and the servo oil service pump.
- ⇒ Remedy all the damage and leaks discovered during the previous running period and the checks made after shut down.
- ⇒ Carry out any scheduled overhauls, observing the general guidelines for maintenance (see Maintenance Manual [0011-1](#) and [0012-1](#)).
- Switch off the control box for the automatic filter.
- Where the auxiliary engines and boilers are also put out of operation and there is risk of frost, all cooling systems have to be drained off completely (in such cases the empty cooling spaces have to be protected against corrosion).



**Remark:** If the engine is to be stopped for a long period of time, it must be thoroughly cleaned and preserved at the inside and the outside (ask for preserving instructions from the manufacturer).

## Operating Media

### Diesel Engine Fuels

---

#### Overview

|    |                                                       |     |
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| 1. | General .....                                         | 1/6 |
| 2. | Characteristic values of marine fuel oils .....       | 2/6 |
| 3. | Heavy fuel oil .....                                  | 3/6 |
| 4. | Notes to fuel oil requirements (heavy fuel oil) ..... | 4/6 |

#### 1. General

Almost all mineral fuel oils may be burned in a diesel engine provided suitable measures are taken. Nevertheless, the quality of the fuel will have a bearing on the frequency of overhauls and the necessary effort required for the preparation of the fuel. Consequently it is primarily economic considerations which – according to the type, size and speed of the engine, as well as its application – determine the fuel quality margins.

Gas oils and diesel oils (distillates) can be used in all our engines. Whether a specific engine type is suited to run on heavy fuel and up to what grade, can be found in the 'Quality specification for heavy fuel oils'. In case of fuels with very low sulphur content care must be taken, particularly when running-in new piston rings and cylinder liners.

Heavy fuel oil must be treated in an appropriate fuel treatment plant.

The attached table under section 2 summarizes the characteristic values of marine fuel oil available on the market.

When bunkering, the fuel suppliers may report only a few of the values listed in 'Quality requirements', frequently merely the density and maximum viscosity. This also handicaps the assessment of a fuel oil.

The supplier should guarantee the stability of the fuel, i.e. resistance to the formation of sludge. Furthermore, the fuel must not have any corrosive effect on the injection equipment.

Mixing of fuel oils from different supplies should be avoided as far as practicable, since there is a risk of incompatibility difficulties if fuels having different compositions are mixed (for instance this may cause fouling of filters).

The following table under section 2 may be used as a guide for first classification of fuels according to certain characteristic values.

## Diesel Engine Fuels

**2. Characteristic values of marine fuel oils**

(This summary does not represent a quality specification)

| Properties                                                                                 | Marine Gas Oil                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Marine Diesel Oil | Intermediate Fuel | Bunker Fuel Oil |
|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------|-----------------|
| <b>Density</b><br>at 15 °C [kg/m <sup>3</sup> ]                                            | 820 to 870                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 850 to 920        | 900 to 991        | up to 1010      |
| <b>Viscosity</b><br>at 40 °C mm <sup>2</sup> /s [cSt]<br>at 50 °C mm <sup>2</sup> /s [cSt] | 1.5 to 7<br>–                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 to 14<br>–      | –<br>30 to 420    | –<br>up to 700  |
|                                                                                            | High viscosity fuels must be heated to reduce the viscosity to the recommended value at engine inlet.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                   |                 |
| <b>Pour point</b> [°C]                                                                     | –6 to +6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | –6 to +6          | 0 to 20           | up to 30        |
|                                                                                            | The fuel can no longer be pumped in the vicinity of the pour point and heating devices are necessary for tanks and pipes at corresponding ambient temperatures.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                   |                 |
| <b>Sulphur</b> [%]                                                                         | 0.2 to 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0.2 to 2          | 1 to 5            | 1 to 5          |
|                                                                                            | <p>During combustion the sulphur of the fuel burns to form sulphur oxides which in turn form sulphuric acids. These acids are very corrosive to the cylinder liner walls and the piston rings primarily if temperatures of these components are below the dew point. The corrosive attack can be combated by using a cylinder oil with sufficient alkalinity, expressed by its BN (Base Number).</p> <p>Regarding the selection of the BN in relation to the sulphur content of the fuel, reference is made to instructions 0750–1 'Cylinder lubricating oil'.</p> <p>Experience shows that also an excessive BN can have detrimental effects such as forming hard deposits in the combustion chamber of the engine.</p> |                   |                   |                 |
| <b>Carbon residue</b> [%]<br>MCR                                                           | up to 0.20                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | up to 2.5         | up to 18          | up to 20        |
|                                                                                            | A high conradson figure shows that the fuel tends to form deposits during combustion, and thus favours the fouling of nozzles, piston ring grooves, gas outlet ducts and scavenge ports.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                   |                 |
| <b>Ash content</b> [%]                                                                     | up to 0.01                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | up to 0.02        | up to 0.15        | up to 0.20      |
|                                                                                            | Ash grinds piston rings, cylinders and valves, and can also promote fouling and burn-off especially with a high vanadium and sodium content. The sodium content should be less than 1/3 of the vanadium content.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                   |                   |                 |
| <b>Water content</b> [%]                                                                   | 0 to 0.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0 to 0.25         | 0.1 to 1          | 0.1 to 1        |
| <b>Ignition quality</b><br>Cetane number/index<br>CCAI                                     | ~40<br>–                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 40 to 20<br>–     | –<br>870          | –<br>870        |
|                                                                                            | see sections 3 and 4.9.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                   |                   |                 |
| <b>Flash point</b> [°C]                                                                    | minimum 60                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                   |                   |                 |
| <b>Remark:</b>                                                                             | <p>This summary gives only a very general survey of available fuel oils but does not indicate their suitability.</p> <p>Regarding the respective permissible limiting value, see quality requirements under sections 3 and 4. It is not necessarily complete, other properties may also influence the engine performance.</p> <p>Marine Diesel Oil can be pure distillates or may be blended. Some properties of blended oil may exceed the fuel quality requirements for specific engine types.</p>                                                                                                                                                                                                                     |                   |                   |                 |

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Diesel Engine Fuels

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**3. Heavy fuel oil**

Diesel engine fuels include a variety of petroleum products ranging from gas oil to heavy fuel oil. Gas oil is produced from crude oil by distillation and processing whereas heavy fuel oil is mainly the residue left after distillation of the crude oil. To obtain the desired viscosity the residue is blended down with lighter, less viscous components. Modern refineries also apply so-called secondary conversion processes such as visbreaking and catalytic cracking to obtain a higher proportion of lighter products. These products are used as blending stocks for heavy fuel oil.

Marine fuels are usually differentiated by viscosity. The viscosity is indicated in centistokes (cSt) at 50 °C. The fuels are classified according to ISO 8217:2005, ISO–RMK700.

It has to be noted that viscosity itself is not a quality criterion. To evaluate the quality and suitability of a fuel for use in a diesel engine, a number of characteristics such as those listed in the fuel oil requirements table have also to be considered.

For assessing the ignition properties of a distillate diesel fuel the CETANE number (by standardized engine test) or the CETANE index (by calculation) have been used. The CCAI (Calculated Carbon Aromaticity Index) is recommended for marine fuels. The inflammability is of particular importance for medium and high-speed engines. Experience has shown that for slow-speed diesel engines the ignition properties are of minor importance.

The use of fuel oils with properties approaching the maximum limits requires very good supervision and maintenance of the engine and, in particular, of the fuel treatment equipment. With fuels of poor quality and inadequate fuel preparation, premature overhauling and added maintenance costs have to be faced.

The values in the column 'Bunker limit' (RMK700) indicate the minimum quality of heavy fuel as bunkered, i.e. as supplied to the ship/installation. Good operating results have been achieved with commercially available fuels within these limits.

The column 'Recommended fuel quality' is an example of a good quality fuel of the type commonly used in diesel engines. This variety of fuel can be expected to have a positive influence on overhaul periods, by improving combustion, wear and exhaust gas composition.

The fuel oil as bunkered must be processed before it enters the engine. For the design of the fuel treatment plant, it is recommended to follow the relevant recommendations of Wärtsilä Switzerland Ltd. The difference between the recommended fuel quality of bunker and at engine inlet is an approximate indication of the improvement that must be achieved by fuel oil treatment. If catalyst fines are present they must be removed. The fuel oil should contain no foreign substances or chemical waste (ISO 8217:2005, see paragraph 5.1), hazardous to the safety of the ship or detrimental to the performance of machinery.

## Diesel Engine Fuels

| Fuel oil requirements and quality limits      |                          |                             |                            |                          |              |
|-----------------------------------------------|--------------------------|-----------------------------|----------------------------|--------------------------|--------------|
| Parameter                                     | Unit                     | Bunker limit <sup>*3)</sup> | Test method <sup>*2)</sup> | Recommended fuel quality |              |
|                                               |                          |                             |                            | Bunker                   | Engine inlet |
| Density at 15 °C                              | kg/m <sup>3</sup>        | max. 1010 <sup>*1)</sup>    | ISO 3675/12185             | max. 1010                | max. 1010    |
| Kinematic viscosity <sup>1)</sup><br>at 50 °C | mm <sup>2</sup> /s [cSt] | –                           | ISO 3104                   | –                        | 13–17        |
|                                               | mm <sup>2</sup> /s [cSt] | max. 700                    | ISO 3104                   | max. 700                 | –            |
| Carbon residue <sup>2)</sup>                  | m/m [%]                  | max. 22                     | ISO 10370                  | max. 15                  | max. 15      |
| Sulphur <sup>3)</sup>                         | m/m [%]                  | max. 4.5                    | ISO 8754/14596             | max. 3.5                 | max. 3.5     |
| Ash <sup>4)</sup>                             | m/m [%]                  | max. 0,15                   | ISO 6245                   | max. 0.05                | max. 0.05    |
| Vanadium <sup>4)</sup>                        | mg/kg [ppm]              | max. 600                    | ISO 14597/<br>IP501/470    | max. 100                 | max. 100     |
| Sodium <sup>4)</sup>                          | mg/kg [ppm]              |                             | AAS                        | max. 50                  | max. 30      |
| Aluminium + Silicon <sup>5)</sup>             | mg/kg [ppm]              | max. 80                     | ISO 10478/<br>IP501/470    | max. 30                  | max. 15      |
| Total sediment, pot. <sup>2)</sup>            | m/m [%]                  | max. 0.10                   | ISO 10307–2                | max. 0.1                 | max. 0.1     |
| Water <sup>6)</sup>                           | v/v [%]                  | max. 0.5                    | ISO 3733                   | max. 0.5                 | max. 0.3     |
| Flash point <sup>7)</sup>                     | °C                       | min. 60                     | ISO 2719                   | min. 60                  | min. 60      |
| Pour point <sup>8)</sup>                      | °C                       | max. 30                     | ISO 3016                   | max. 30                  | max. 30      |

Notes <sup>1)</sup> to <sup>8)</sup> to Quality requirements see under section 4.

1cSt (centistokes) = 1mm<sup>2</sup>/s

<sup>\*1)</sup> Limited to max. 991kg/m<sup>3</sup> (ISO–F–RMH55) if the fuel treatment plant cannot remove water from high-density fuel oil.

<sup>\*2)</sup> ISO standards can be obtained from the ISO Central Secretariat, Geneva, Switzerland ([www.iso.ch](http://www.iso.ch)).

<sup>\*3)</sup> ISO 8217:2005, RMK700.

#### 4. Notes to Fuel oil requirements (heavy fuel oil)

##### 4.1 Viscosity

The maximum admissible viscosity of the fuel that can be used in an installation depends on the heating and fuel preparation facilities available. As a guidance, the necessary preheating temperature for a given nominal viscosity can be taken from the viscosity-temperature diagram (0270–2). The recommended viscosity range before engine is 13–17 cSt [mm<sup>2</sup>/s].

##### 4.2 Carbon residue, asphaltenes, sediment

High levels of carbon residue and asphaltenes impair the combustion quality of the fuel and promote increased wear and fouling of engine components. Asphaltenes also have a bearing on the stability of blended fuels and can cause problems of excessive sludge formation in centrifugal separators, filters and on the tank bottom. To minimize compatibility risks, care should be taken to avoid mixing bunkers from different suppliers and sources in the storage tanks on board. Care must also be taken when heavy fuel oil is blended onboard to reduce the viscosity. Paraffinic distillate, when added to a heavy fuel oil of low stability reserve, can cause the asphaltenes to settle out, resulting in heavy sludge formation. A standard heavy fuel oil contains up to 14% asphaltenes and a good quality fuel up to 8% asphaltenes.

## Diesel Engine Fuels

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### 4.3 Sulphur

The alkalinity (BN) of the cylinder lubricating oil should be selected with regard to the sulphur level of the fuel in use.

Indications for the selection of the BN of lubricating oil in relation to the sulphur content of the fuel oil are found in group [0750–1](#).

### 4.4 Ash and trace metals

Fuels oils with low contents of ash, vanadium and sodium are preferable. These components are detrimental since they tend to promote mechanical wear, high-temperature corrosion and the formation of deposits in the turbocharger and on the exhaust valve.

Since sodium compounds (oxides, sulphates) depress the melting point of the vanadium, which is very corrosive in the liquid phase, the sodium content should be as low as possible. With certain ratios of the vanadium to sodium content, the compounds form a eutectic with a minimum melting point which must be avoided. High sodium levels at engine inlet can cause fouling of turbocharger components.

The effect of high-temperature corrosion and the formation of deposits can be counteracted by application of suitable fuel treatments, known as so-called ash modifiers.

### 4.5 Aluminium, silicon

Aluminium and silicon found in appreciable concentrations in the fuel oil are regarded as an indication of the presence of so-called catalytic fines (cat fines). These are particles of hard oxides which cause high abrasive wear to piston rings and cylinder liners. This material is used as a catalyst in certain processes in petroleum refining and can find its way into marine fuels. The most dangerous cat fines are of the size 10 to 20 microns. They tend to be attracted to water droplets and are very difficult to remove from the fuel oil. Practical experience has shown that with proper treatment in the fuel separator a sum of aluminium and silicon of 80 ppm (mg/kg) can be reduced to less than 15 ppm (mg/kg) which may be considered as just tolerable. Proper treatment means reduced throughput in the separator and a fuel temperature of as close as possible to 98 °C.

### 4.6 Water

The water content of the fuel oil must be further reduced by careful purification. This is accomplished most effectively by centrifuging and by use of proper draining arrangements on the settling and service tanks. A thorough removal of water is strongly recommended, to reduce the content of cat fines and sodium in the fuel oil. Cat fines potentially reside in the water droplets and marine fuel oil is often contaminated with sea water containing sodium, 1.0% sea water in the fuel oil corresponds to 100 ppm sodium.

To achieve a good separating effect, the throughput and the temperature of the fuel must be adjusted in relation to the viscosity. With high-viscosity fuels, the separating temperature must be increased whereas the throughput must be decreased in relation to the nominal capacity of the separator. For recommended operating data, refer also to the separator instruction manual.

## Diesel Engine Fuels

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### 4.7 Flash point

This is a legal requirement with regard to the fire hazards of petroleum based fuels.

### 4.8 Pour point

The lowest operating temperature of the fuel should be kept about 5–10 °C above the pour point to secure easy pumping.

### 4.9 Ignition quality (CCAI)

The CCAI = Calculated Carbon Aromaticity Index (ISO 8217:2005) is a function of viscosity and density, and is an indication of the ignition quality for medium and high speed diesel engines. In low speed engines ignition delay as given by the CCAI is of minor importance. There is no rigidly applicable limit for this quantity, but good results have been obtained with commercially available fuels which have CCAI values up to 870.

**Operating Media**Fuel Treatment, Fuel Oil System

---

**1. General**

Heavy fuel oils, as they are supplied today for burning in diesel engines, require a careful treatment which makes the installation of a suitable plant necessary. According to present techniques the most effective cleaning of liquid fuels from solids and water is achieved by centrifugal separators.

**2. Treatment of heavy fuel oils and treatment plant**

Heavy fuel oils are contaminated mostly with solids and water. Should uncleaned or insufficiently treated heavy fuel oil enter the engine, it can cause unacceptably rapid wear on engine components like piston rings, cylinder liners, injection pumps, valves etc. Furthermore excessive sediment can be formed in the combustion spaces.

Particularly sodium in the fuel oil (which originates from sea water) leads to formation of deposits on pistons and in the turbocharger. For this reason, water must be separated carefully out of the fuel oil.

Settling tanks are used for the first steps of treatment. However, they only effect a coarse separation, particularly of free water from the heavy fuel oil. To keep them effective settling tanks must have the sludge and water, accumulating in the tank bottom, periodically drained off.

The main cleaning is effected by optimally dimensioned and correctly adjusted and operated centrifuges. Modern designs render superfluous the previously necessary adaptation of the gravity discs to varying densities of heavy fuel oils in use. Modern machines automatically expel the sludge from the centrifuge. For modern power plants, designed for burning heavy fuel oils of the lowest grade, such centrifuges are an absolute necessity. This applies in particular when heavy fuel oils with densities of 991 kg/m<sup>3</sup> and higher and with viscosities of 700 cSt/50 °C must be used.

Homogenizers can improve combustion properties to some extent. They will, however, be of no help in the removal of solids from the fuel oil. They are therefore to be regarded solely as auxiliaries in the treatment plant.

Filters hold back solids of a specified size and shape. They can, however, practically not hold back water. Water will partly even cause accelerated fouling of filters.

### 3. Heavy fuel oil and diesel fuel oil separation (see Fig. 'A')

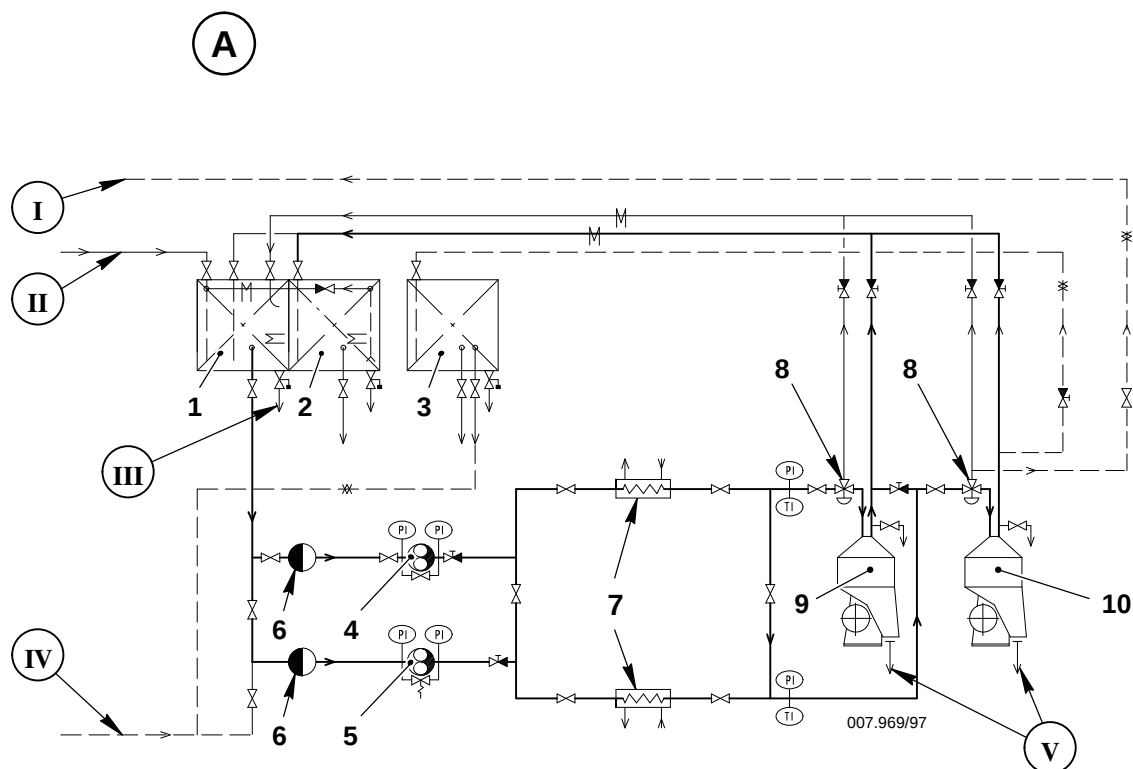
As a result of experience we strongly recommend the use of modern centrifuges for the treatment of heavy fuel oils.

The separating effect, i.e. the cleaning effect depends on the throughput and on the viscosity of the heavy fuel oil. As a general rule, the smaller the throughput ( $\text{m}^3/\text{h}$  or  $\text{ltr}/\text{h}$ ) and the lower the viscosity of the heavy fuel oil, the better the separating efficiency. A too high throughput and/or too low separation temperature would considerably reduce the separator efficiency. If the heavy fuel oil separators are not operating at peak efficiency, impurities (e.g. cat fines) in the bunkers might not be sufficiently removed and this can cause extensive damage (high piston ring, cylinder liner and fuel injection equipment wear) to the main engine.

This necessitates heating the heavy fuel oil before it enters the centrifuge and maintaining the working temperature at a constant level within a tolerance of  $\pm 2^\circ\text{C}$ . The separation temperature is to be as close as possible to  $98^\circ\text{C}$ .

**It is important when processing heavy fuel oils that strict adherence is made to the separator maker's instructions!**

The sludge removed by centrifuging must be removed periodically from the separator drum. In the case of self cleaning centrifuges the sequence of the emptying process may be controlled automatically but even in such a plant the correct function and the frequency of proceedings must be kept under control by the operating personnel. Of utmost importance is the unimpeded drain of the sludge from the drum, so that unacceptably high back pressure does not impair the function of separation and thereby of cleaning the heavy fuel oil. This point must absolutely be assured in operation by periodical inspections.



**4. Layout of fuel oil system (see [Fig. 'B'](#))**

In the recommended standard plant the complete fuel system is kept under pressure to prevent the evaporation of any water in the fuel at the temperature required for the heavy fuel oil.

At the corresponding position of the 3-way valve 21, heavy fuel is drawn from the daily tank 2 by the low pressure feed pump 23 which supplies it to the mixing unit 24. The booster pump 25 takes the fuel from there and delivers it to the fuel pumps 28 via end-heater 26 and filter 27. The rated capacity of the booster pump 25 is several times higher than that of the engine fuel consumption rate. The fuel not consumed by the engine flows back to mixing unit 24.

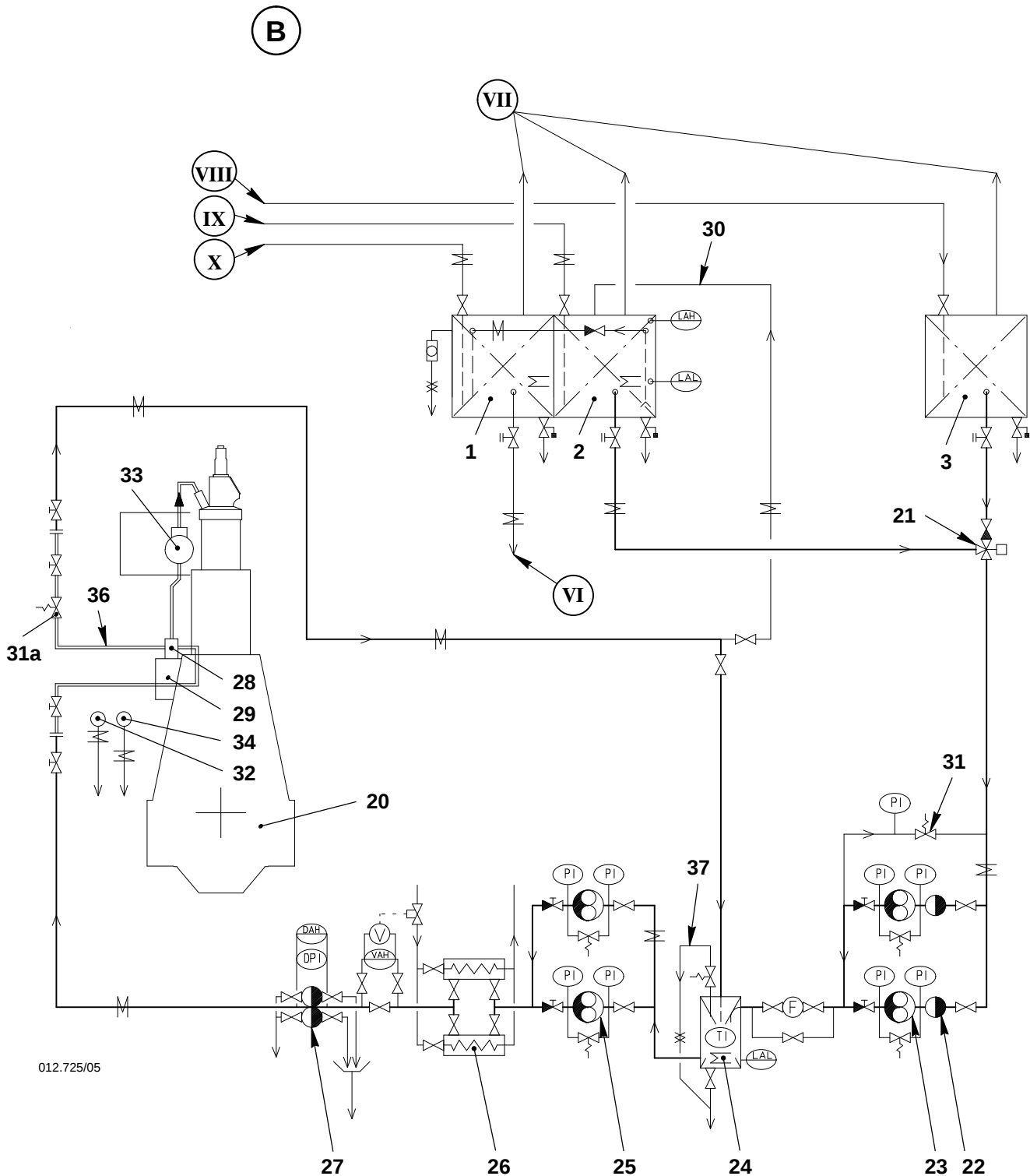
The required system pressure is set by the pressure regulating valve 31, the pressure at inlet to the fuel pumps by pressure retaining valve 31a (adjusting value see Operating Data Sheet [0250-1](#)).

The pump 23 supplies only as much fuel from the daily tank 2 as the engine consumes. The contents of the heavy fuel oil daily tank 2 must be heated, if necessary. However, the official safety regulations limit the temperature to which it can be heated.

Only the fuel oil between the mixing unit 24 and the fuel system on the engine must be heated to the required injection temperature. This is done by the end-heater 26. If necessary during preheating, the heating systems of the mixing unit 24 and the return pipe can be put on.

The installation should be laid out with non-return valves in such a manner that no heavy fuel oil can enter the diesel oil daily tank 3.

## Fuel Treatment, Fuel Oil System



Fuel Treatment, Fuel Oil System

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**Key to Illustrations: 'A' Heavy fuel and diesel oil separating system  
'B' Layout of fuel oil system**

- |                                                        |                                        |
|--------------------------------------------------------|----------------------------------------|
| 1 Heavy fuel oil settling tank                         | 24 Mixing unit, heatable and insulated |
| 2 Heavy fuel oil daily tank                            | 25 Booster pump                        |
| 3 Diesel oil daily tank                                | 26 End-heater                          |
| 4 Heavy fuel oil separator supply pump                 | 27 Fuel filter, heatable               |
| 5 Heavy fuel and diesel oil supply pump                | 28 Fuel pump                           |
| 6 Suction filter                                       | 29 Supply unit                         |
| 7 Heavy fuel oil preheater                             | 30 Bypass pipe                         |
| 8 Three-way valve                                      | 31 Pressure regulating valve           |
| 9 Self-cleaning heavy fuel oil separator               | 31a Pressure retaining valve           |
| 10 Self-cleaning heavy fuel oil / diesel oil separator | 32 Fuel leakage rail unit              |
| 20 Main engine                                         | 33 Fuel rail                           |
| 21 Three-way valve                                     | 34 Fuel leakage supply unit            |
| 22 Suction filter                                      | 36 Return pipe                         |
| 23 Low pressure feed pump                              | 37 Air overflow pipe                   |

- |                                      |                                  |
|--------------------------------------|----------------------------------|
| I To diesel oil storage tank         | VI To heavy fuel oil separator   |
| II From heavy fuel oil transfer pump | VII To vent manifold             |
| III Draining/de-watering             | VIII From diesel oil separator   |
| IV From diesel oil storage tank      | IX From heavy fuel oil separator |
| V To separator sludge tank           | X From the transfer pump         |

-  Flow indicator  
 Heated & insulated pipes  
 Insulated pipes  
 Pressure regulating valve  
 Sight glass  
 Viscosimeter

- PI Pressure gauge  
 TI Thermometer  
 DAH Differential pressure alarm high  
 DPI Differential pressure indication  
 LAL Fluid level alarm, low  
 LAH Fluid level alarm high  
 VAH Viscosity alarm high



**Operating Media**Scavenge Air and Compressed Air

---

**1. Scavenge air**

The air required for scavenging and charging of the cylinders is drawn in and compressed (see Turbocharging [6500–1](#)) by the turbocharger either from the engine room or from outside, depending on the installation.

The aspirated air must be as clean as possible, to keep the wear of cylinder liner, piston rings, compressor wheel of the turbocharger etc. small. For this purpose silencers are fitted to the suction part, which must be serviced and or cleaned (see Cleaning the Turbocharger in Operation [6510–1](#)).

**2. Starting air / control air****2.1 Starting air**

The starting air required for starting the engine (max. 30 bar) is pumped into the starting air bottles by compressors. For starting the air enters the cylinder directly. It must therefore be clean and dry. The starting air bottles must be drained periodically of accumulated condensed water (see Starting Air Diagram [8018–1](#)).

**2.2 Control air**

The control and air spring air taken from the shipboard system must be clean and dry required for the engine control.

To safeguard of control air supply unit **A**, additional compressed air, available at reduced pressure from the starting air, takes over in case the air supply fails (see Control Diagram [4003–2](#)).

## Operating Media

### Lubricating Oils

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#### 1. General

The engine has separate systems for system and cylinder lubrication.

#### 2. System oil

The system oil (bearing oil) provides lubrication for the bearings, the running parts of the engine and for the crosshead assembly. In addition, it is used as hydraulic fluid in the servo oil system of the engine (see [8016–1](#)).

An additive-type crankcase oil of the SAE 30 viscosity grade must be used as system oil. It must have a minimum BN of 5, detergent properties and meet load carrying performance of the FZG gear machine method IP 334/90, load stage fail 11. Good thermal stability, anticorrosion and antifoam properties and good demulsifying performance are further requirements.



**Remark:** Approved lubricating oils are shown in the 'Oil List of Wärtsilä Switzerland Ltd' currently valid for the respective engine type (see also [section 7](#)). For other or new lubricants, please contact Wärtsilä Switzerland Ltd.

##### 2.1 Oil care

###### **System oil:**

In order to always maintain the lubricating oil in good condition over a long period of time, effective oil treatment is necessary. This is achieved by using a self-cleaning, centrifugal separator working as purifier in by-pass, by circulating the oil from the oil tank through the separator. The system oil volume should be centrifuged at least three times a day through the separator operating at 40% through-put of its rated capacity. The recommended oil temperature for this treatment is 90 to 95 °C unless otherwise advised by the oil supplier.

Solid contaminants (dirt) and water must be removed from the oil as completely as possible. There is always the risk that water can enter the system and cause corrosive attack on engine parts, particularly with sea water. Water contamination can also lead to bacterial infection of the oil resulting in loss of lubrication capability and heavy corrosion of the system. Good housekeeping is the most effective precaution to keep water out of the oil. The water content of the lubricating oil should not exceed 0.3% by mass over an extended period of time. If higher water contamination is observed, special measures such as intensified treatment in the separator or in a renovating tank must be considered.

###### **Servo oil system:**

In order to prolong the lifetime of the sliding parts, fine filtered oil is used in this system. Branched off from the system oil it passes an additional automatic filter with a mesh size of 25 µm, which flushes back to the system oil.

The function of the flushing process and the low differential pressure shall be monitored during operation of the automatic filter (see Normal Running [0240–1](#) and documentation of the automatic filter manufacturer).

The bypass filter element may be used temporarily for inspecting and cleaning the regular elements, or if these must be removed for any reason.

## Lubricating Oils

## 2.2 Taking oil samples

At regular intervals, i.e. about every **3000** operating hours, it is recommended to take a sample of the engine oil and send it to a laboratory for an analysis. With the oil pump running and the engine oil at operating temperature, drain a small quantity of oil from a cock in the lubricating system to flush out any dirt accumulated in this cock.

Subsequently take an oil sample in a clean bottle marked with the following information for the laboratory:

- Ship's name or name of plant
- Engine type
- Engine serial number
- Date of sampling
- Operating hours of oil and of engine
- Oil brand and quality

## 2.3 Attention limits for selected system oil parameters

The condition of the lubricating system oil charge can be assessed by analysing selected parameters. With regular checks a deterioration can be detected at an early stage and remedial measures taken.

The following guiding limits should not be exceeded for a long period in service:

| Parameter          | Unit                     | Limit     | Test method         |
|--------------------|--------------------------|-----------|---------------------|
| Viscosity at 40 °C | mm <sup>2</sup> /s [cSt] | max. 140  | ASTM D 445          |
| Flash point (COC)  | °C                       | min. 200  | ASTM D 92           |
| Total insolubles   | m/m [%]                  | max. 0.70 | ASTM D 893b         |
| Base Number (BN)   | mgKOH/g                  | max. 12   | ASTM D 2896         |
| Water content      | m/m [%]                  | max. 0.20 | ASTM D 95 or D 1744 |
| Calcium            | mg/kg [ppm]              | max. 6000 | ICP                 |
| Zinc               | mg/kg [ppm]              | min. 100  | ICP                 |
| Phosphorus         | mg/kg [ppm]              | min. 100  | ICP                 |

If one of the limits is reached (fine filter monitoring) appropriate remedial action should be considered to correct the situation. Such action may be intensified purification (reduction of throughput, adjustment of temperatures), treating in a renovating tank (settling tank) or partial exchange of the oil charge. It is advisable to consult the oil supplier in such a case.

These limits are set out as a guidance. The quality condition of the oil in circulation, however, cannot be fully judged by a single parameter. Other oil parameters as well must be used in context to be able to find the cause of the problem and the appropriate remedy for correction.

If the Base Number (BN) of the system oil rises sharply check the piston rod gland and piston rod condition.

A certain consumption and replenishment of system oil is required to keep the system oil in good condition. The replenishment prevents a rise in system oil BN. A small rise in BN is often an indication that the system oil consumption is low.

## Lubricating Oils

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The open cup type of flash point determination (e.g. COC) should be used to decide if a partial or complete change of oil charge is necessary. The closed cup flash point determination (e.g. PMCC) can be used to monitor the system oil condition, as it is the more sensitive to small changes in oil condition, but not for oil change.

The FZG of the oil charge is particularly important if a new gear wheel is fitted, in order to provide protection against scuffing during the running-in of the gears.

### 3. Cylinder lubricating oil

A high-alkaline cylinder lubricating oil is recommended. The alkalinity of the oil is indicated by its Base Number (BN) [mgKOH/g]. Latest engine designs with high load output benefit from the use of the highest quality lubricants. The base number of BN 70 lubricants is not an index for detergency, but a direct measure of alkalinity. The alkalinity of the lubricating oil must be chosen with regard to the sulphur content of the fuel and lubricating oil feed rate, the higher the sulphur content, the higher the lubricating oil's BN must be (see [section 7](#) 'Lubricating oil list').

The choice between BN 40 and BN 70 lubricants depends on sulphur content as follows:

| Sulphur content in fuel oil [%] | Recommended cylinder oil (BN) |
|---------------------------------|-------------------------------|
| below 1                         | 40 <sup>1)</sup>              |
| 1.0 to 1.5                      | 40 (70) <sup>2)</sup>         |
| 1.5 to 2.0                      | 70 (40) <sup>3)</sup>         |
| 2.0 and above                   | 70                            |

- 1) In exceptional circumstances BN 70 can be used, but only at low feed rate.
- 2) BN 70 lubricant but only at reduced feed rate and for a short period of time.
- 3) BN 40 lubricant possible at slightly higher feed rate.

BN 40 lubricants are formulated with neutral additives (low BN contribution) to boost the detergency level and thermal stability back to the level of a BN 70 lubricant. No significant increase in corrosive cylinder liner and piston ring wear is to be expected when using BN 40 lubricants, at least up to 2.0 % sulphur.

## Lubricating Oils

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To avoid problems with fuel sulphur content, it is good practice to keep enough of the previous bunker. This can be used until an analysis of the sulphur content of the new bunker has been received.

BN 40 lubricants, compared to the BN 70 (or 80) products at the same feed rate, tend to form less and softer deposits on the piston top-land and in the exhaust regions, e.g. on the turbocharger nozzle ring.

Some engines have an anti-polishing ring fitted to remove hard deposits from the piston top-land and provide good piston running conditions with low sulphur fuel. Engines with an anti-polishing ring still have to follow the above recommendations for choice of cylinder lubricant and feed rate, because excessive scraped-off hard deposit can contaminate the piston ring grooves. However, the anti-polishing ring reduces the risk of piston running problems, if for example for some reason a too high cylinder lubricant feed rate is used.



**Remark:** The BN 40 products can safely be used with heavy fuel oil with sulphur content over 1.5% as well, the feed rate may have to be increased somewhat depending on remaining BN measured in the drain oil.

### 3.1 Oil analysis of piston underside drain

Oil analysis of the piston underside drain is gaining in importance. Not just to assess cylinder liner and ring wear rates and to optimize the cylinder oil feed rate (wear metals, rest BN, fuel components, water), but also to monitor the piston rod gland condition (system oil additive metals). It is important to monitor trends and not absolute values, and to consider the actual amount of oil that is being drained in relation to the analysis results.

### 3.2 Cylinder lubricating oil for running-in

For running-in it is recommended the **use of normal approved cylinder lubricating oil** (see list in [section 7](#)).

## 4. Turbocharger oil (with independent lubricating system)

To select and maintain the turbocharger lubricating oil, the recommendations given for correct viscosity grade in the supplier's instruction manual must be observed.

## 5. Turning gear oil

For the choice and maintenance of the lubricant, the recommendations given in the supplier's instruction manual must be observed.

## 6. Lubricant for flywheel and pinion gear teeth

The selection and application of the lubricant must be in compliance with the specification by Wärtsilä Switzerland Ltd, instructions 3206–1 in the Maintenance Manual and the recommendations by the supplier (see also [paragraph 7.2](#)).

## Lubricating Oils

**7. Lubricating oil list****7.1 Lubricating oil**

| Oil Supplier                                | System Oil                       | Cylinder Oil                                  | Cylinder Oil                      |
|---------------------------------------------|----------------------------------|-----------------------------------------------|-----------------------------------|
|                                             |                                  | more than 1% sulphur (BN 70–80)               | less than 2% sulphur (BN 40)      |
| <b>BP</b><br><b>Castrol</b>                 | Energol OE-HT 30<br>CDX 30       | Energol CLO 50M<br>Cyltech 80AW<br>Cyltech 70 | Energol CL–DX 405<br>Cyltech 40SX |
| <b>Chevron</b><br>(FAMM, Texaco,<br>Caltex) | Veritas 800 Marine Oil 30        | Taro Special HT70                             | Taro Special HT LS 40             |
| <b>ExxonMobil</b>                           | Mobilgard 300<br>EXXMAR XA       | Mobilgard 570<br>EXXMAR X 70                  | Mobilgard L 540                   |
| <b>Shell</b>                                | Melina S Oil 30<br>Melina Oil 30 | Alexia Oil 50                                 | Alexia LS                         |
| <b>Total</b>                                | Atlanta Marine D 3005            | Talusia HR 70                                 | Talusia LS 40                     |

The application must be in compliance with the Wärtsilä general lubricating oil requirements and recommendations. The supplying oil company undertakes all responsibility for the performance of the oil in service to the exclusion of any liability of Wärtsilä Switzerland Ltd.

**7.2 Lubricant for flywheel and pinion gear teeth**

| Supplier                             | Brand                      |
|--------------------------------------|----------------------------|
| <b>Lubrication Engineers Inc.</b>    | LE 5182<br>PYROSHIELD      |
| <b>Klüber Lubrication München KG</b> | Klüberfluid<br>C–F 3 ULTRA |

The application must be in compliance with the general requirements and instructions 3206–1 in the Maintenance Manual. The supplying company undertakes all responsibility for the performance of the lubricant in service to the exclusion of any liability of Wärtsilä Switzerland Ltd.



**Operating Media**Cooling Water / Cooling Water Treatment

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**1. General**

To avoid service stoppages the cooling water must have certain properties, which generally can only be attained by a suitable **cooling water treatment**. Untreated cooling water very soon leads to trouble in the cooling system due to corrosion and/or formation of sediments and incrustations.

**2. Raw water for closed cooling water circuits**

For a fresh filling the raw water must without fail be **totally desalinated water** or condensate water from e.g. the fresh water generators or from auxiliary steam systems with additives. Condensate water is highly corrosive and must therefore be made suitable as coolant by corrosion inhibitors.

Only in exceptional situations should drinking water or process water be used from the local mains. Its hardness must on no account exceed 10 °dH (German hardness degrees). If the water exceeds this limit it must be desalinated and brought to the hardness value indicated below.

Sea water must never be used as raw water because of its high content of salts.

The following values should be used as a nominal guide for the desired raw water quality:

| Parameter                          | Value                      |
|------------------------------------|----------------------------|
| Hardness                           | 3 to 10 °dH                |
| Content of chlorides and sulphates | not more than 100 mg/liter |
| pH value                           | 8 to 10                    |

In cases of doubt a water analysis must be carried out and advice be sought from **Wärtsilä Switzerland Ltd.**

It is generally not recommended to use corrosion protective oils (emulsion oils) for treating the cooling water, as, if instructions are not strictly adhered to and insufficient checking of the coolant is carried out (a water-oil emulsion), considerable risks are run to foul the cooling system.

## Cooling Water / Cooling Water Treatment

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### 3. Cooling water in operation

To be suitable, cooling water must, as already mentioned before, be treated by the right, and correctly administered corrosion inhibitor. Well proven in service are inhibitors with NITRITE and BORATE as active ingredients. A listing of proven and tested marketed products can be obtained from **Wärtsilä Switzerland Ltd.** upon request. The dosage must be strictly in accordance with the instructions of the manufacturer, and it must be periodically checked in service to maintain the correct concentration.

It is recommended to choose such suppliers of inhibitors who can also provide expert advice for the fresh filling as well as for later in service.

Coolant leakages have to be made good by adding the right water amount with the correctly metered additive. Loss by evaporation has to be made up by appropriate raw water (see above). By this an over concentration of inhibitors is prevented.

The cooling water in the cooling system should have a **pH value of 8 to maximum 10.**

### 4. Cleaning the cooling water system

For a fresh filling the complete cooling system must be clean, free from grease and oil and must not contain any foreign particles or remainders from the manufacture.

Later, in service, a cleaning can become necessary if, by influx of oil or due to gradual formation of sediments, the heat transfer and with it the cooling effect is diminished. Such problems will occur earlier where the care of the cooling water and of the cooling system has not been given the required attention. The complete system must then be treated with a suitable detergent agent (degreasing, dissolution of chalk sediments). Prior to filling with the prepared cooling water, the system has to be thoroughly rinsed and any residual acid remains neutralized.

For this purpose numerous suitable cleaning agents are available, which we do not wish to list here. We again recommend, however, to consult a firm of specialists for assistance.

## Operating Troubles

### General

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#### 1. General

If the operating and maintenance instructions are conscientiously observed, unforeseen operating interruptions can be avoided to a large extent.

Should a fault occur just the same, do not search for faults at random but investigate possible causes systematically. This applies in particular to difficulties in starting and stopping the engine.

Possible failures listed below are described with their possible causes to be found in the respective group.

##### 1.1 Troubles during starting and stopping (see [0810–1](#))

- Engine does not turn when starting
- Engine oscillates back at start or fails to attain speed
- Engine turns on starting air but receives no fuel oil
- Engine does not fire when starting
- Individual cylinders do not fire or do not fire properly when starting
- Engine fires violently when starting
- Engine cannot be stopped

##### 1.2 Irregularities during operation (see [0820–1](#))

At the same load indication in comparison with previous readings or with data in the shop trial documents.

- Scavenge air pressure drops
- Scavenge air pressure rises
- Exhaust temperature before turbocharger rises
- Exhaust temperature of individual cylinder rises
- Exhaust temperature of individual cylinder drops
- Firing pressure of all cylinders drops
- Engine speed drops
- Exhaust smoky
- Engine runs irregularly or misfires at times (individual or all cylinders)
- Engine stops by itself
- Irregularities in the cylinder cooling water system
- Cylinder lubrication fails
- Trouble with exhaust valve
- Surging of turbochargers
- Oil mist detector gives alarm

##### 1.3 Troubles and damages with engine parts (see [0840–1](#))

- Hot running of a piston
- Hot running of running gear parts

##### 1.4 Failures and defects of WECS components (see [0850–1](#))

- WECS passive failure
- WECS common failure
- WECS cylinder failure
- WECS pressure failure
- WECS critical failure (WECS engine failure)
- Malfunction of cylinder lubrication

**Operating Troubles**

## Troubles during Starting and Stopping

**1. Troubles during starting**(Designations and part code numbers see Control Diagram [4003-2](#))

| Case of trouble                           | Possible causes                                                                                                                                                                               | Remedial measures                                                                                                                                                                                                 |
|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Engine does not turn when starting</b> | Shut-off valves on starting air bottles are closed                                                                                                                                            | Open shut-off valves                                                                                                                                                                                              |
|                                           | Starting air pressure is too low                                                                                                                                                              | Fill air bottles                                                                                                                                                                                                  |
|                                           | Oil pressure, water pressure or air pressure for air spring are too low, pressure switches have triggered a SHUT-DOWN                                                                         | Reset SHUT-DOWN                                                                                                                                                                                                   |
|                                           | Exhaust valve not closed by air spring, i.e. upper housing is filled up with oil in consequence of too early starting or too late stopping of lubricating oil pump and servo oil service pump | Switch off lubricating oil pump and servo oil service pump, wait (up to about 30 min.) until the oil is pressed out from upper housing through orifice<br>Restart oil pumps only if all exhaust valves are closed |
| <b>Starting from control room:</b>        | Inactive control stand                                                                                                                                                                        | Press corresponding button for mode transfer or to take over the control                                                                                                                                          |
|                                           | Failure in remote control system / telegraph system                                                                                                                                           | Check Remote Control System or contact supplier                                                                                                                                                                   |
|                                           | Starting interlock by RCS                                                                                                                                                                     | Check indication of starting interlock in RCS (turning gear, shut-down, auxiliary blower), release interlock                                                                                                      |
|                                           | Signal interruption from RCS to WECS-9520                                                                                                                                                     | Check plugs, activity of CAN-BUS, for loose or broken wires                                                                                                                                                       |
| <b>Starting at the engine:</b>            | Inactive control stand                                                                                                                                                                        | Press corresponding button for mode transfer or to take over the control                                                                                                                                          |
|                                           | Turning gear is engaged, blocking valve 2.13 prevents passage of control air to v. unit <b>E</b>                                                                                              | Disengage turning gear                                                                                                                                                                                            |
|                                           | Control valve 2.05 to starting air shut-off valve is either jammed or does not open fully                                                                                                     | Clean control valve 2.05                                                                                                                                                                                          |
|                                           | Solenoid valves ZV7013C and ZV7014C fail in valve unit <b>E</b>                                                                                                                               | Clean or replace, check cabling                                                                                                                                                                                   |
|                                           | Plug(s) removed from solenoid valve(s) in valve unit <b>E</b>                                                                                                                                 | Plug in                                                                                                                                                                                                           |
|                                           | Shut-off valve for starting air is in position CLOSED (closed by hand)                                                                                                                        | Turn shut-off valve to position AUTOMAT                                                                                                                                                                           |
|                                           | Shut-off valve for starting air does not open, being stuck; non-return valve is jammed and does not fully open                                                                                | Clean and overhaul shut-off valve completely                                                                                                                                                                      |

## Troubles during Starting and Stopping

| Case of trouble                                                                                                         | Possible causes                                                                                                                                                                           | Remedial measures                                                                                                                         |
|-------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                         | Auxiliary blowers do not run                                                                                                                                                              | Start auxiliary blowers                                                                                                                   |
|                                                                                                                         | Air flaps in scavenge air receiver defective (no pressure can be built up by the auxiliary blowers)                                                                                       | Overhaul or replace air flaps                                                                                                             |
|                                                                                                                         | No air spring pressure or pressure too low                                                                                                                                                | Open shut-off cock 4.08, adjust pressure to 6 bar in control air supply unit <b>A</b>                                                     |
|                                                                                                                         | Non-return valve on exhaust valve (air inlet to air spring) wrongly fitted, heavy knocking noises and valve does not completely close                                                     | Check and fit properly (see Maintenance Manual <a href="#">2751–2</a> )                                                                   |
|                                                                                                                         | Starting valves jammed or plug not connected                                                                                                                                              | Overhaul starting valves or reconnect plug                                                                                                |
|                                                                                                                         | Different causes                                                                                                                                                                          | Try to start in opposite running direction                                                                                                |
| <b>Engine oscillates on starting or fails to come up to speed</b>                                                       | Individual cylinders receive either no, or insufficient starting air (restriction in starting air piping, solenoid valve(s) ZV7241 (to 52C) seized, cabling interrupted to FCM–20 module) | Check starting air piping, flame arrester and remedy restriction, clean or replace corresponding solenoid valve(s), check electric signal |
|                                                                                                                         | Starting air pressure too low                                                                                                                                                             | Fill air bottles                                                                                                                          |
|                                                                                                                         | Wrong positions of shut-off valves and stop valves in servo oil system                                                                                                                    | Check positions (see <a href="#">0130–1</a> )                                                                                             |
| <b>Engine turns on starting air but receives no fuel oil, regulation of fuel injection quantity is in Pos. 'zero' %</b> | Speed control system is defective, does not release regulation of fuel injection quantity                                                                                                 | See documentation of remote control supplier. Check electric signal from speed control system to WECS–9520                                |
| <b>Engine turns on starting air but receives no fuel oil</b>                                                            | Fuel rail pressure too low, connection between actuators and fuel pumps disconnected                                                                                                      | Fit connecting elements (see Maintenance Manual <a href="#">5583–1</a> )                                                                  |
|                                                                                                                         | Fuel rail pressure too low, fuel pump actuators are in position 'zero'                                                                                                                    | Check power supply at E85, E98.01 and E98.02                                                                                              |
|                                                                                                                         | Fuel rail pressure too low, knurled screw of fuel pressure control valve 3.06 not at lower stop                                                                                           | Check fuel pressure control valve 3.06 (see <a href="#">0515–1</a> )                                                                      |
|                                                                                                                         | Piston or control slide in injection control unit 3.02, piston in pre-control valve ZV7201 seized                                                                                         | Replace injection control unit or pre-control valve (see <a href="#">0515–1</a> )                                                         |
|                                                                                                                         | Heavy leakage in high pressure circuit (fuel) on engine                                                                                                                                   | Check for leakage, see <a href="#">8019–1</a> 'Fuel leakage system'                                                                       |
|                                                                                                                         | Fuel booster pressure is insufficient, pressure retaining valve is set too low, booster pump does not discharge                                                                           | Adjust fuel booster pressure                                                                                                              |
|                                                                                                                         | Shut-off valves before engine closed                                                                                                                                                      | Open shut-off valves                                                                                                                      |

## Troubles during Starting and Stopping

| Case of trouble                                                               | Possible causes                                                                                         | Remedial measures                                                                                                                         |
|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| <b>No ignitions when starting</b>                                             | Injected fuel quantity is too small, speed setting is in too low a position                             | Readjust speed setting                                                                                                                    |
|                                                                               | Fuel oil is either unsuitable or its viscosity is too high                                              | Prepare fuel oil system (see <a href="#">0120–1</a> )                                                                                     |
|                                                                               | Starting air pressure is insufficient to turn engine over fast enough                                   | Fill air bottles                                                                                                                          |
|                                                                               | Auxiliary blower or air flaps in scavenge air receiver defective                                        | Overhaul or replace auxiliary blower or air flaps                                                                                         |
|                                                                               | Compression pressures are too low, piston rings in poor condition, exhaust valves do not close properly | Replace piston rings, grind seating surfaces of valve head and valve seat                                                                 |
|                                                                               | High pressure circuit leaking (fuel pumps, rising pipes, fuel rail, injection control units)            | Investigate and remedy leakage with servo oil service pump in operation; pipe (tool 94583) between fuel rail and servo oil rail connected |
| <b>Individual cylinders do not fire or do not fire properly when starting</b> | Injection control unit cut out by WECS–9520 (function)                                                  | Switch on injection in remote control (user parameter 'Inj. RUN')                                                                         |
|                                                                               | Injection control unit cut out                                                                          | Cut in injection control unit, see <a href="#">0510–1</a>                                                                                 |
|                                                                               | Ball valves of servo oil inlet and outlet (control of rail valves) are closed                           | Open ball valves (see <a href="#">0515–1</a> )                                                                                            |
|                                                                               | Connections leaking on injection control unit                                                           | Tighten properly, regrind sealing faces                                                                                                   |
|                                                                               | Solenoid valve(s) ZV7201C (to H) defective                                                              | Replace defective solenoid valve(s)                                                                                                       |
|                                                                               | No electric signal to solenoid valve(s) ZV7201C(to H)                                                   | Check cabling, check LEDs on FCM–20 module, if necessary replace it                                                                       |
|                                                                               | Exhaust valve malfunction, no electric signal to solenoid valve(s) ZV7201A/B (to 12A/B)                 | Check cabling, check LEDs on FCM–20 module, if necessary replace it                                                                       |
|                                                                               | Injection nozzles leaking, nozzle needles sticking                                                      | Replace injection nozzles                                                                                                                 |
|                                                                               | Individual holes in injection nozzle blocked                                                            | Replace nozzle tip                                                                                                                        |
|                                                                               | Compression pressure in cylinder insufficient to ignite fuel oil                                        | Replace piston rings, grind seating surfaces of valve head and valve seat                                                                 |
|                                                                               | Exhaust valve spindle seized                                                                            | Replace defective parts                                                                                                                   |
|                                                                               | FCM–20 module, power supply interrupted, plug removed or wrongly connected, internal failure            | Switch on power supply, connect plug, replace FCM–20 module                                                                               |
|                                                                               | Piston or slide rod in exhaust valve control unit 4.10 or piston in pre-control valve ZV7201 seized     | Replace exhaust valve control unit or pre-control valve                                                                                   |
|                                                                               | Exhaust valve control unit cut out                                                                      | Cut in exhaust valve control unit (see <a href="#">0520–1</a> )                                                                           |

## Troubles during Starting and Stopping

| Case of trouble                     | Possible causes                                                                                                    | Remedial measures                                                                                       |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
|                                     | Starting valves do not open, either being stuck or damaged or getting no signal                                    | Overhaul or replace starting valves, check cabling                                                      |
| <b>Violent firing when starting</b> | Fuel rail pressure too high, fuel regulation fails                                                                 | Check power supply, cabling, regulating linkage                                                         |
|                                     | Cylinders were over-lubricated before starting, accumulation of cylinder oil in combustion spaces                  | Reduce speed setting (fuel injection quantity) till oil accumulation has burned, avoid over-lubrication |
|                                     | Auxiliary blowers were not running during previous starting attempts, accumulation of fuel oil in combustion space | Reduce speed setting shortly (fuel injection quantity)                                                  |
|                                     | Fuel injection quantity (start fuel charge) is set too high                                                        | Reduce speed setting (fuel injection quantity)                                                          |
|                                     | Fuel limiter is set too high                                                                                       | Readjust setting to standard value                                                                      |

## 2. Troubles with stopping

|                                                                                 |                           |                                                                                    |
|---------------------------------------------------------------------------------|---------------------------|------------------------------------------------------------------------------------|
| <b>Engine cannot be stopped with rotary switch or telegraph in control room</b> | Cable connector defective | Stop engine with EMERGENCY STOP button (see Shutting Down <a href="#">0310–1</a> ) |
| <b>Engine cannot be stopped with rotary switch on local control panel</b>       | Cable connector defective | Stop engine with EMERGENCY STOP button (see Shutting Down <a href="#">0310–1</a> ) |

## Operating Troubles

### Irregularities during Operation

At the same load indication in comparison with previous readings or with data in the acceptance records:

| Case of trouble                                      | Possible causes                                                                                          | Remedial measures                                                                                                                                               |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Scavenge air pressure drops</b>                   | Scavenge air cooler fouled on air side<br>Water separator fouled or damaged                              | See <a href="#">6606-1</a> 'Air side cleaning of the SAC in service'                                                                                            |
|                                                      | High intake temperature before turbocharger                                                              | Ensure air intake                                                                                                                                               |
|                                                      | Diffusor, blower and inducer to turbocharger fouled or damaged                                           | See Cleaning the Turbocharger in Operation <a href="#">6510-1</a> and Manual of Turbocharger                                                                    |
|                                                      | Silencer before turbocharger fouled                                                                      |                                                                                                                                                                 |
|                                                      | Turbine rotor blading fouled or damaged                                                                  |                                                                                                                                                                 |
|                                                      | Nozzle ring of turbocharger damaged                                                                      |                                                                                                                                                                 |
|                                                      | Exhaust gas boiler (plant side) fouled, increased resistance or back pressure after turbine respectively | Clean at first opportunity                                                                                                                                      |
| <b>Scavenge air pressure rises</b>                   | Nozzle ring of turbocharger fouled or partially choked                                                   | See Cleaning the Turbocharger in Operation <a href="#">6510-1</a>                                                                                               |
| <b>Exhaust temperature before turbocharger rises</b> | Air deficiency due to defect or considerable fouling of turbocharger, silencer or scavenge air cooler    | See Cleaning the Turbocharger in Operation <a href="#">6510-1</a> , <a href="#">6606-1</a> 'Air side cleaning of the SAC in service' and Manual of Turbocharger |
|                                                      | Air flaps in scavenge air receiver fouled or defective                                                   | Clean, overhaul or replace                                                                                                                                      |
|                                                      | Injection nozzles worn                                                                                   | Replace                                                                                                                                                         |
|                                                      | High intake temperature before turbocharger                                                              | Ensure air intake                                                                                                                                               |
|                                                      | Scavenge ports in cylinder liner dirty                                                                   | Clean                                                                                                                                                           |
| <b>Exhaust temp. of individual cylinders rises</b>   | Air flaps in scavenge air receiver fouled or defective                                                   | Clean, overhaul or replace                                                                                                                                      |
|                                                      | Injection nozzles worn                                                                                   | Replace                                                                                                                                                         |
|                                                      | Scavenge ports in cylinder liner dirty                                                                   | Clean                                                                                                                                                           |
|                                                      | Fire in piston underside space                                                                           | see Measures against Fouling and Fires in the Scavenge Air Spaces <a href="#">0450-1</a>                                                                        |
|                                                      | Exhaust valve leaking                                                                                    | Grind valve seat and head                                                                                                                                       |
|                                                      | Exh. thermometer of resp. cylinder defective                                                             | Replace                                                                                                                                                         |
| <b>Exhaust temp. of individual cylinders drops</b>   | Injection nozzles in poor condition, nozzle tip broken                                                   | Replace nozzle tip                                                                                                                                              |
|                                                      | The respective cylinder receives less fuel oil due to leaking HP pipes or injection valves               | Grind sealing faces or replace defective parts                                                                                                                  |
|                                                      | Exhaust valve does not open, exhaust valve control unit or its actuator pipe defective                   | Cut out injection and exhaust valve control unit of resp. cylinder (see <a href="#">0510-1</a> & <a href="#">0520-1</a> )                                       |
|                                                      | Exh. thermometer of resp. cylinder defective                                                             | Replace                                                                                                                                                         |

## Irregularities during Operation

| Case of trouble                                                                  | Possible causes                                                                                                                                                               | Remedial measures                                                                   |
|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| <b>Firing pressure of all cylinders drops</b>                                    | Spring fracture in connecting unit of shaft encoder drive (crank angle sensor unit)                                                                                           | Replace                                                                             |
| <b>Engine speed drops</b>                                                        | Speed setting from speed control system reduced or limited                                                                                                                    | Check speed control system                                                          |
|                                                                                  | Fuel injection quantity from speed control system limited to avoid overload at heavy sea                                                                                      | Normal situation                                                                    |
|                                                                                  | Hull resistance increased due to growth/ageing, propeller damaged                                                                                                             | See Interrelationship between Engine and Propeller 0070-1                           |
|                                                                                  | Defect in an injection control unit, defective injection pipe                                                                                                                 | Cut out or replace (see 0510-1 and 0515-1)                                          |
|                                                                                  | Fouling of air and exhaust gas passages                                                                                                                                       | See section 1 'Scavenge air pressure drops'                                         |
| <b>Exhaust smoky</b>                                                             | Air deficiency! Fouling of either gas or air side of turbocharger, scavenge air cooler, air flaps in receiver, scavenge ports in cylinder liners or fouling in exhaust boiler | See section 1 'Scavenge air pressure drops'                                         |
|                                                                                  | Engine overloaded                                                                                                                                                             | Reduce fuel injection quantity                                                      |
|                                                                                  | Engine runs with excessive cylinder lubricating oil                                                                                                                           | See 7218-1 and 7218-2                                                               |
|                                                                                  | Injection nozzles atomize fuel oil incompletely, e.g. due to trumpet formation, eroded or blocked spray holes                                                                 | Clean, check and readjust or replace                                                |
|                                                                                  | Fuel oil unsuitable or of too high a viscosity, insufficiently pre-heated                                                                                                     | See 0270-1 'Recommended viscosity before fuel pumps'                                |
|                                                                                  | Compression pressure too low, piston rings leaking, exhaust valve leaking                                                                                                     | Replace piston rings, grind valve seat and head                                     |
|                                                                                  | Bores in orifice for upper housing of exhaust valve choked up, exhaust valves close too late                                                                                  | Check and clean                                                                     |
|                                                                                  | Servo oil pressure too low, servo oil pump control defective, oil leakage                                                                                                     | Check oil flow, investigate and remedy leakage                                      |
|                                                                                  | No or only one auxiliary blower runs at part load                                                                                                                             | Switch on auxiliary blowers                                                         |
| <b>Engine runs irregularly or misfires at times, individual or all cylinders</b> | High water content in the fuel oil                                                                                                                                            | See 0720-1 'Treatment of heavy fuel oils and treatment plant'                       |
|                                                                                  | Fuel oil temperature before fuel pumps too low or too high                                                                                                                    | See 0270-1 'Recommended viscosity before fuel pumps'                                |
|                                                                                  | Pressure in the fuel rail too low, disturbance with fuel pressure control valve 3.06, one or several fuel pumps do not deliver fuel                                           | See 0515-1 'Defective fuel pressure control valve 3.06', check pressure transmitter |

## Irregularities during Operation

| Case of trouble                                                                           | Possible causes                                                                                                                                                                              | Remedial measures                                                                                                                                 |
|-------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Engine stops by itself (without shut-down indication)</b>                              | Fuel oil daily tank empty or fuel supply interrupted, fuel oil filters choked, booster pump failed, faulty switching, fuel rail pressure too low, regulating linkage defective, fuel leakage | Top up daily tank, clean filter, investigate other causes and remedy them, check regulating linkage, repair fault, investigate and remedy leakage |
|                                                                                           | Failure in electric power supply to WECS-9520                                                                                                                                                | Remedy cause and restart WECS-9520                                                                                                                |
|                                                                                           | Speed setting system defective, e.g. broken wires                                                                                                                                            | Clear fault                                                                                                                                       |
|                                                                                           | Engine fails at heavy sea                                                                                                                                                                    | Switch on Heavy Sea Mode see <a href="#">4002-3</a> 'User parameters'                                                                             |
| <b>Irregularities in cylinder cooling water system</b><br><br><b>Pressure fluctuates:</b> | Air collecting in cooling spaces or in pipes due to insufficient venting                                                                                                                     | Vent                                                                                                                                              |
|                                                                                           | Drop of static pressure at inlet to cooling water pump due to throttling in return pipe or draining of expansion tank                                                                        | See plant instructions                                                                                                                            |
|                                                                                           | Exhaust gases blowing into cooling water due to a crack (cylinder liner, cylinder cover, valve cage)                                                                                         | See Operation with Water Leakage into the Combustion Chamber <a href="#">0545-1</a>                                                               |
| <b>Increased cooling water temperature at outlet of individual cylinders:</b>             | Shut-off valves in pipes of affected cylinders shut by mistake or defective                                                                                                                  | Open or replace                                                                                                                                   |
|                                                                                           | Cooling spaces insufficiently vented                                                                                                                                                         | Vent                                                                                                                                              |
|                                                                                           | Cooling water pipes or water passages choked, insufficient water flow                                                                                                                        | See Cooling Water / Cooling Water Treatment <a href="#">0760-1</a>                                                                                |
|                                                                                           | Piston running hot                                                                                                                                                                           | See Troubles and Damages with Engine Parts <a href="#">0840-1</a>                                                                                 |
|                                                                                           | Exhaust gases blowing into cooling water due to a crack (cylinder liner, cylinder cover, valve cage)                                                                                         | See Operation with Water Leakage into the Combustion Chamber <a href="#">0545-1</a>                                                               |
| <b>Increased cooling water temperature on all cylinders:</b>                              | Plant side faulty (regulating valve, cooling water cooler etc.)                                                                                                                              | See plant instructions                                                                                                                            |

## Irregularities during Operation

## Cylinder lubrication

Full or partial failure of cylinder lubrication leads to earlier wear of piston rings and cylinder liners. However, it may also lead to piston seizure. Only in emergencies, and then at reduced power and only for the minimum possible time, should an engine be operated without cylinder lubrication.

Failures and defects in the cylinder lubricating system cause failure messages in the WECS–9520 which are led to the alarm and monitoring system.

In addition LEDs on the ALM–20 modules light up indicating the relevant failures and defects (see also 0850–1 'Malfunction of cylinder lubrication' and [7218–1](#) 'LED indications').

| Case of trouble                                                      | Possible causes                                                                                      | Remedial measures                                                                                                                                                                             |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Cylinder lubrication fails</b><br><i>Lack of lubricating oil:</i> | Daily tank empty, ball valve after lubricating oil filter 8.17 closed or filter element clogged      | Top up daily tank, open ball valve, exchange or clean filter element                                                                                                                          |
|                                                                      | Shut-off valve (lubricating oil) on lubricating pump(s) closed or air in cylinder lubricating system | Open shut-off valve (lubricating oil) or vent cylinder lubricating system (filter, pump, pipes to lubricating quills)                                                                         |
|                                                                      | One or several lubricating quill(s) blocked on cylinder liner                                        | Check lubricating quill(s), if necessary overhaul it(them) or replace defective parts                                                                                                         |
| <b>Failure of lubricating pump:</b>                                  | No or too low servo oil pressure                                                                     | Open stop valves 4.30–5, –6, check servo oil pressure, adjust pressure on pressure reducing valves 8.11–1, –2 if required or check and adjust settings of shut-off valves on lubricating pump |
|                                                                      | 4/2-way solenoid valve, pressure transmitter or pump body defect                                     | Replace defective parts (see documentation of lubricating pump manufacturer)                                                                                                                  |

## Irregularities during Operation

| Case of trouble                                                        | Possible causes                                                            | Remedial measures                                                                     |
|------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <b>Troubles with exhaust valve</b><br><br><i>Exhaust valves knock:</i> | Step piston in exhaust valve defective                                     | Overhaul, replace                                                                     |
|                                                                        | Orifice or filter in exhaust valve control units clogged                   | Clean orifice or filter (see Maintenance Manual <a href="#">5612-1</a> )              |
|                                                                        | Strainer holes in orifice to exhaust valve considerably enlarged (erosion) | Replace orifice                                                                       |
|                                                                        | Leakage in hydraulic piping                                                | Remedy leakage, replace piping                                                        |
| <i>Exhaust valve does not open:</i>                                    | Non-return valve 4.06 on exhaust valve defective                           | Overhaul, replace                                                                     |
|                                                                        | Piston or slide rod in exhaust valve control unit seized                   | Replace exhaust valve control unit as whole unit                                      |
|                                                                        | Pre-control valve (rail valve) defective or cable plug loose               | Pre-control (rail valve) or re-connect cable plug (see <a href="#">0525-1</a> )       |
| <i>Exhaust valve does not shut:</i>                                    | Air spring pressure too low (< 2 bar)                                      | Investigate cause: leakage, pressure reducing valve, pressure in starting air bottles |
|                                                                        | Exhaust valve shank or step piston seized                                  | Overhaul, replace                                                                     |

**Turbocharger**

Short, loud howling with simultaneous pressure fluctuations on the air side.

When this occurs sporadically, surging does not directly affect the engine, but the air flow rate is diminished.

| Case of trouble                 | Possible causes                                   | Remedial measures                                                                                                                                               |
|---------------------------------|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Surging of turbochargers</b> | Overload, air deficiency                          | See Cleaning the Turbocharger in Operation <a href="#">6510-1</a> , <a href="#">6606-1</a> 'Air side cleaning of the SAC in service' and Manual of Turbocharger |
|                                 | Cylinder fails (injection, exhaust valve control) | Check control of injection and exhaust valve                                                                                                                    |

Irregularities during Operation

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**Oil mist detector**

**Risk of explosion!** Keep away from engine! Particularly avoid areas next to explosion relief valves (see Instruction Concerning the Prevention of Crankcase Explosions [0460-1](#)).

| Case of trouble               | Possible causes                    | Remedial measures                                                                                                                                                                                                                                           |
|-------------------------------|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Oil mist detector gives alarm | Part of a running gear getting hot | Reduce load (rpm) immediately<br>Stop engine as soon as the situation permits<br>Investigate cause, remedy as far as possible (see Safety Precautions and Warnings <a href="#">0210-1</a> & Troubles and Damages with Engine Parts <a href="#">0840-1</a> ) |

**Operating Troubles**

## Troubles and Damages with Engine Parts

**1. Hot running of a piston****Possible indications:**

(although the combustion is in order)

- Increase of piston cooling oil outlet temperature
- Increase of jacket cooling water outlet temperature
- Increase of piston underside temperature

| Possible causes                                                                                                              | Remedial measures                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gas blow-by via defective or worn piston rings<br>Scuffing at cylinder liner surface due to lack of cylinder lubricating oil | <p>Cut out injection of affected cylinder for a while (see <a href="#">0510–1</a>)</p> <p>Increase cylinder lubrication oil feed rate of affected cylinder with user parameter 'Lubrication' → 'Feed Rate' (see <a href="#">7218–1</a> 'Adjusting the feed rate of lubricating oil')</p> <p>Should temperature still not drop, or rise again after injection is cut in, cut injection out again (see <a href="#">0510–1</a>) and stop engine as soon as possible, then wait until cylinder and piston have cooled down</p> <p>Check running surface of piston and cylinder liner</p> <p>If the damage is slight, seizure portions can be smoothed out with an oil stone</p> <p>If the damage is heavy, replace piston, piston skirt and cylinder liner</p> <p>Should a replacement of these parts not be feasible for any reason, remove piston, taking necessary precautions (see <a href="#">0540–1</a>)</p> |

**2. Hot running of running gear parts**

| Possible causes                                                                                                                                                                                                                                                                                                                                                                                                                                 | Remedial measures                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Defective oil pipe or pipe connection<br>Water in lubricating oil (rusty journals)<br>Dirt in lubricating oil<br>Physical damage to bearing or journals during fitting<br>Insufficient bearing clearance<br>Bearing deformation (waisted studs not tightened according to instructions)<br>Insufficient bearing oil pressure (check pressure gauge and oil pressure monitoring system)<br>Level in oil tank too low. Pump partially drawing air | <p>Reduce speed (power) and increase bearing oil pressure</p> <p>If temperature continues to increase, engine has to be stopped and allowed to cool down</p> <p>Take necessary precautions for preventing crankcase explosions (see <a href="#">0460–1</a>)</p> <p>Inspect and dismantle bearing which has been running hot</p> <p>Depending on possibilities, either overhaul or replace damaged parts, or remove defective running gear (see <a href="#">0540–1</a>)</p> |

## Operating Troubles

### Failures and Defects of WECS Components

---

#### Overview

|     |                                                   |       |
|-----|---------------------------------------------------|-------|
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#### 1. General

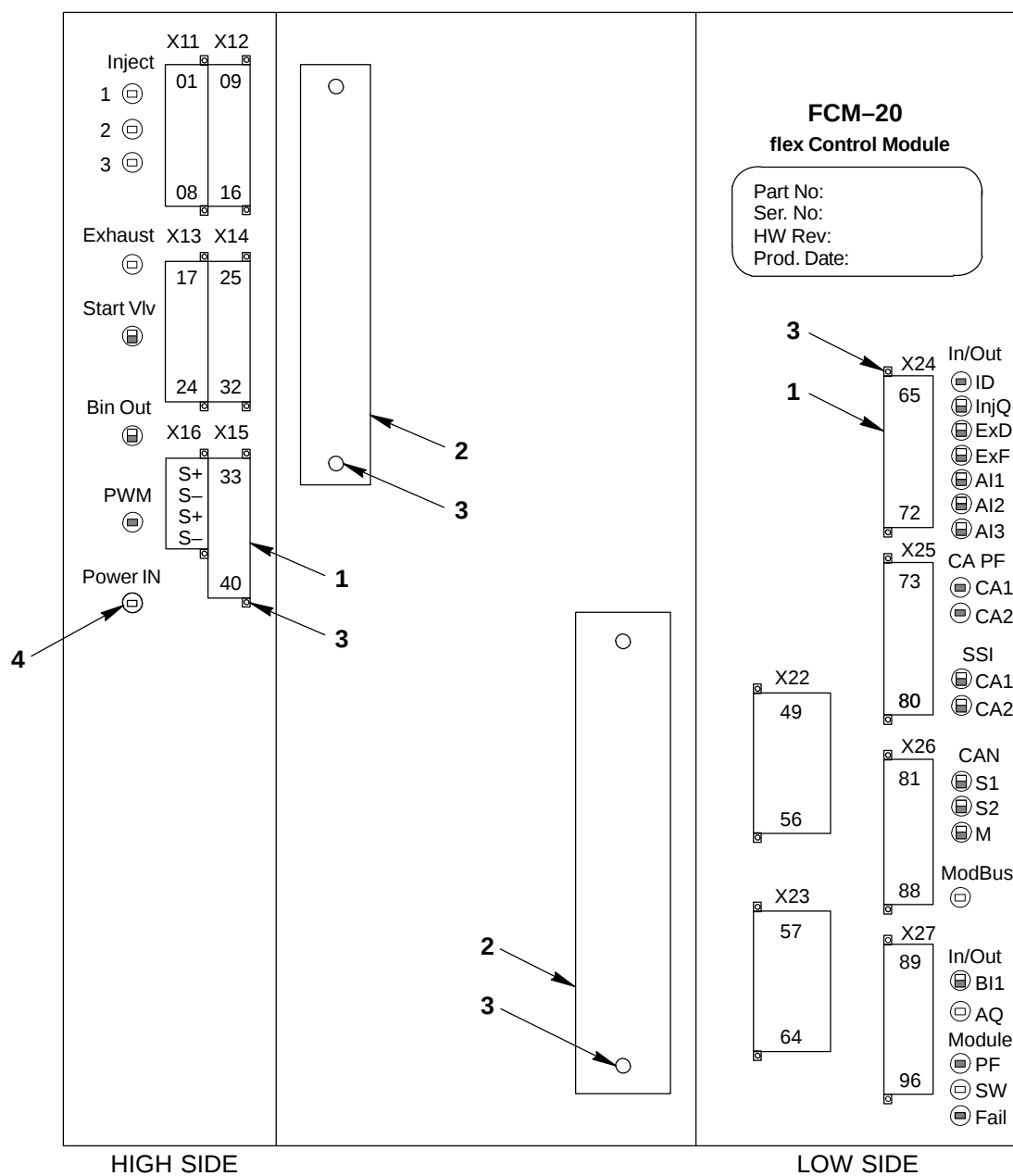
Failures and defects of WECS components cause failure messages which are led to the operator flexView and alarm and monitoring system.

The following tables are an overview helping to interpret all failure indications. An additional blink code of the LEDs is provided on the FCM–20 or ALM–20 modules in order to render more precisely if there are several failure indications.

## Failures and Defects of WECS Components

## 2. LED indications on FCM-20 module

A



## Key to Illustration: 'A'

- 1 Connector (COMBICON)
- 2 Cable holder
- 3 Screw
- 4 LEDs

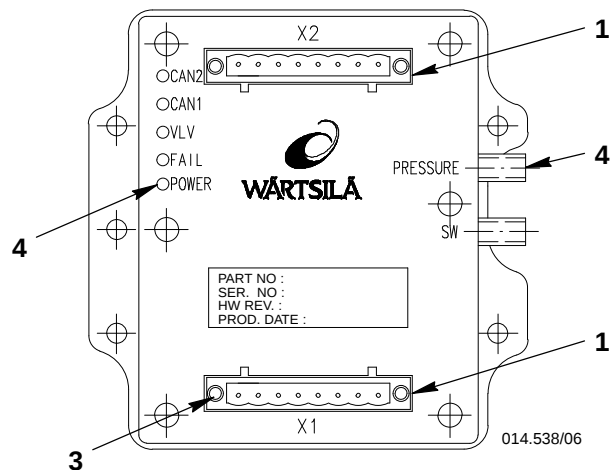
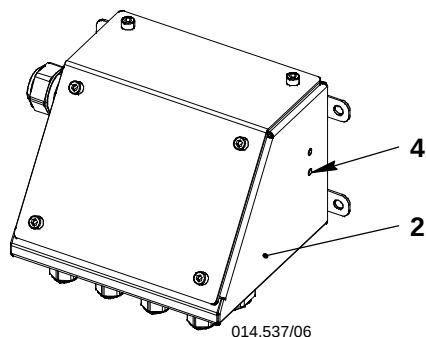


**Remark:** Screws 3 of connectors 1 and cable holders 2 must always be tightened!  
The LEDs are not directly connected with the connector nearby. Only the textlabel next to them indicates their meaning.

## Failures and Defects of WECS Components

### 3. LED indications on ALM-20 module

**B**



#### Key to Illustration: 'B'

- 1 Connector (COMBICON)
- 2 Control box 41.nn
- 3 Screw
- 4 LEDs

## Failures and Defects of WECS Components

## 4. Failure indications

### 4.1 Failure grouping

All WECS failure indications are part of the following failure groupings and are always indicated together with the corresponding group.

| Failure group                                 | Failure effects                                                                                                                                      | Measures                                                                                                |
|-----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| WECS passive failures                         | Failures of redundancy systems (failure of a redundant component, system or an assembly), do not have direct influence on engine operation           | Investigate cause and repair at earliest opportunity                                                    |
| WECS common failures                          | Failures of common kind, have little influence on engine operation                                                                                   | Investigate cause and repair at earliest opportunity                                                    |
| WECS cylinder failures                        | Failures that result in loss of a cylinder resulting in engine power reduction, trigger an immediate slow-down in safety system                      | Immediate repair required for unrestricted engine operation                                             |
| WECS pressure failures                        | A few failures in pressure systems of the engine (fuel, servo oil rail etc.) affecting whole engine, trigger an immediate slow-down in safety system | Overriding of slow-down is not recommended, immediate repair required for unrestricted engine operation |
| WECS critical failures (WECS engine failures) | Failures affecting an engine stop by the WECS                                                                                                        | Must be repaired immediately to restart the engine                                                      |

### 4.2 Failure of pulse lubrication

| Type of failure                          | Failure effects                                                                                                                                                                                      | Measures                                                                                                                                                  |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| WECS lubrication passive failures        | Failures do not have direct influence on cylinder lubrication, however, they trigger a WECS passive failure, i.e. failures of redundancy systems (power supply, CAN Bus to ALM-20 or FCM-20 modules) | Investigate cause and repair at earliest opportunity                                                                                                      |
| Cylinder lubrication malfunction Cyl. #n | Failures cause malfunction of cylinder lubrication of a cylinder triggering a slow-down in safety system                                                                                             | Immediate repair required for unrestricted engine operation<br>Fuel injection of corresponding cylinder should be cut out until failure has been remedied |
| Cylinder lubrication malfunction         | Failures that result in loss of cylinder lubrication triggering a slow-down in safety system                                                                                                         | Immediate repair required for unrestricted engine operation<br>Fuel injection of corresponding cylinder should be cut out until failure has been remedied |

#### **Additional information of flexView alarm journal:**

The alarm journal of flexView displays additional helpful details, if flexView is brought to access level 'Adjust'. Go to page ADJUST attempting to change any parameter. A password ('flexView') is asked and when it's entered, the new access level is set. No any parameter must be changed.

## Failures and Defects of WECS Components

## 4.3 Blink code

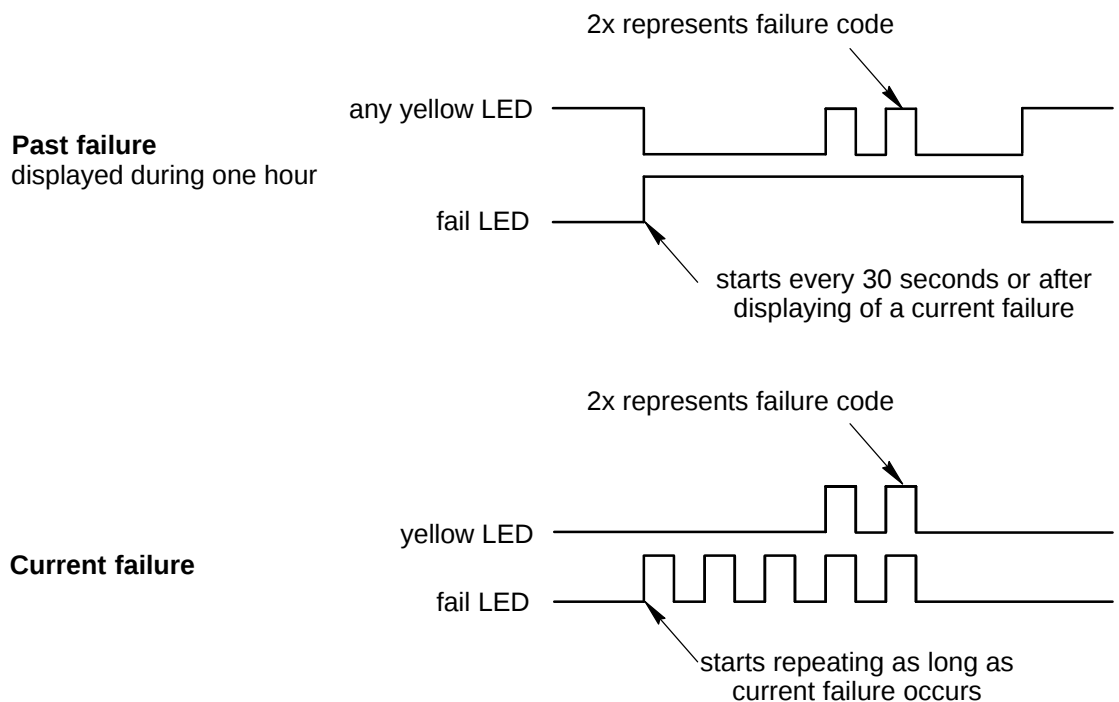
**RED LED Fail.:**

The RED LED Fail. indicates a failure on the corresponding FCM-20 module and whether the failure status is active or inactive on YELLOW LEDs.

| Failure status           | LED Fail.      |
|--------------------------|----------------|
| active (present failure) | blinking       |
| inactive (old failure)   | permanently on |
| no failure               | off (dark)     |



**Remark:** Due to the location of control boxes E95.01 to E95.12, danger of mistakes exist with the view of the LEDs on FCM-20 modules. Therefore, always make sure that the correct LEDs are checked!

**Startup:****Right side (low side):**

After switching power ON, the LEDs SSI (CA1, CA2) and CAN (S1, S2 and M) are lighting red about four seconds. The fail LED is lighting red about two seconds. Thereafter the yellow LEDs In/Out (from InjQ to Al3), CAN (S1, S2, and M) and the green SW LED lights up.

**Left side (high side):**

After switching power ON, the green 'Power IN' LED lights up.

## Failures and Defects of WECS Components

## 4.4 WECS passive failure

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ME scavenge air pressure sensor #1 meas. fail. |        |                 |  |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|--------|-----------------|--|
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | LED                                            |        | Blink intervals |  |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                |        |                 |  |
|                          | #03                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | AI2                                            | Yellow | 1 x             |  |
| Cause:                   | Sensor signal < 2mA or > 22mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                |        |                 |  |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Check pressure transmitter PT4043C</li> <li>– Check supply voltage 24 VDC on plug X27 (terminals 94+/96–) in E95.03 and on transmitter plug (2+/1–)</li> <li>– Check cabling from pressure transmitter PT4043C to E12 and E95.03</li> <li>– Re-establish proper wiring from pressure transmitter PT4043C to E95.03</li> <li>– Exchange pressure transmitter PT4043C if necessary</li> </ul>                                                                                                                                 |                                                |        |                 |  |
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | LED                                            |        | Blink intervals |  |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                |        |                 |  |
|                          | #03                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | AI2                                            | Red    | None            |  |
| Cause:                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                |        |                 |  |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Unplug pressure transmitter PT4043C and plug X27 in E95.03</li> <li>– Measure cables with multimeter on plug X27 terminal 94 and 95 against each other and against ground for short circuit or earth fault</li> <li>– Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available</li> <li>– Measure transmitter for earth fault, replace pressure transmitter PT4043C if required</li> <li>– If red LED remains ON with disconnected X27, replace FCM-20 module #03</li> </ul> |                                                |        |                 |  |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ME scavenge air pressure sensor #2 meas. fail. |        |                 |  |
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | LED                                            |        | Blink intervals |  |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                |        |                 |  |
|                          | #04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | AI2                                            | Yellow | 1 x             |  |
| Cause:                   | Sensor signal < 2mA or > 22mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                |        |                 |  |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Check pressure transmitter PT4044C</li> <li>– Check supply voltage 24 VDC on plug X27 (terminals 94+/96–) in E95.04 and on transmitter plug (2+/1–)</li> <li>– Check cabling from pressure transmitter PT4044C to E12 and E95.04</li> <li>– Re-establish proper wiring from pressure transmitter PT4044C to E95.04</li> <li>– Exchange pressure transmitter PT4044C if necessary</li> </ul>                                                                                                                                 |                                                |        |                 |  |
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | LED                                            |        | Blink intervals |  |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                |        |                 |  |
|                          | #04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | AI2                                            | Red    | None            |  |
| Cause:                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                |        |                 |  |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Unplug pressure transmitter PT4044C and plug X27 in E95.04</li> <li>– Measure cables with multimeter on plug X27 terminal 94 and 95 against each other and against ground for short circuit or earth fault</li> <li>– Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available</li> <li>– Measure transmitter for earth fault, replace pressure transmitter PT4044C if required</li> <li>– If red LED remains ON with disconnected X27, replace FCM-20 module #04</li> </ul> |                                                |        |                 |  |

## Failures and Defects of WECS Components

| Failure text                                           | ME servo oil pressure sensor #1 meas. fail.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |        |                 |
|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------|-----------------|
| Failure LED:<br><br>Cause:<br>Fault finding, remedies: | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | LED |        | Blink intervals |
|                                                        | #01                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | AI2 | Yellow | 1 x             |
|                                                        | Sensor signal < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |        |                 |
|                                                        | <ul style="list-style-type: none"><li>– Check pressure transmitter PT2071C on servo oil rail</li><li>– Check supply voltage 24 VDC on plug X27 (terminals 94+/96–) in E95.01 and on transmitter plug</li><li>– Check cabling from pressure transmitter PT2071C to E95.01</li><li>– Re-establish proper wiring from pressure transmitter PT2071C to E95.01</li><li>– Exchange pressure transmitter PT2071C if necessary</li></ul>                                                                                                                                |     |        |                 |
|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |     |        |                 |
| Failure LED:<br><br>Cause:<br>Fault finding, remedies: | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | LED |        | Blink intervals |
|                                                        | #01                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | AI2 | Red    | None            |
|                                                        | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |        |                 |
|                                                        | <ul style="list-style-type: none"><li>– Unplug pressure transmitter PT2071C and plug X27 in E95.01</li><li>– Measure cables with multimeter on plug X27 terminals 94 and 95 against each other and against ground for short circuit or earth fault</li><li>– Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available</li><li>– Measure transmitter for earth fault, replace pressure transmitter PT2071C if required</li><li>– If red LED remains ON with disconnected X27, replace FCM-20 module #01</li></ul> |     |        |                 |
|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |     |        |                 |
| Failure text                                           | ME servo oil pressure sensor #2 meas. fail.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |        |                 |
| Failure LED:<br><br>Cause:<br>Fault finding, remedies: | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | LED |        | Blink intervals |
|                                                        | #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | AI2 | Yellow | 1 x             |
|                                                        | Sensor signal < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |        |                 |
|                                                        | <ul style="list-style-type: none"><li>– Check pressure transmitter PT2072C on servo oil rail</li><li>– Check supply voltage 24 VDC on plug X27 (terminals 94+/96–) in E95.02 and on transmitter plug</li><li>– Check cabling from pressure transmitter PT2072C to E95.02</li><li>– Re-establish proper wiring from pressure transmitter PT2072C to E95.02</li><li>– Exchange pressure transmitter PT2072C if necessary</li></ul>                                                                                                                                |     |        |                 |
|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |     |        |                 |
| Failure LED:<br><br>Cause:<br>Fault finding, remedies: | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | LED |        | Blink intervals |
|                                                        | #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | AI2 | Red    | None            |
|                                                        | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |        |                 |
|                                                        | <ul style="list-style-type: none"><li>– Unplug pressure transmitter PT2072C and plug X27 in E95.02</li><li>– Measure cables with multimeter on plug X27 terminals 94 and 95 against each other and against ground for short circuit or earth fault</li><li>– Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available</li><li>– Measure transmitter for earth fault, replace pressure transmitter PT2072C if required</li><li>– If red LED remains ON with disconnected X27, replace FCM-20 module #02</li></ul> |     |        |                 |
|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |     |        |                 |

## Failures and Defects of WECS Components

| Failure text                                                             |                                                                                                                                         | ME fuel rail pressure sensor #1 meas. fail. |        |                 |
|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|--------|-----------------|
| Failure LED:                                                             | FCM-20 No.                                                                                                                              | LED                                         |        | Blink intervals |
|                                                                          | #03                                                                                                                                     | AI1                                         | Yellow | 1 x             |
| Cause:                                                                   | Sensor signal < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)                                                           |                                             |        |                 |
| Fault finding, remedies:                                                 | – Check pressure transmitter PT3461C on fuel rail                                                                                       |                                             |        |                 |
|                                                                          | – Check supply voltage 24 VDC on plug X25 (terminal 79+ / housing –) in E95.03 and on transmitter plug                                  |                                             |        |                 |
|                                                                          | – Check cabling from pressure transmitter PT3461C to E95.03                                                                             |                                             |        |                 |
|                                                                          | – Re-establish proper wiring from pressure transmitter PT3461C to E95.03                                                                |                                             |        |                 |
|                                                                          | – Exchange pressure transmitter PT3461C if necessary                                                                                    |                                             |        |                 |
| Failure LED:                                                             | FCM-20 No.                                                                                                                              | LED                                         |        | Blink intervals |
|                                                                          | #03                                                                                                                                     | AI1                                         | Red    | None            |
| Cause:                                                                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                             |                                             |        |                 |
| Fault finding, remedies:                                                 | – Unplug pressure transmitter PT3461C and plug X25 in E95.03                                                                            |                                             |        |                 |
|                                                                          | <b>Remark:</b> ID fault FCM-20 module #03 comes up                                                                                      |                                             |        |                 |
|                                                                          | – Measure cables with multimeter on plug X25 terminals 79 and 80 against each other and against ground for short circuit or earth fault |                                             |        |                 |
|                                                                          | – Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available                               |                                             |        |                 |
|                                                                          | – Measure transmitter for earth fault, replace pressure transmitter PT3461C if required                                                 |                                             |        |                 |
| – If red LED remains ON with disconnected X25, replace FCM-20 module #03 |                                                                                                                                         |                                             |        |                 |
| Failure text                                                             |                                                                                                                                         | ME fuel rail pressure sensor #2 meas. fail. |        |                 |
| Failure LED:                                                             | FCM-20 No.                                                                                                                              | LED                                         |        | Blink intervals |
|                                                                          | #04                                                                                                                                     | AI1                                         | Yellow | 1 x             |
| Cause:                                                                   | Sensor Signal < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)                                                           |                                             |        |                 |
| Fault finding, remedies:                                                 | – Check pressure transmitter PT3462C on fuel rail                                                                                       |                                             |        |                 |
|                                                                          | – Check supply voltage 24 VDC on plug X25 (terminal 79+ / housing –) in E95.04 and on transmitter plug                                  |                                             |        |                 |
|                                                                          | – Check cabling from pressure transmitter PT3462C to E95.04                                                                             |                                             |        |                 |
|                                                                          | – Re-establish proper wiring from pressure transmitter PT3462C to E95.04                                                                |                                             |        |                 |
|                                                                          | – Exchange pressure transmitter PT3462C if necessary                                                                                    |                                             |        |                 |
| Failure LED:                                                             | FCM-20 No.                                                                                                                              | LED                                         |        | Blink intervals |
|                                                                          | #04                                                                                                                                     | AI1                                         | Red    | None            |
| Cause:                                                                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                             |                                             |        |                 |
| Fault finding, remedies:                                                 | – Unplug pressure transmitter PT3462C and plug X25 in E95.04                                                                            |                                             |        |                 |
|                                                                          | <b>Remark:</b> ID fault FCM-20 module #04 comes up                                                                                      |                                             |        |                 |
|                                                                          | – Measure cables with multimeter on plug X25 terminals 79 and 80 against each other and against ground for short circuit or earth fault |                                             |        |                 |
|                                                                          | – Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available                               |                                             |        |                 |
|                                                                          | – Measure transmitter for earth fault, replace pressure transmitter PT3462C if required                                                 |                                             |        |                 |
| – If red LED remains ON with disconnected X25, replace FCM-20 module #04 |                                                                                                                                         |                                             |        |                 |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                     | WECS module FCM–20 #00 fail.               |          |                 |          |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|----------|-----------------|----------|
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                          | LED                                        |          | Blink intervals |          |
|                          |                                                                                                                                                                                                                                                                                                                                                                                     | #00 (E90)                                  | Fail     | Red or None     | None     |
| Cause:                   | Missing communication on CAN S1 <b>and</b> CAN S2 bus on FCM–20 module #00<br>No heartbeat signal from this module received by the remaining modules in the system on <b>either</b> S-bus                                                                                                                                                                                           |                                            |          |                 |          |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check that both CAN S-bus plugs X22 <b>and</b> X23 are correctly inserted</li><li>– Check that wiring of S-bus cables to plugs X22 and X23 is correct (no mixup of + and –)</li><li>– Check that FCM–20 module #00 is powered1-on</li><li>– Replace FCM–20 'online spare' module if necessary</li></ul>                                     |                                            |          |                 |          |
|                          | <b>Remark:</b> In case of this failure a service computer possibly connected to CAN M #0 will loose its communication                                                                                                                                                                                                                                                               |                                            |          |                 |          |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                     | WECS any FCM–20 module cyl. ID lost        |          |                 |          |
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                          | LED                                        |          | Blink intervals |          |
|                          |                                                                                                                                                                                                                                                                                                                                                                                     | #00 to #12                                 | ID       | Red             | None     |
| Cause:                   | Invalid identification jumper setting on X25                                                                                                                                                                                                                                                                                                                                        |                                            |          |                 |          |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check cabling address on plug X25 of corresponding FCM–20 module</li><li>– Re-establish proper wiring of identification jumpers on X25 of the corresponding FCM–20 module</li></ul>                                                                                                                                                         |                                            |          |                 |          |
|                          | <b>Remark:</b> If this failure occurs during a running FCM–20 module, it will not affect engine operation<br><br>If this failure occurs when the FCM–20 module is powered-off or a FCM–20 module restarts with this failure present, then the running FCM–20 module will not resume its function and the corresponding cylinder is cut out                                          |                                            |          |                 |          |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                     | WECS CAN S-bus connection fail. FCM–20 #00 |          |                 |          |
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                          | LED                                        |          | Blink intervals |          |
|                          |                                                                                                                                                                                                                                                                                                                                                                                     | #00 (E90)                                  | S1 or S2 | Red             | flashing |
| Cause:                   | Missing bus connection on CAN S-bus #1 or CAN S-bus #2 on FCM–20 #00 module                                                                                                                                                                                                                                                                                                         |                                            |          |                 |          |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check that both CAN S-bus plugs X22 and X23 are correctly inserted on this 'online spare' module</li><li>– Re-establish proper cable connection on plugs X22 and X23 on FCM–20 'online spare' module</li><li>– Cycle module's power supply off and on for this module</li><li>– Replace the FCM–20 #00 module if failure persists</li></ul> |                                            |          |                 |          |

## Failures and Defects of WECS Components

| Failure text             |            | WECS CAN S-/ SSI bus connection fail. FCM-20 #nn                                                                                                                                                                                                                                                                                                                                                                                             |      |                 |
|--------------------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----------------|
| Failure LED:             | FCM-20 No. | LED                                                                                                                                                                                                                                                                                                                                                                                                                                          |      | Blink intervals |
|                          | #01 to #12 | None                                                                                                                                                                                                                                                                                                                                                                                                                                         | None | None            |
|                          | Cause:     | Either both CAN S-bus #1 and crankangle signal #1 or CAN S-bus #2 and crankangle signal #2 missing on FCM-20 module                                                                                                                                                                                                                                                                                                                          |      |                 |
| Fault finding, remedies: |            | <ul style="list-style-type: none"> <li>– Check that plug X22 is correctly connected to the corresponding FCM-20 module</li> <li>– Connect plug X22 properly to corresponding FCM-20 module</li> </ul>                                                                                                                                                                                                                                        |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |
| Failure:                 | FCM-20 No. | LED                                                                                                                                                                                                                                                                                                                                                                                                                                          |      | Blink intervals |
|                          | #01 to #12 | S2 and CA2                                                                                                                                                                                                                                                                                                                                                                                                                                   | Red  | None            |
|                          | Cause:     | Either both CAN S-bus #1 and crankangle signal #1 or CAN S-bus #2 and crankangle signal #2 missing on FCM-20 module                                                                                                                                                                                                                                                                                                                          |      |                 |
| Fault finding, Remedies: |            | <ul style="list-style-type: none"> <li>– Check that plug X23 is correctly connected to the corresponding FCM-20 module</li> <li>– Connect plug X23 properly to corresponding FCM-20 module</li> </ul>                                                                                                                                                                                                                                        |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |
| Failure text             |            | WECS CAN S1-bus fail.                                                                                                                                                                                                                                                                                                                                                                                                                        |      |                 |
| Failure LED:             | FCM-20 No. | LED                                                                                                                                                                                                                                                                                                                                                                                                                                          |      | Blink intervals |
|                          | #01 to #12 | S1                                                                                                                                                                                                                                                                                                                                                                                                                                           | Red  | Flashing        |
|                          | Cause:     | CAN system bus #1 monitoring / CAN controller failure (failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                          |      |                 |
| Fault finding, remedies: |            | <ul style="list-style-type: none"> <li>– Check cable connection on corresponding FCM-20 module (plug X22, terminals 49/50)</li> <li>– Check proper termination of S1-bus with 120 ohm resistors on first and last FCM-20 plug X22 (refer to el. drawings)</li> <li>– Re-establish proper cable connection corresponding on FCM-20 module</li> <li>– Replace the corresponding FCM-20 module if failure appears on one module only</li> </ul> |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |
| Failure text             |            | WECS CAN S2-bus fail.                                                                                                                                                                                                                                                                                                                                                                                                                        |      |                 |
| Failure LED:             | FCM-20 No. | LED                                                                                                                                                                                                                                                                                                                                                                                                                                          |      | Blink intervals |
|                          | #01 to #12 | S2                                                                                                                                                                                                                                                                                                                                                                                                                                           | Red  | Flashing        |
|                          | Cause:     | CAN system bus #2 monitoring / CAN controller failure (failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                          |      |                 |
| Fault finding, remedies: |            | <ul style="list-style-type: none"> <li>– Check cable connection on corresponding FCM-20 module (plug X23, terminals 57/58)</li> <li>– Check proper termination of S2-bus with 120 ohm resistors on first and last FCM-20 plug X23 (refer to el. drawings)</li> <li>– Re-establish proper cable connection corresponding on FCM-20 module</li> <li>– Replace the corresponding FCM-20 module if failure appears on one module only</li> </ul> |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |
|                          |            |                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                 |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | WECS Modbus fail. FCM–20 #01 or #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        |                 |      |  |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-----------------|------|--|
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | LED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        | Blink intervals |      |  |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | #01 and #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Modbus | Dark            | None |  |
|                          | Cause:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Modbus monitoring, no communication (failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |        |                 |      |  |
|                          | Fault finding, remedies:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <ul style="list-style-type: none"><li>– Check cable connection in corresponding FCM–20 module (plug X23, terminals 63/64) if LED does not light up</li><li>– Check cabling and connections in control boxes E90 and AMS / PCS boxes</li><li>– Check proper termination of modbus with 120 ohm resistors on AMS / PCS side and FCM–20 side (refer to el. drawings)</li><li>– Re-establish proper cabling, connection and termination in the corresponding FCM–20 module and control boxes</li><li>– Replace the corresponding FCM–20 module if failure appears on one module only</li></ul> |        |                 |      |  |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | WECS CAN M-bus fail. FCM–20 #01 to #04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |        |                 |      |  |
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | LED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |        | Blink intervals |      |  |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | #01 to #04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | M      | Red             | None |  |
| Cause:                   | CAN M-bus monitoring, except FCM–20 #00 failure (failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                 |      |  |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check cable connection in corresponding FCM–20 module (plug X22, terminals 55/56)</li><li>– Check bus cabling and connections in control box E90:</li><li>– Check bus cabling on PCS side (FCM–20 #01 and #02)</li><li>– Check bus cabling on ECR manual control panel side (FCM–20 #03)</li><li>– Check bus cabling on LC manual control panel side (FCM–20 #04)</li><li>– Check CAN M-bus cabling on ALM–20 modules to FCM–20 modules of last and penultimate cylinders</li><li>– Re-establish proper cabling, connection and termination at the corresponding FCM–20 module and control boxes</li><li>– Replace the corresponding FCM–20 module if necessary</li></ul> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |        |                 |      |  |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ME crank angle #1 fail. |     |                 |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----|-----------------|
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | LED                     |     | Blink intervals |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | SSI CA1                 | Red | 1 x             |
| Cause:                   | Crank angle sensor (GT5126C) data transmission failure or FCM-20 module (penultimate cylinder) switched off                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |     |                 |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– If failure is indicated on all cylinder modules, check sensor (GT5126C) and replace it if necessary</li><li>– Otherwise check SSI-bus terminating resistors 120 ohm on plug X22 (terminals 51/52, 53/54) of FCM-20 #01</li><li>– If failure is indicated on one module only, check on corresponding module, whether cable connections are ok on plug X22 (terminals 51/52, 53/54)</li><li>– If failure indication on a successive group of FCMs: Check SSI-bus cabling on plug X22 (terminals 51/52, 53/54) from highest failing cylinder and to next higher cylinder without alarm</li><li>– Re-establish proper cabling and connection in the corresponding FCM-20 module</li><li>– Re-establish proper SSI-bus terminating resistors 120 ohm on plug X22 (terminals 51/52, 53/54) of FCM-20 #01</li><li>– Replace the corresponding FCM-20 module if failure appears on one module only</li></ul> |                         |     |                 |

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ME crank angle #2 fail. |     |                 |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----|-----------------|
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | LED                     |     | Blink intervals |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | SSI CA2                 | Red | 1 x             |
| Cause:                   | Crank angle sensor (GT5127C) data transmission failure or FCM-20 module (last cylinder) switched off                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                         |     |                 |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– If failure is indicated on all cylinder modules, check sensor (GT5127C) and replace it if necessary</li><li>– Otherwise check SSI-bus terminating resistors 120 ohm on plug X23 (terminals 59/60, 61/62) of FCM-20 #01</li><li>– If failure is indicated on one module only, check on corresponding module, whether cable connections are ok on plug X23 (terminals 59/60, 61/62)</li><li>– If failure indication on a successive group of FCMs: Check SSI-bus cabling on plug X23 (terminals 59/60, 61/62) from highest failing cylinder and to next higher cylinder without alarm</li><li>– Re-establish proper cabling and connection in the corresponding FCM-20 module</li><li>– Re-establish proper SSI-bus terminating resistors 120 ohm on plug X23 (terminals 59/60, 61/62) of FCM-20 #01</li><li>– Replace the corresponding FCM-20 module if failure appears on one module only</li></ul> |                         |     |                 |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ME exhaust valve #nn position meas. fail. |           |                 |      |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|-----------|-----------------|------|
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | LED                                       |           | Blink intervals |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | #01 to #12                                | Ex.D      | Yellow          | 1 x  |
| Cause:                   | Sensors ZT5421C to 32C, signal < 2 mA or > 22 mA<br>(failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                            |                                           |           |                 |      |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check plug on corresponding terminal box E95.21 to E95.32 at cylinder cover</li><li>– Check corresponding cabling to sensor and FCM-20 module (plug X24, terminals 68 to 72)</li><li>– Re-establish proper cabling and connections in the corresponding FCM-20 module and in the terminal box</li><li>– Replace corresponding sensor if necessary</li><li>– If failure appears periodically, temporarily plug can be disconnected on terminal box until repair is possible</li></ul> |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | LED                                       |           | Blink intervals |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | #01 to #12                                | Ex.D      | Red             | None |
| Cause:                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                                                                                                                                                                                                                                                                                                                                                                                                  |                                           |           |                 |      |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check corresponding cabling to sensor and FCM-20 module (plug X24, terminals 68 to 72)</li><li>– Re-establish proper cabling and connections in the corresponding FCM-20 module and in the terminal box</li><li>– Replace corresponding sensor if necessary</li><li>– If failure appears periodically, exchange cable-plug assembly to E95 with spare</li></ul>                                                                                                                      |                                           |           |                 |      |
|                          | <b>Remark:</b> Temporarily plug can be disconnected on terminal box until repair is possible                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ME start pilot valve #nn loop fail.       |           |                 |      |
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | LED                                       |           | Blink intervals |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | #01 to #12                                | Start Vlv | Red             | None |
| Cause:                   | Broken connection or short circuit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                           |           |                 |      |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check plug in terminal box E95.41 to E95.52 at cylinder cover</li><li>– Check cabling between corresponding solenoid valve and FCM-20 module (plug X15, terminals 33/34) for earth faults, short circuit or bad contact</li><li>– Re-establish proper cabling and connections between corresponding solenoid valve and FCM-20 module (plug X15)</li></ul>                                                                                                                            |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | WECS cylinder lubrication passive failure |           |                 |      |
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | LED                                       |           | Blink intervals |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           | None      | None            | None |
| Cause:                   | Interrupted power supply #1 or #2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                           |           |                 |      |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check cabling in E85, E90 and E41.xx</li><li>– Check whether power supply is interrupted by circuit breakers in E85</li><li>– Re-establish proper cabling and connections in E85, E90 (terminals 40/41) and E41.xx (plug X2, terminals 21/22)</li></ul>                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |           |                 |      |

## Failures and Defects of WECS Components

| Failure text                                           | WECS cylinder lubrication passive failure                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |     |                        |
|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-----|------------------------|
| Failure LED:<br><br>Cause:<br>Fault finding, remedies: | <b>FCM-20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>LED</b> |     | <b>Blink intervals</b> |
|                                                        | Last or penultimate                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | CAN M      | Red | None                   |
|                                                        | No signal communication CAN M#YY or #XX                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |     |                        |
|                                                        | – Check cabling in FCM-20 module of last and penultimate cylinders (plug X22, terminals 55/56)<br>– Check whether defective CAN M-Bus is indicated on ALM-20 modules (LED: CAN1 or CAN2)<br>– Re-establish proper cabling and connections in FCM-20 module of last and penultimate cylinders (plug X22, terminals 55/56)<br>– Re-establish proper wiring of corresponding CAN M-Bus                                                                                                                                                                         |            |     |                        |
|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |     |                        |
| Failure LED:<br><br>Cause:<br>Fault finding, remedies: | <b>ALM-20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>LED</b> |     | <b>Blink intervals</b> |
|                                                        | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Fail       | Red | 3 x                    |
|                                                        | ALM-20 module occurs an identification failure                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |     |                        |
|                                                        | – Check corresponding ALM-20 module is active, however, after a restarting of all ALM-20 modules, corresponding ALM-20 remains inactive<br>– Check cabling address on plug X1 of corresponding ALM-20 module<br>– Check on ALM-20 modules (plug X1, terminals 16/17) and corresponding resistor (for values see 7218-1 'Resistor on plug X1)<br>– Re-establish correct connections in corresponding ALM-20 module (plug X1, terminals 16/17)<br>– Replace resistor on plug X1 of corresponding ALM-20 module<br>– Replace corresponding ALM-20 if necessary |            |     |                        |
|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |     |                        |

## Failures and Defects of WECS Components

## 4.5 WECS common failure

| Failure text             | ME scavenge air pressure sensor #1+2 meas. fail.                                                                                        |     |        |                 |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-----|--------|-----------------|
| Failure LED:             | FCM–20 No.                                                                                                                              | LED |        | Blink intervals |
|                          | #03 and #04                                                                                                                             | AI2 | Yellow | 2 x             |
| Cause:                   | Both sensor signals < 2 mA or > 22 mA                                                                                                   |     |        |                 |
| Fault finding, remedies: | – Check pressure transmitters PT4043C and PT4044C                                                                                       |     |        |                 |
|                          | – Check supply voltage 24 VDC on plugs (X27) and cabling in E12, E95.03 and E95.04                                                      |     |        |                 |
|                          | – Check cabling to E12, E95.03 and E95.04                                                                                               |     |        |                 |
|                          | – Re-establish proper cabling and connections in E12, E95.03 and E95.04                                                                 |     |        |                 |
|                          | – Replace at least one pressure transmitter immediately                                                                                 |     |        |                 |
| Failure LED:             | FCM–20 No.                                                                                                                              | LED |        | Blink intervals |
|                          | #03 and #04                                                                                                                             | AI2 | Red    | None            |
| Cause:                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                             |     |        |                 |
| Fault finding, remedies: | – Unplug pressure transmitters PT4043 and PT4044C and plugs X27                                                                         |     |        |                 |
|                          | – Measure cables with multimeter on plug X27 terminals 94 and 95 against each other and against ground for short circuit or earth fault |     |        |                 |
|                          | – Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available                               |     |        |                 |
|                          | – Measure transmitters for earth fault, replace if required                                                                             |     |        |                 |
|                          | – If red LED remains ON with disconnected plug X27, replace corresponding FCM–20 module                                                 |     |        |                 |
| Failure text             | ME scavenge air pressure meas. fail. diff. high                                                                                         |     |        |                 |
| Failure LED:             | FCM–20 No.                                                                                                                              | LED |        | Blink intervals |
|                          | #03 and #04                                                                                                                             | AI2 | Yellow | 3 x             |
| Cause:                   | Sensor PT4043C and PT4044C ok, but difference > 0.2 bar (failure signal release is 5 seconds delayed)                                   |     |        |                 |
| Fault finding, remedies: | – Compare both scavenge air pressure indications in 'operator interface' with pressure gauge to detect differing pressure transmitter   |     |        |                 |
|                          | – Check cabling in E12, E95.03 and E95.04                                                                                               |     |        |                 |
|                          | – Readjust transmitter or replace it if necessary                                                                                       |     |        |                 |

## Failures and Defects of WECS Components

| Failure text |                          | ME servo oil pressure sensor #1+#2 meas. fail.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |                 |      |  |
|--------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------------|------|--|
| Failure LED: | FCM-20 No.               | LED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | Blink intervals |      |  |
|              |                          | #01 and #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | AI2 | Yellow          | 2 x  |  |
|              | Cause:                   | Both sensor signals < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |                 |      |  |
|              | Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check pressure transmitters PT2071C and PT2072C on servo oil rail</li><li>– Check supply voltage 24 VDC on plugs X27 (terminals 94+/96–) in E95.01 and E95.02 and on transmitter plugs</li><li>– Check cabling to E95.01 and E95.02</li><li>– Re-establish proper wiring from pressure transmitter to E95.01 or E95.02</li><li>– Replace at least one pressure transmitter immediately</li></ul>                                                                                                                                                                                           |     |                 |      |  |
| Failure LED: | FCM-20 No.               | LED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | Blink intervals |      |  |
|              |                          | #01 and #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | AI2 | Red             | None |  |
|              | Cause:                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |     |                 |      |  |
|              | Fault finding, remedies: | <ul style="list-style-type: none"><li>– Unplug pressure transmitters PT2071C and PT2072C and plugs X27</li><li>– Measure cables with multimeter on plugs X27 terminals 94 and 95 against each other and against ground for short circuit or earth fault</li><li>– Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available</li><li>– Measure transmitters for earth fault, replace pressure transmitter if required</li><li>– If red LED remains ON with disconnected plug X27, replace corresponding FCM-20 module</li></ul>                                                       |     |                 |      |  |
| Failure text |                          | ME servo oil pressure meas. fail. diff. high                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |     |                 |      |  |
| Failure LED: | FCM-20 No.               | LED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | Blink intervals |      |  |
|              |                          | #01 and #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | AI2 | Yellow          | 3 x  |  |
|              | Cause:                   | Sensor PT2071C and PT2072C ok, but difference > 10 bar (failure signal release is 7 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |     |                 |      |  |
|              | Fault finding, remedies: | <ul style="list-style-type: none"><li>– Compare both servo oil pressure indications</li><li>– With engine stopped and servo oil rail depressurised, establish which of the pressure transmitters deviates</li><li>– If possible, change engine load through a wider range and verify which pressure transmitter does not follow linearly to the changing servo oil pressure</li><li>– Check cabling in E95.01 and E95.02 of differing pressure transmitter (plug X27, terminals 94/95)</li><li>– Re-establish proper cabling of differing pressure transmitter</li><li>– Replace pressure transmitter PT2071C or PT2072C</li></ul> |     |                 |      |  |
| Failure text |                          | ME servo oil pressure high                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     |                 |      |  |
| Failure LED: | FCM-20 No.               | LED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     | Blink intervals |      |  |
|              |                          | #01 and #02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | AI2 | Yellow          | 4 x  |  |
|              | Cause:                   | Servo oil pressure 15 bar > setpoint, engine speed > 8% (failure signal release is 5 seconds delayed)<br><b>Remark:</b> Failure is suppressed under following conditions:<br>Slow turning and air run<br>Pressure controllers not adjusted in servo oil pumps after overhaul<br>Dirt particle obstructs the function of a pressure controller                                                                                                                                                                                                                                                                                      |     |                 |      |  |
|              | Fault finding, remedies: | <ul style="list-style-type: none"><li>– Adjust pressure controllers in servo oil pumps</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |                 |      |  |

## Failures and Defects of WECS Components

| Failure text                                                                                                                             |                                                                                                                                      | ME servo oil pressure low  |     |                 |
|------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-----|-----------------|
| Failure LED:                                                                                                                             | FCM–20 No.                                                                                                                           | LED                        |     | Blink intervals |
|                                                                                                                                          |                                                                                                                                      | #01 and #02                | AI2 | Yellow          |
| Cause:                                                                                                                                   | Servo oil pressure 15 bar < setpoint, engine speed > 8% (failure signal release is 10 seconds delayed)                               |                            |     |                 |
| Fault finding, remedies:                                                                                                                 | <b>Remark:</b> Failure is suppressed under following conditions:<br>Slow turning, air run, shut-down and servo oil pressure very low |                            |     |                 |
|                                                                                                                                          | – Check oil pressure after automatic filter                                                                                          |                            |     |                 |
|                                                                                                                                          | – Check control signals and cabling to servo oil pumps                                                                               |                            |     |                 |
|                                                                                                                                          | – Safety valve 4.23 open?                                                                                                            |                            |     |                 |
|                                                                                                                                          | – Pump drive, shaft 4.50 broken (pump temperatur low, no vibrations) or pump defective                                               |                            |     |                 |
| – Leakages on the rising pipes between servo oil pumps and servo oil rail                                                                |                                                                                                                                      |                            |     |                 |
| – Exchange pressure controller (CV7221C, CV7222C, CV7223C) if necessary                                                                  |                                                                                                                                      |                            |     |                 |
| – Eliminate leakages                                                                                                                     |                                                                                                                                      |                            |     |                 |
| <b>Remark:</b> In severe cases temporarily switch off injection and exhaust valve operation on 1 or 2 units to raise servo oil pressure  |                                                                                                                                      |                            |     |                 |
| <b>Attention:</b> Prevent switching off units in firing order sequence, do not operate engine near resonance vibrations due to misfiring |                                                                                                                                      |                            |     |                 |
| Failure text                                                                                                                             |                                                                                                                                      | ME servo oil pump #1 fail. |     |                 |
| Failure LED:                                                                                                                             | FCM–20 No.                                                                                                                           | LED                        |     | Blink intervals |
|                                                                                                                                          |                                                                                                                                      | #03                        | PWM | Red             |
| Cause:                                                                                                                                   | Setpoint pressure controller of servo oil pump CV7221C > 100 mA (Failure signal release is 30 seconds delayed)                       |                            |     |                 |
| Fault finding, remedies:                                                                                                                 | – Check cable connections between pump #1 and E95.03                                                                                 |                            |     |                 |
|                                                                                                                                          | – Check plug connection on pressure controller CV7221C                                                                               |                            |     |                 |
|                                                                                                                                          | – FCM–20 #03 in E85 switched off                                                                                                     |                            |     |                 |
|                                                                                                                                          | – Re-establish proper cabling and connections between pump #1 and E95.03                                                             |                            |     |                 |
|                                                                                                                                          | – If necessary change pressure controller CV7221C                                                                                    |                            |     |                 |
| Failure text                                                                                                                             |                                                                                                                                      | ME servo oil pump #2 fail. |     |                 |
| Failure LED:                                                                                                                             | FCM–20 No.                                                                                                                           | LED                        |     | Blink intervals |
|                                                                                                                                          |                                                                                                                                      | #04                        | PWM | Red             |
| Cause:                                                                                                                                   | Setpoint pressure controller of servo oil pump CV7222C > 100 mA (failure signal release is 30 seconds delayed)                       |                            |     |                 |
| Fault finding, remedies:                                                                                                                 | – Check cable connections between pump #2 and E95.04                                                                                 |                            |     |                 |
|                                                                                                                                          | – Check plug connection on pressure controller CV7222C                                                                               |                            |     |                 |
|                                                                                                                                          | – FCM–20 #04 in E85 switched off                                                                                                     |                            |     |                 |
|                                                                                                                                          | – Re-establish proper cabling and connections between pump #2 and E95.04                                                             |                            |     |                 |
|                                                                                                                                          | – If necessary change pressure controller CV7222C                                                                                    |                            |     |                 |

## Failures and Defects of WECS Components

| Failure text                                                                            |                                                                                                                                         | ME servo oil pump #3 fail.                     |     |                 |
|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-----|-----------------|
| Failure LED:                                                                            | FCM-20 No.                                                                                                                              | LED                                            |     | Blink intervals |
|                                                                                         |                                                                                                                                         | #05                                            | PWM | Red             |
| Cause:                                                                                  | Setpoint pressure controller of servo oil pump CV7223C > 100 mA (failure signal release is 30 seconds delayed)                          |                                                |     |                 |
| Fault finding, remedies:                                                                | – Check cable connections between pump #3 and E95.05                                                                                    |                                                |     |                 |
|                                                                                         | – Check plug connection on pressure controller CV7223C                                                                                  |                                                |     |                 |
|                                                                                         | – FCM-20 #05 in E85 switched off                                                                                                        |                                                |     |                 |
|                                                                                         | – Re-establish proper cabling and connections between pump #3 and E95.05                                                                |                                                |     |                 |
|                                                                                         | – If necessary change pressure controller CV7223C                                                                                       |                                                |     |                 |
| Failure text                                                                            |                                                                                                                                         | ME fuel rail pressure sensor #1+#2 meas. fail. |     |                 |
| Failure LED:                                                                            | FCM-20 No.                                                                                                                              | LED                                            |     | Blink intervals |
|                                                                                         |                                                                                                                                         | #03 and #04                                    | AI1 | Yellow          |
| Cause:                                                                                  | Both sensor signals < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)                                                     |                                                |     |                 |
| Fault finding, remedies:                                                                | – Check pressure transmitters PT3461C and PT3462C on fuel rail                                                                          |                                                |     |                 |
|                                                                                         | – Check supply voltage 24 VDC on plugs (X25, terminal 79 and ground) and cabling to E95.03 and E95.04                                   |                                                |     |                 |
|                                                                                         | – Check cabling to E95.03 and E95.04                                                                                                    |                                                |     |                 |
|                                                                                         | – Re-establish proper wiring from pressure transmitter to E95.03 or E95.04                                                              |                                                |     |                 |
|                                                                                         | – Replace at least one pressure transmitter immediately                                                                                 |                                                |     |                 |
| Failure LED:                                                                            | FCM-20 No.                                                                                                                              | LED                                            |     | Blink intervals |
|                                                                                         |                                                                                                                                         | #03 and #04                                    | AI2 | Red             |
| Cause:                                                                                  | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                             |                                                |     |                 |
| Fault finding, remedies:                                                                | – Unplug pressure transmitters PT 3461C and PT3462C and plugs X25                                                                       |                                                |     |                 |
|                                                                                         | <b>Remark:</b> ID fault FCM-20 module #03 and #04 come up                                                                               |                                                |     |                 |
|                                                                                         | – Measure cables with multimeter on plug X25 terminals 79 and 80 against each other and against ground for short circuit or earth fault |                                                |     |                 |
|                                                                                         | – Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available                               |                                                |     |                 |
|                                                                                         | – Measure transmitters for earth fault, replace pressure transmitter if required                                                        |                                                |     |                 |
| – If red LED remains ON with disconnected plug X25, replace corresponding FCM-20 module |                                                                                                                                         |                                                |     |                 |
| Failure text                                                                            |                                                                                                                                         | ME fuel rail pressure meas. fail. diff. high   |     |                 |
| Failure LED:                                                                            | FCM-20 No.                                                                                                                              | LED                                            |     | Blink intervals |
|                                                                                         |                                                                                                                                         | #03 and #04                                    | AI1 | Yellow          |
| Cause:                                                                                  | Sensor PT3461C and PT3462C ok, but difference > 50 bar (failure signal release is 7 seconds delayed)                                    |                                                |     |                 |
| Fault finding, remedies:                                                                | – Compare both fuel rail pressure indications                                                                                           |                                                |     |                 |
|                                                                                         | – With engine stopped and fuel rail depressurised, establish witch of the pressure transmitters deviates                                |                                                |     |                 |
|                                                                                         | – If possible change engine load range to vary fuel rail pressure and verify which sensor does not follow linearly                      |                                                |     |                 |
|                                                                                         | – Check cabling of differing pressure transmitter (plug X25, terminal 79/80)                                                            |                                                |     |                 |
|                                                                                         | – Re-establish proper cabling of differing pressure transmitter                                                                         |                                                |     |                 |
| – Replace pressure transmitter if necessary                                             |                                                                                                                                         |                                                |     |                 |

## Failures and Defects of WECS Components

| Failure text                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | ME fuel rail pressure high |     |                 |
|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-----|-----------------|
| Failure LED:                                                                                       | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | LED                        |     | Blink intervals |
|                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | #03 and #04                | AI1 | Yellow          |
| Cause:                                                                                             | Fuel rail pressure 100 bar > fuel pressure setpoint (failure signal release is 10 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |     |                 |
| Fault finding, remedies:                                                                           | Remark: Failure is suppressed at engine stand still                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |     |                 |
|                                                                                                    | <ul style="list-style-type: none"><li>– Check if fuel pump actuators are switched on and working.</li><li>– All fuel pump racks must move freely</li><li>– Check for actuator alarms in alarm monitoring system</li><li>– If alarms come up every time the engine speed is reduced, check that all fuel pump racks are in no delivery position, when actuator output is 0%</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                            |     |                 |
|                                                                                                    | Remark: Can appear if engine is repeatedly started and stopped without having any fuel injection release in between                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |     |                 |
| <ul style="list-style-type: none"><li>– If required exchange damaged fuel pump actuators</li></ul> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |     |                 |
| Failure text                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | ME fuel rail pressure low  |     |                 |
| Failure LED:                                                                                       | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | LED                        |     | Blink intervals |
|                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | #03 and #04                | AI1 | Yellow          |
| Cause:                                                                                             | Fuel rail pressure 100 bar < fuel pressure setpoint (failure signal release is 10 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |     |                 |
| Fault finding, remedies:                                                                           | Remark: Failure is suppressed under following conditions:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                            |     |                 |
|                                                                                                    | No engine running, no start command, fuel rail pressure very low                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |     |                 |
|                                                                                                    | <ul style="list-style-type: none"><li>– Check whether fuel pump actuators are switched on and act properly</li><li>– All fuel pump racks must move freely</li><li>– Check actuator alarms in AMS</li><li>– Check whether fuel supply pressure of 7 to 10 bar is ok</li><li>– Any leakage alarms active?</li><li>– Check whether oil supply to fuel pressure control valve 3.06 is ok or valve seat seized</li><li>– Check if fuel pressure control valve 3.06 is leaking (this can be heard by a whistling sound)</li><li>– Check alarms (TE3431 to 36A) for temperature monitoring</li><li>– Fuel overpressure safety valve 3.52 leaking</li><li>– Non-return valves 3.81 (–1 to –6) on fuel rail and 3.22 in fuel pump covers damaged?</li><li>– Check: Fuel pump plunger seized (fuel pump does not deliver)</li><li>– If required exchange damaged fuel pump actuators</li><li>– Eliminate leakages</li><li>– Replace defective valves</li><li>– Regrind sealing surfaces on rising pipes between fuel pump and fuel rail if there are leakages discovered</li></ul> |                            |     |                 |

## Failures and Defects of WECS Components

| Failure text             | ME crank angle difference between #1 and #2                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |        |                        |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--------|------------------------|
| Failure LED:             | <b>FCM-20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>LED</b> |        | <b>Blink intervals</b> |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | SSI CA1    | Red    | 3 x                    |
| Cause:                   | Crank angle sensor #1 and #2 ok, but difference > 1.0°                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |        |                        |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Check if toothed belt has shifted or slackened</li> <li>– When flywheel is at TDC of Cyl. 1, both sensors must indicate 0° CA (in 'operator interface')</li> <li>– Adjust offset parameter in flexView or belt position on the sensor drive unit</li> <li>– Engine stopped: Run trend line of both crank angle sensor signals in flexView</li> <li>– Turn engine over once on turning gear and confirm both sensors are exactly parallel</li> </ul> |            |        |                        |
| Failure text             | ME crank angle #1 / TDC low shift                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |        |                        |
| Failure LED:             | <b>FCM-20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>LED</b> |        | <b>Blink intervals</b> |
|                          | #05                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | BI1        | Yellow | 2 x                    |
| Cause:                   | Tolerance > ± 2.0°                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |        |                        |
|                          | Crank angle sensor or toothed belt shifted                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |        |                        |
|                          | <b>Remark:</b> Failure is suppressed at shut-down                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |        |                        |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Check for wrong TDC offset adjustment</li> <li>– Check possibility of shifted crankshaft</li> <li>– Adjust correct distance of TDC pickup to flywheel tooth</li> <li>– Adjust offset parameter or belt position if necessary</li> </ul>                                                                                                                                                                                                             |            |        |                        |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                                       | ME crank angle #2 / TDC low shift  |     |                 |     |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------|------------------------------------|-----|-----------------|-----|
| Failure LED:             | FCM-20 No.                                                                                                            | LED                                |     | Blink intervals |     |
|                          |                                                                                                                       | #05                                | BI1 | Yellow          | 4 x |
| Cause:                   | Tolerance > ± 2.0°<br>Crank angle sensor or toothed belt shifted<br><b>Remark:</b> Failure is suppressed at shut-down |                                    |     |                 |     |
| Fault finding, remedies: | – Check for wrong TDC offset adjustment                                                                               |                                    |     |                 |     |
|                          | – Check possibility of shifted crankshaft                                                                             |                                    |     |                 |     |
|                          | – Adjust correct distance of TDC pickup to flywheel tooth                                                             |                                    |     |                 |     |
|                          | – Adjust offset parameter or belt position if necessary                                                               |                                    |     |                 |     |
| Failure text             |                                                                                                                       | ME crank angle #1 / TDC high shift |     |                 |     |
| Failure LED:             | FCM-20 No.                                                                                                            | LED                                |     | Blink intervals |     |
|                          |                                                                                                                       | #05                                | BI1 | Yellow          | 3 x |
| Cause:                   | Tolerance > ± 4.0°<br>Crank angle sensor or toothed belt shifted<br><b>Remark:</b> Failure is suppressed at shut-down |                                    |     |                 |     |
| Fault finding, remedies: | – Check for wrong TDC offset adjustment                                                                               |                                    |     |                 |     |
|                          | – Check possibility of shifted crankshaft                                                                             |                                    |     |                 |     |
|                          | – Adjust correct distance of TDC pickup to flywheel tooth                                                             |                                    |     |                 |     |
|                          | – Adjust offset parameter or belt position if necessary                                                               |                                    |     |                 |     |
| Failure text             |                                                                                                                       | ME crank angle #2 / TDC high shift |     |                 |     |
| Failure LED:             | FCM-20 No.                                                                                                            | LED                                |     | Blink intervals |     |
|                          |                                                                                                                       | #05                                | BI1 | Yellow          | 5 x |
| Cause:                   | Tolerance > ± 4.0°<br>Crank angle sensor or toothed belt shifted<br><b>Remark:</b> Failure is suppressed at shut-down |                                    |     |                 |     |
| Fault finding, remedies: | – Check for wrong TDC offset adjustment                                                                               |                                    |     |                 |     |
|                          | – Check possibility of shifted crankshaft                                                                             |                                    |     |                 |     |
|                          | – Adjust correct distance of TDC pickup to flywheel tooth                                                             |                                    |     |                 |     |
|                          | – Adjust offset parameter or belt position if necessary                                                               |                                    |     |                 |     |
| Failure text             |                                                                                                                       | ME TDC signal fail.                |     |                 |     |
| Failure LED:             | FCM-20 No.                                                                                                            | LED                                |     | Blink intervals |     |
|                          |                                                                                                                       | #05                                | BI1 | Yellow          | 1 x |
| Cause:                   | No TDC signal from pickup ZS5123C (failure signal release is 10 seconds delayed)                                      |                                    |     |                 |     |
| Fault finding, remedies: | – Check cabling from pickup ZS5123C to E95.05 and correct distance between pickup and flywheel tooth                  |                                    |     |                 |     |
|                          | – Check cabling, supply voltage and signal from pickup ZS5123C to E95.05 (plug X27, terminals 89/90/91)               |                                    |     |                 |     |
|                          | – Re-establish proper cabling from pickup ZS5123C to E95.05                                                           |                                    |     |                 |     |
|                          | – Adjust distance between pickup and flywheel tooth if necessary                                                      |                                    |     |                 |     |
|                          | – Replace pickup if necessary                                                                                         |                                    |     |                 |     |
|                          | – For emergency operation disconnect TDC pickup temporarily if pickup fault prevents engine operation                 |                                    |     |                 |     |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                                                                      | ME TDC signal fail.                          |      |                 |      |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------|-----------------|------|
| Failure LED:             | FCM–20 No.                                                                                                                                           | LED                                          |      | Blink intervals |      |
|                          |                                                                                                                                                      | #05                                          | BI1  | Red             | None |
| Cause:                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                          |                                              |      |                 |      |
| Fault finding, remedies: | – Unplug TDC pickup ZS5123C and plug X27 in E95.05                                                                                                   |                                              |      |                 |      |
|                          | – Measure cable with multimeter on plug X27 terminals 89 and 90 against each other and against ground for short circuit or earth fault               |                                              |      |                 |      |
|                          | – Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available                                            |                                              |      |                 |      |
|                          | – Measure pickup for earth fault, replace if required                                                                                                |                                              |      |                 |      |
|                          | – If red LED remains ON with disconnected X27, replace FCM–20 module #05                                                                             |                                              |      |                 |      |
| Failure text             |                                                                                                                                                      | ME injection quantity sensor #nn meas. fail. |      |                 |      |
| Failure LED:             | FCM–20 No.                                                                                                                                           | LED                                          |      | Blink intervals |      |
|                          |                                                                                                                                                      | #01 to #12                                   | InjQ | Yellow          | 1 x  |
| Cause:                   | Sensor signal ZT5461C to 72C < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)                                                         |                                              |      |                 |      |
| Fault finding, remedies: | – Check cabling to corresponding fuel quantity sensor                                                                                                |                                              |      |                 |      |
|                          | – Check: Plug must fit tightly on socket                                                                                                             |                                              |      |                 |      |
|                          | – Make sure whether measuring sleeve is properly mounted on fuel quantity piston                                                                     |                                              |      |                 |      |
|                          | – Re-establish proper cabling between corresponding FCM–20 module and fuel quantity sensor                                                           |                                              |      |                 |      |
|                          | – Replace sensor if feedback is instable or disconnect plug temporarily if no spares available                                                       |                                              |      |                 |      |
| Failure LED:             | FCM–20 No.                                                                                                                                           | LED                                          |      | Blink intervals |      |
|                          |                                                                                                                                                      | #01 to #12                                   | InjQ | Red             | None |
| Cause:                   | A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED                                          |                                              |      |                 |      |
| Fault finding, remedies: | – Unplug fuel quantity sensor and plug X26                                                                                                           |                                              |      |                 |      |
|                          | <b>Remark:</b> CA sensor failure if FCM # last or penultimate cylinder                                                                               |                                              |      |                 |      |
|                          | – Measure cable with multimeter on plug X26 terminals 86 and 87 against each other and against ground (terminal 88) for short circuit or earth fault |                                              |      |                 |      |
|                          | – Exchange damaged cables or provisionally fix with insulation tape for remedy until spares are available                                            |                                              |      |                 |      |
|                          | – Exchange fuel quantity sensor if required                                                                                                          |                                              |      |                 |      |
|                          | – If red LED remains ON with disconnected plug X26, replace corresponding FCM–20 module                                                              |                                              |      |                 |      |

## Failures and Defects of WECS Components

| Failure text             | ME injection timing fail. cylinder #nn (injection time too short)                                                                                             |      |        |                 |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------|-----------------|
| Failure LED:             | FCM-20 No.                                                                                                                                                    | LED  |        | Blink intervals |
|                          | #01 to #12                                                                                                                                                    | InjQ | Yellow | 5 x             |
| Failure text             | ME injection timing fail. cylinder #nn (injection time too long)                                                                                              |      |        |                 |
| Failure LED:             | FCM-20 No.                                                                                                                                                    | LED  |        | Blink intervals |
|                          | #01 to #12                                                                                                                                                    | InjQ | Yellow | 6 x             |
| Cause:                   | Injection timing on corresponding cylinder to injection timing average < 0.6 or >1.5 (failure signal release is 60 seconds delayed)                           |      |        |                 |
| Fault finding, remedies: | <b>Remark:</b> Failure is suppressed under following conditions:<br>Engine speed below low load, injection cylinder #nn cut off                               |      |        |                 |
|                          | – Check: Injection time on cylinders deviates from other cylinders                                                                                            |      |        |                 |
|                          | – Check injection curve with flexView                                                                                                                         |      |        |                 |
|                          | – Check: Cracked, seized or stuck injection nozzle                                                                                                            |      |        |                 |
|                          | – Check: Leakage from injection pipe (alarm)                                                                                                                  |      |        |                 |
|                          | – Check: Too low opening pressure of injection valves                                                                                                         |      |        |                 |
|                          | – Check: Consequence of rail valve 3.76 failure: Check 'return ON-time' in 'operator interface' (can occur when operating with temporarily disconnected plug) |      |        |                 |
|                          | – Eliminate the leakage from injection pipe                                                                                                                   |      |        |                 |
|                          | – Replace the corresponding nozzle tip or rail valve if necessary                                                                                             |      |        |                 |
|                          | – Replace injection control unit if required                                                                                                                  |      |        |                 |

## Failures and Defects of WECS Components

## 4.6 WECS cylinder failure

| Failure text                                                                                                                                                                                  |                                                                                                         | WECS module FCM–20 #nn fail.                    |      |                 |             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------|------|-----------------|-------------|
| Failure LED:                                                                                                                                                                                  | FCM–20 No.                                                                                              | LED                                             |      | Blink intervals |             |
|                                                                                                                                                                                               |                                                                                                         | #01 to #12                                      | Fail | Red             | None        |
| Cause:                                                                                                                                                                                        | Can S1 and S2 bus monitoring FCM #01 to #12 no heartbeat (failure signal release is 12 seconds delayed) |                                                 |      |                 |             |
| Fault finding, remedies:                                                                                                                                                                      | – Check LEDs on FCM–20 module                                                                           |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Red LED lights up: Check cabling on corresponding FCM–20 module and plugs X22 and X23                 |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Re-establish proper cabling on corresponding FCM–20 module and plugs X22 and X23                      |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Replace corresponding FCM–20 module if failure occurs on one module only                              |                                                 |      |                 |             |
| Failure text                                                                                                                                                                                  |                                                                                                         | ME both CA / TDC low shift                      |      |                 |             |
| Failure LED:                                                                                                                                                                                  | FCM–20 No.                                                                                              | LED                                             |      | Blink intervals |             |
|                                                                                                                                                                                               |                                                                                                         | #05                                             | BI1  | Yellow          | 2 x and 4 x |
| Cause:                                                                                                                                                                                        | CA low shift CA #1 and CA #2                                                                            |                                                 |      |                 |             |
| Fault finding, remedies:                                                                                                                                                                      | – Check if TDC offset is wrongly adjusted                                                               |                                                 |      |                 |             |
|                                                                                                                                                                                               | – CA sensors mounted without correct setting of flywheel to TDC angle?                                  |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Crank angle sensor drive shaft wrongly assembled after overhaul?                                      |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Check possibility of shifted crankshaft                                                               |                                                 |      |                 |             |
| – Adjust offset parameter or belt position as required                                                                                                                                        |                                                                                                         |                                                 |      |                 |             |
| <b>Remark:</b> Measured offset in flexView changes depending of engine speed. Do not adjust offset to zero at full engine speed, as it may trigger this failure at higher ASTERN revolutions. |                                                                                                         |                                                 |      |                 |             |
| – Assemble sensor drive properly                                                                                                                                                              |                                                                                                         |                                                 |      |                 |             |
| Failure text                                                                                                                                                                                  |                                                                                                         | ME exhaust valve #nn fail. (late / not opening) |      |                 |             |
| Failure LED:                                                                                                                                                                                  | FCM–20 No.                                                                                              | LED                                             |      | Blink intervals |             |
|                                                                                                                                                                                               |                                                                                                         | #01 to #12                                      | Ex.D | Yellow          | 2 x         |
| Cause:                                                                                                                                                                                        | Late opening ≥ 15° (failure signal release is 3 revolutions delayed)                                    |                                                 |      |                 |             |
| Fault finding, remedies:                                                                                                                                                                      | – Check rail valve 4.76 (ON times high?)                                                                |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Check cable connection between rail valve and corresponding FCM–20 module                             |                                                 |      |                 |             |
|                                                                                                                                                                                               | – If on all units: Check air spring pressure too high?                                                  |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Check: Orifice choked in exhaust valve control unit 4.10                                              |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Check: Mechanical failure in exhaust valve control unit 4.10                                          |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Check: Seized hydraulic piston in valve drive 4.03                                                    |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Check: FCM–20 module defective                                                                        |                                                 |      |                 |             |
|                                                                                                                                                                                               | – Re-establish proper cable connection between rail valve and corresponding FCM–20 module               |                                                 |      |                 |             |
| – Replace corresponding FCM–20 module or exhaust valve control unit if necessary                                                                                                              |                                                                                                         |                                                 |      |                 |             |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                             | ME exhaust valve #nn fail. (early closing)             |      |                 |      |
|--------------------------|-------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|------|-----------------|------|
| Failure LED:             | FCM–20 No.                                                                                                  | LED                                                    |      | Blink intervals |      |
|                          |                                                                                                             | #01 to #12                                             | Ex.D | Yellow          | 3 x  |
| Cause:                   | Early closing ≥ 10° (failure signal release is 2 revolutions delayed)                                       |                                                        |      |                 |      |
| Fault finding, remedies: | – Check air spring pressure (too high?)                                                                     |                                                        |      |                 |      |
|                          | – Check: Orifice choked in exhaust valve control unit 4.10                                                  |                                                        |      |                 |      |
|                          | – Check: Mechanical failure in exhaust valve control unit 4.10                                              |                                                        |      |                 |      |
|                          | – Check: FCM–20 module defective                                                                            |                                                        |      |                 |      |
|                          | – Replace corresponding FCM–20 module or exhaust valve control unit if necessary                            |                                                        |      |                 |      |
| Failure text             |                                                                                                             | ME exhaust valve #nn fail. (late / not closing)        |      |                 |      |
| Failure LED:             | FCM–20 No.                                                                                                  | LED                                                    |      | Blink intervals |      |
|                          |                                                                                                             | #01 to #12                                             | Ex.D | Yellow          | 4 x  |
| Cause:                   | Late closing ≥ 15° (Failure signal release is 3 revolutions delayed)                                        |                                                        |      |                 |      |
| Fault finding, remedies: | – Check rail valve 4.76 (ON times high?)                                                                    |                                                        |      |                 |      |
|                          | – Check cable connection between rail valve and corresponding FCM–20 module                                 |                                                        |      |                 |      |
|                          | – Check air spring pressure (too low?)                                                                      |                                                        |      |                 |      |
|                          | – Check non-return valve 4.06 in connection of air spring pipe on cylinder cover                            |                                                        |      |                 |      |
|                          | – Check: Mechanical failure in exhaust valve control unit 4.10                                              |                                                        |      |                 |      |
|                          | – Check: Seized hydraulic piston in valve drive 4.03                                                        |                                                        |      |                 |      |
|                          | – Check: FCM–20 module defective                                                                            |                                                        |      |                 |      |
|                          | – Re-establish proper cable connection between rail valve and corresponding FCM–20 module                   |                                                        |      |                 |      |
| Fault finding, remedies: | – Replace corresponding FCM–20 module or exhaust valve control unit if necessary                            |                                                        |      |                 |      |
|                          | – Replace rail valve or non-return valve 4.06 if necessary                                                  |                                                        |      |                 |      |
| Failure text             |                                                                                                             | ME exhaust valve #nn fail. (closing deadtime too long) |      |                 |      |
| Failure LED:             | FCM–20 No.                                                                                                  | LED                                                    |      | Blink intervals |      |
|                          |                                                                                                             | #01 to #12                                             | Ex.D | Yellow          | 5 x  |
| Cause:                   | Closing deadtime Cyl. #nn / Closing deadtime average >1.5 (failure signal release is 4 revolutions delayed) |                                                        |      |                 |      |
| Fault finding, remedies: | <b>Remark:</b> Failure is suppressed at shut-down                                                           |                                                        |      |                 |      |
|                          | – Check air spring pressure (too low?)                                                                      |                                                        |      |                 |      |
|                          | – Check non-return valve 4.06 in connection of air spring pipe on cylinder cover                            |                                                        |      |                 |      |
|                          | – Check: Valve drive 4.03 seized or valve stem fretting on guide bush                                       |                                                        |      |                 |      |
|                          | – Check: Mechanical failure in exhaust valve control unit 4.10                                              |                                                        |      |                 |      |
| Fault finding, remedies: | – Replace corresponding exhaust valve, drive or control unit, if necessary                                  |                                                        |      |                 |      |
|                          | – Replace rail valve or non-return valve 4.06 if necessary                                                  |                                                        |      |                 |      |
| Failure text             |                                                                                                             | ME manual injection cutoff cylinder #nn                |      |                 |      |
| Failure LED:             | FCM–20 No.                                                                                                  | LED                                                    |      | Blink intervals |      |
|                          |                                                                                                             | #01 to #12                                             | None | None            | None |
| Cause:                   | Indication of a manually selected cut-off, no failure!                                                      |                                                        |      |                 |      |

## Failures and Defects of WECS Components

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ME injection quantity piston fail. cylinder #nn (late / no return) |      |                 |     |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|------|-----------------|-----|
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | LED                                                                |      | Blink intervals |     |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | #01 to #12                                                         | InjQ | Yellow          | 2 x |
| Cause:                   | Injection quantity piston return value > 5.5 mA (failure signal release is 30 seconds delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                    |      |                 |     |
|                          | <b>Remark:</b> Failure is suppressed under following conditions:<br>Engine stand still, injection quantity piston stuck in max. position, injection quantity measurement fail                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                    |      |                 |     |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Consequence of rail valve 3.76 failure: Check 'return ON-time' in 'operator interface'</li><li>– Check injection curve with flexView</li><li>– Check: Plug must fit tightly on socket</li><li>– Make sure measuring sleeve is properly mounted on fuel quantity piston</li><li>– Check: Viscosity of fuel too high? (after longer engine stop and shut off heating)</li><li>– Replace quantity sensor if feedback is instable or disconnect plug temporarily if no spares available</li><li>– Press shortly manual lever on fuel shut-down pilot valve 3.08</li><li>– Briefly stop power to corresponding FCM–20 module</li><li>– Replace rail valve if necessary</li><li>– Can also hint on seized quantity piston, replace injection control unit if confirmed</li></ul> |                                                                    |      |                 |     |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                    |      |                 |     |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ME injection quantity piston fail. cylinder #nn (no movement)      |      |                 |     |
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | LED                                                                |      | Blink intervals |     |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | #01 to #12                                                         | InjQ | Yellow          | 3 x |
| Cause:                   | No piston movement sensed at injection begin angle (failure signal release is 3 revolutions delayed)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                    |      |                 |     |
|                          | <b>Remark:</b> Failure is suppressed under following conditions:<br>Engine stand still, injection quantity piston stuck in max. position, injection quantity measurement fail                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                    |      |                 |     |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Consequence of rail valve 3.76 failure: Check 'inject ON-time' in 'operator interface'</li><li>– Check injection curve with flexView</li><li>– Make sure measuring sleeve is properly mounted on fuel quantity piston</li><li>– Check: Viscosity of fuel too high? (after longer engine stop and shut off heating)</li><li>– Replace rail valve if necessary</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                    |      |                 |     |
|                          | <b>Remark:</b> Failure can appear if injection control unit is operated with disconnected fuel quantity sensor and fV Adjust PARA Art.InjQtyRate is set too high                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                    |      |                 |     |

## Failures and Defects of WECS Components

| Failure text             | ME injection quantity piston fail. cylinder #nn (stuck in max. position)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |        |                        |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--------|------------------------|
| Failure LED:             | <b>FCM-20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>LED</b> |        | <b>Blink intervals</b> |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | InjQ       | Yellow | 4 x                    |
| Cause:                   | Injection quantity piston return value > 18 mA (failure signal release is 30 seconds delayed)<br>Failure signal recovery is 10 seconds delayed                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |        |                        |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Consequence of rail valve 3.76 failure: Check 'return ON-time' in 'operator interface'</li> <li>– Check injection curve with flexView</li> <li>– Check: Plug must fit tightly on socket</li> <li>– Make sure measuring sleeve is properly mounted on fuel quantity piston</li> <li>– Check: Viscosity of fuel too high? (after longer engine stop and shut off heating)</li> <li>– Replace sensor if feedback is instable or disconnect plug temporarily if no spares available</li> <li>– Press shortly manual lever on fuel shut-down pilot valve 3.08</li> <li>– Replace rail valve if necessary</li> <li>– Can also hint on seized fuel quantity piston, replace injection control unit</li> </ul> <p><b>Remark:</b> Failure can appear if injection control unit is operated with disconnected fuel quantity sensor and fV Adjust PARA Art.InjQtyRate is set too low</p> |            |        |                        |

## Failures and Defects of WECS Components

## 4.7 WECS pressure failure

| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | ME scavenge air overpressure   |     |                 |     |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-----|-----------------|-----|
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | LED                            |     | Blink intervals |     |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | #03 and #04                    | AI2 | Yellow          | 4 x |
| Cause:                   | Scavenge air pressure > 3.2 bar (failure signal release is 2 seconds delayed)<br><b>Remark:</b> Failure is suppressed under following conditions:<br>Shut-down, stop command, scavenge air pressure sensor #1+2 meas. fail.                                                                                                                                                                                                                                                                                                            |                                |     |                 |     |
| Fault finding, remedies: | – Reduce engine power<br>– Take countermeasures (see manual of turbocharger manufacturer)                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                |     |                 |     |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                |     |                 |     |
| Failure text             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | ME servo oil pressure very low |     |                 |     |
| Failure LED:             | FCM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | LED                            |     | Blink intervals |     |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | #01 and #02                    | AI2 | Yellow          | 6 x |
| Cause:                   | Servo oil pressure 50 bar < setpoint, engine speed > 8% (failure signal release is 5 seconds delayed)<br><b>Remark:</b> Failure is suppressed under following conditions:<br>Shut-down, stop command, air run, slow turning, servo oil pressure sensor #1+2 meas. fail.                                                                                                                                                                                                                                                                |                                |     |                 |     |
| Fault finding, remedies: | – Check oil pressure after automatic filter<br>– Check control signals and cabling to servo oil pumps<br>– Safety valve 4.23 open?<br>– Pump drive, shaft 4.50 broken (pump temperatur low, no vibrations) or pump defective<br>– Leakages on the rising pipes between servo oil pumps and servo oil rail<br>– Exchange pressure controller (CV7221C, CV7222C, CV7223C) if necessary<br>– Eliminate leakages<br>– Regrind sealing surfaces on rising pipes between servo oil pump and servo oil rail, if there are leakages discovered |                                |     |                 |     |
|                          | <b>Remark:</b> In severe cases you can temporarily switch off injection and exhaust valve operation on 1 or 2 units to raise servo oil pressure<br><b>Attention:</b> Prevent switching off units in firing order sequence, do not operate engine near resonance vibrations due to misfiring                                                                                                                                                                                                                                            |                                |     |                 |     |

## Failures and Defects of WECS Components

| Failure text             | ME fuel rail pressure very low                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |     |        |                 |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------|-----------------|
| Failure LED:             | FCM-20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | LED |        | Blink intervals |
|                          | #03 and #04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | AI1 | Yellow | 6 x             |
| Cause:                   | Fuel rail pressure 150 bar < fuel pressure setpoint (failure signal release is 10 seconds delayed)<br><b>Remark:</b> Failure is suppressed under following conditions:<br>Stop command, shut-down, engine stand still, fuel rail pressure sensor #1+2 meas. fail.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |     |        |                 |
| Fault finding, remedies: | <ul style="list-style-type: none"><li>– Check whether fuel pump actuators are switched on and act properly</li><li>– All fuel pump racks must move freely</li><li>– Check actuator alarms in AMS</li><li>– Check whether fuel supply pressure of 7 to 10 bar is ok</li><li>– Any leakage alarms active?</li><li>– Check whether oil supply to fuel pressure control valve 3.06 is ok or valve seat seized</li><li>– Check if fuel pressure control valve 3.06 is leaking (this can be heard by a whistling sound)</li><li>– Check alarms (TE3431 to 36A) for temperature monitoring</li><li>– Fuel overpressure safety valve 3.52 leaking</li><li>– Non-return valves 3.81 (–1 to –6) on fuel rail and 3.22 in fuel pump covers damaged?</li><li>– Check: Fuel pump plunger seized (fuel pump does not deliver)</li><li>– If required exchange damaged fuel pump actuators</li><li>– Eliminate leakages</li><li>– Replace defective valves</li><li>– Regrind sealing surfaces on rising pipes between fuel pump and fuel rail if there are leakages discovered</li></ul> |     |        |                 |

## Failures and Defects of WECS Components

## 4.8 WECS critical failure (WECS engine failure)

| Failure text             | ME crank angle #1+2 fail.                                                                                                          |                 |        |                 |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------|-----------------|--------|-----------------|
| Failure LED:             | FCM–20 No.                                                                                                                         | LED             |        | Blink intervals |
|                          | #01 to #12                                                                                                                         | SSI CA1 and CA2 | Red    | 2 x             |
| Cause:                   | Both crank angle measurements failure<br>2 FCMs detecting a crank angle 1+2 failure                                                |                 |        |                 |
| Fault finding, remedies: | – Check crank angle sensor unit and terminal box E96 for damage                                                                    |                 |        |                 |
|                          | – Check: LED also lights up if FCM–20 module of penultimate cylinder will be switched off (no 'clockmaster')                       |                 |        |                 |
|                          | – Check: LED indication on all modules: Check SSI-bus terminating resistors on plugs X22 and X23 of FCM–20 #01                     |                 |        |                 |
|                          | – If failure is indicated on one module only, check on corresponding module, whether cable connections are ok on plugs X22 and X23 |                 |        |                 |
|                          | – Re-establish proper cabling and connections in E96                                                                               |                 |        |                 |
|                          | – Replace at least one crank angle sensor immediately                                                                              |                 |        |                 |
| Failure text             | ME both CA / TDC high shift                                                                                                        |                 |        |                 |
| Failure LED:             | FCM–20 No.                                                                                                                         | LED             |        | Blink intervals |
|                          | #05                                                                                                                                | BI1             | Yellow | 3 x and 5 x     |
| Cause:                   | Tolerance > ± 4.0°<br>Crank angle sensor or toothed belt shifted                                                                   |                 |        |                 |
| Fault finding, remedies: | – Check whether TDC offset wrongly adjusted                                                                                        |                 |        |                 |
|                          | – Check possibility of shifted crankshaft                                                                                          |                 |        |                 |
|                          | – Adjust correct distance of TDC pickup to flywheel tooth                                                                          |                 |        |                 |
|                          | – Adjust offset parameter or belt position if necessary                                                                            |                 |        |                 |
| Failure text             | ME excessive engine speed                                                                                                          |                 |        |                 |
| Failure LED:             | FCM–20 No.                                                                                                                         | LED             |        | Blink intervals |
|                          |                                                                                                                                    | None            | None   | None            |
| Cause:                   | Engine was overspeeding (> 115% nominal speed)                                                                                     |                 |        |                 |
| Fault finding, remedies: | – Check separate alarms from CA sensors                                                                                            |                 |        |                 |
|                          | – Reduce engine speed in case of heavy sea                                                                                         |                 |        |                 |

## Failures and Defects of WECS Components

**4.9 Malfunction of cylinder lubrication**

Malfunctions and defects of the control system of cylinder lubrication are indicated by LEDs on the ALM–20 modules (see Fig. 'B'), however, irregularities with lubricating pump components or occurring in the lubricating and servo oil system are described in 0820–1 'Cylinder lubrication'.

| Failure text             | ME cylinder lubrication malfunction cylinder #nn                                                                                                                                                                                                                                                                                                                                                                                |                  |     |                        |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-----|------------------------|
| Failure LED:             | <b>ALM–20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                               | <b>LED</b>       |     | <b>Blink intervals</b> |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                      | CAN1 and/or CAN2 | Red | None                   |
| Cause:                   | LED indication on <b>one</b> module: Cable break on plug X2 on corresponding ALM–20 module<br>LED indication on <b>all</b> modules: CAN Bus #1 / #2 malfunction                                                                                                                                                                                                                                                                 |                  |     |                        |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– LED indication on <b>one</b> module: Check cabling on plug X2 (terminals 25 and 26 CAN #1 and/or terminals 27 and 28 CAN #2 on corresponding ALM–20 module)</li> <li>– LED indication on <b>all</b> modules: Check CAN module bus from the last and the penultimate cylinder on FCM–20 module (plug X22, terminals 55 and 56)</li> <li>– Replace ALM–20 module if necessary</li> </ul> |                  |     |                        |
| Failure LED:             | <b>ALM–20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                               | <b>LED</b>       |     | <b>Blink intervals</b> |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                      | VLV and Fail     | Red | None                   |
| Cause:                   | Short circuit of cabling from ALM–20 module (plug X1, terminals 11 and 12) to 4/2-way solenoid valve (ZV7131 to 42C)                                                                                                                                                                                                                                                                                                            |                  |     |                        |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Check corresponding cabling, if cabling ok: 4/2-way solenoid valve malfunction (coil R~18 ohm)</li> <li>– Re-establish proper corresponding cable connection between ALM–20 module (plug X1, terminals 11 and 12) and 4/2-way solenoid valve</li> <li>– Replace corresponding 4/2-way solenoid valve if necessary (see 0820–1 'Cylinder lubrication')</li> </ul>                       |                  |     |                        |
| Failure LED:             | <b>ALM–20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                               | <b>LED</b>       |     | <b>Blink intervals</b> |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                      | VLV and Fail     | Red | None / 1x              |
| Cause:                   | Cable break of cabling from ALM–20 module (plug X1, terminals 11 and 12) to 4/2-way solenoid valve (ZV7131 to 42C)                                                                                                                                                                                                                                                                                                              |                  |     |                        |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Check corresponding cabling, if cabling ok: 4/2-way solenoid valve malfunction (coil R~18 ohm)</li> <li>– Re-establish proper corresponding cable connection between ALM–20 module (plug X1, terminals 11 and 12) and 4/2-way solenoid valve</li> <li>– Replace corresponding 4/2-way solenoid valve if necessary (see 0820–1 'Cylinder lubrication')</li> </ul>                       |                  |     |                        |
| Failure LED:             | <b>ALM–20 No.</b>                                                                                                                                                                                                                                                                                                                                                                                                               | <b>LED</b>       |     | <b>Blink intervals</b> |
|                          | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                      | Fail             | Red | None                   |
| Cause:                   | Short circuit of cabling from ALM–20 module (plug X1, terminals 13 and 14) to pressure transmitter (PT3131 to 42C)                                                                                                                                                                                                                                                                                                              |                  |     |                        |
| Fault finding, remedies: | <ul style="list-style-type: none"> <li>– Check cabling on corresponding ALM–20 module, if cabling ok: pressure transmitter malfunction</li> <li>– Re-establish proper corresponding cable connection between ALM–20 module (plug X1, terminals 13 and 14) and pressure transmitter</li> <li>– Replace corresponding pressure transmitter (PT3131 to 42C) if necessary (see 0820–1 'Cylinder lubrication')</li> </ul>            |                  |     |                        |

## Failures and Defects of WECS Components

| Failure text                                               | ME cylinder lubrication malfunction cylinder #nn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |          |        |                 |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|-----------------|
| Failure LED:<br><br>Cause:<br><br>Fault finding, remedies: | ALM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | LED      |        | Blink intervals |
|                                                            | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Fail     | Red    | 2x              |
|                                                            | Cable break of cabling from ALM–20 module (plug X1, terminals 13 and 14) to pressure transmitter (PT3131 to 42C)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |          |        |                 |
|                                                            | <ul style="list-style-type: none"><li>– Check cabling on corresponding ALM–20 module, if cabling ok: pressure transmitter malfunction</li><li>– Re-establish proper corresponding cable connection between ALM–20 (plug X1, terminals 13 and 14) and pressure transmitter</li><li>– Replace corresponding pressure transmitter (PT3131 to 42C) if necessary (see 0820–1 'Cylinder lubrication')</li></ul>                                                                                                                                                                                                               |          |        |                 |
| Failure LED:<br><br>Cause:<br><br>Fault finding, remedies: | ALM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | LED      |        | Blink intervals |
|                                                            | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Power    | Dark   | None            |
|                                                            | No power supply of individual ALM–20 module                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |          |        |                 |
|                                                            | <ul style="list-style-type: none"><li>– Check power supply units U500 / U501 and their circuit breakers F500 / F501 in E85</li><li>– If green LED 'DC OK' is ON, check cabling on corresponding ALM–20 module (plug X2, terminals 21 and 22 or 23 and 24)</li><li>– f green LED 'DC OK' is flashing, check cabling on corresponding ALM–20 module and / or corresponding ALM–20 module (short circuit?)</li><li>– Re-establish proper cable connection between E85 and corresponding ALM–20 module (plug X2, terminals 21 and 22 or 23 and 24)</li><li>– Replace corresponding ALM–20 module (short circuit?)</li></ul> |          |        |                 |
| Failure text                                               | ME cylinder lubrication malfunction                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |          |        |                 |
| Failure LED:<br><br>Cause:<br><br>Fault finding, remedies: | ALM–20 No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | LED      |        | Blink intervals |
|                                                            | #01 to #12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pressure | Yellow | None            |
|                                                            | No successful pulse lubrication<br>Cylinder lubricating pumps malfunction<br>Malfunction of one or all cylinder lubrication triggers a slow-down                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |          |        |                 |
|                                                            | <ul style="list-style-type: none"><li>– Electrically defect: check cabling to pressure transmitter, 4/2-way solenoid valve and WECS–9520</li><li>– Check malfunction of ALM–20 module</li><li>– Check: No or too low servo oil pressure</li><li>– Check lubrication pump components (see 0820–1 'Cylinder lubrication fails')</li><li>– Re-establish proper cabling to pressure transmitter, 4/2-way solenoid valve and WECS–9520</li><li>– Replace corresponding ALM–20 module or lubrication pump components, if necessary (see 0820–1 'Cylinder lubrication fails')</li></ul>                                        |          |        |                 |

## Main Bearing

### 1. General

The main bearing is equipped with a lower bearing shell 2 and an upper bearing shell 3. The bearing shells are lined with white metal in the running surface.

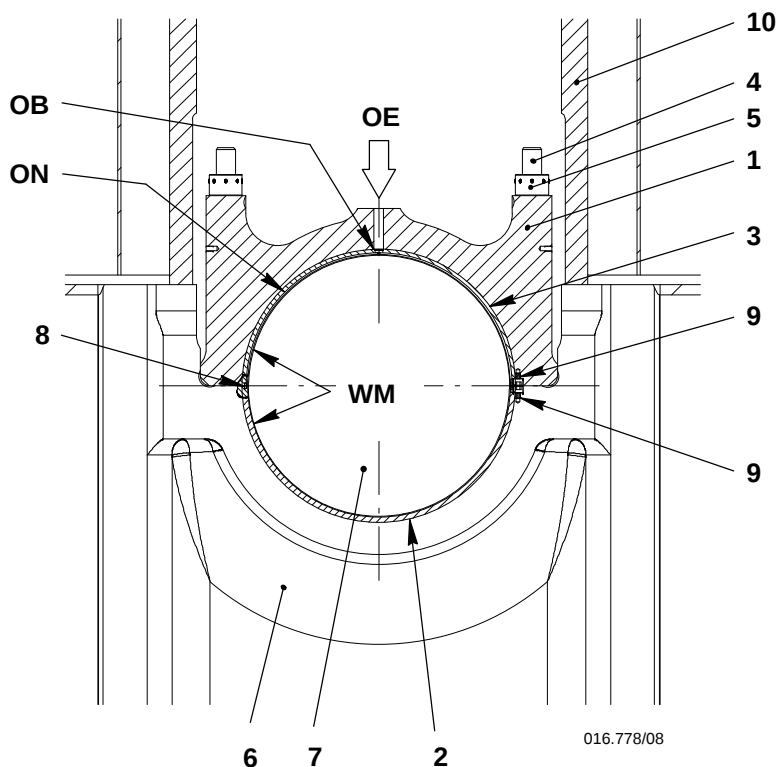
The lower main bearing shell 2 is placed into the bearing girder 6 of the bedplate and the upper main bearing shell 3 into the bearing cover 1. They are located with the screws 9 and held in their position.

To position the bearing covers 1 the spring dowel pin 8 has been provided.

The bearing cover is pressed against the bearing girder by waisted studs 4 and round nuts 5 which are pretensioned hydraulically. The waisted studs 4 are fitted with a non-hardening locking compound.

### 2. Lubrication

The main bearings are supplied with oil via the connection (oil inlet 'OE') at bearing cover 1. The oil reaches the bearing running surface through bore 'OB' and groove 'ON' in the upper main bearing shell 3.



#### Key:

- |    |                          |
|----|--------------------------|
| 1  | Bearing cover            |
| 2  | Lower main bearing shell |
| 3  | Upper main bearing shell |
| 4  | Waisted stud             |
| 5  | Round nut                |
| 6  | Bearing girder           |
| 7  | Crankshaft               |
| 8  | Spring dowel pin         |
| 9  | Screw                    |
| 10 | Column                   |
| OB | Bore                     |
| OE | Oil inlet                |
| ON | Groove                   |
| WM | White metal              |

016.778/08

## Thrust Bearing

### 1. General

The thrust bearing is situated at the driving end of the engine. The thrust created by the ship's propulsion is transmitted by thrust bearing flange 'DF' of the crankshaft via the thrust pads into bedplate 10.

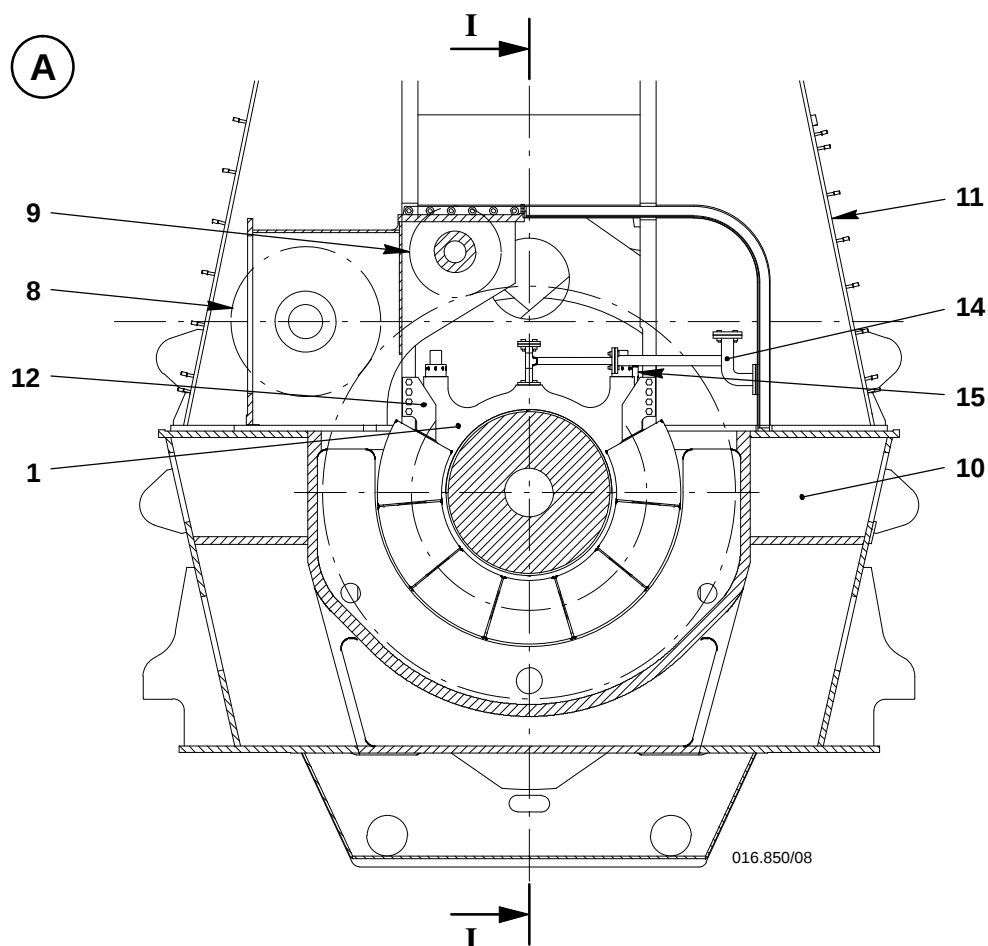
Arbor supports 12 prevent the thrust pads from being turned out. Depending on the sense of rotation of the crankshaft or propeller, thrust pads 2 or 3 take up the axial thrust forces.

There are seven thrust pads on either side of the thrust bearing flange.

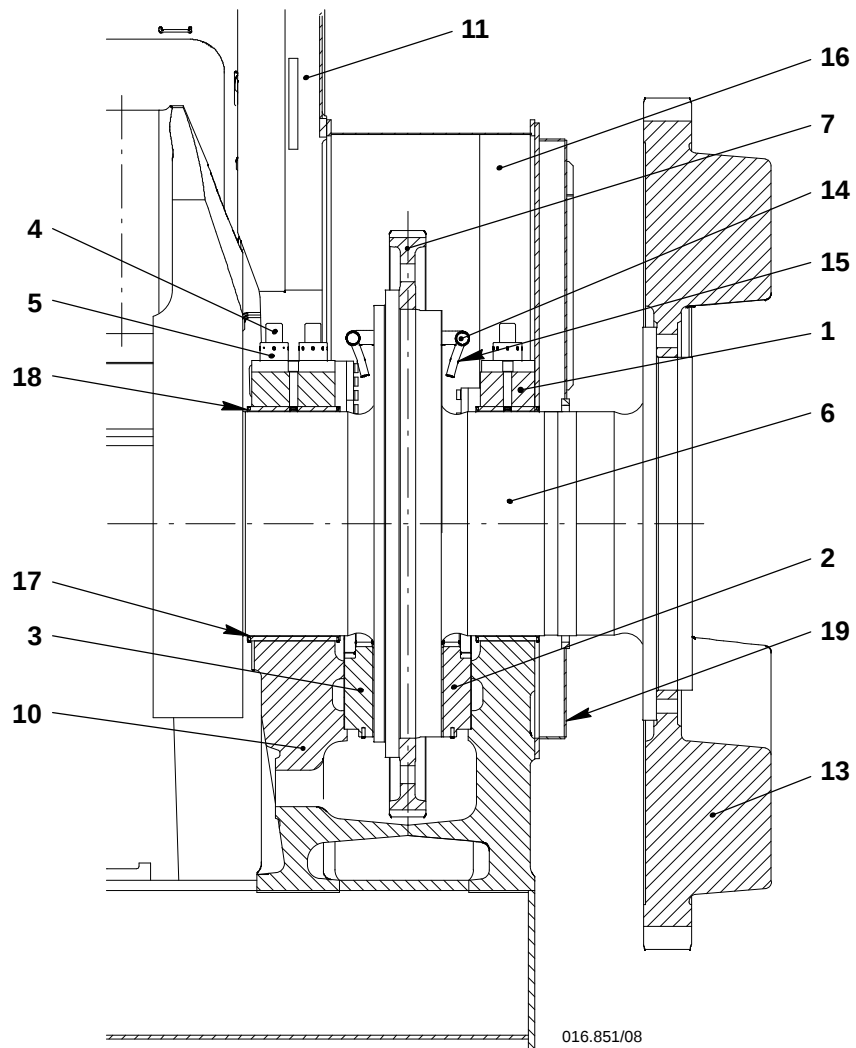
The gear wheel is mounted on crankshaft 7 on top of the thrust bearing flange 'DF' and drives the intermediate wheel for fuel pump unit 8 and the intermediate wheel of servo pump unit 9 (see Fig. 'A').

### 2. Lubrication

The thrust pads are lubricated with bearing oil which is led by lubricating oil pipe 14 to spray nozzles 15. The nozzles are dimensioned in such a way that in operation an oil film forms between thrust bearing flange 'DF' and thrust pads (hydraulic wedge).



## Thrust Bearing

**B**

016.851/08

**Key to Illustrations:** 'A' Cross section 6 to 8 cylinder  
 'B' Longitudinal section 6 to 8 cylinder

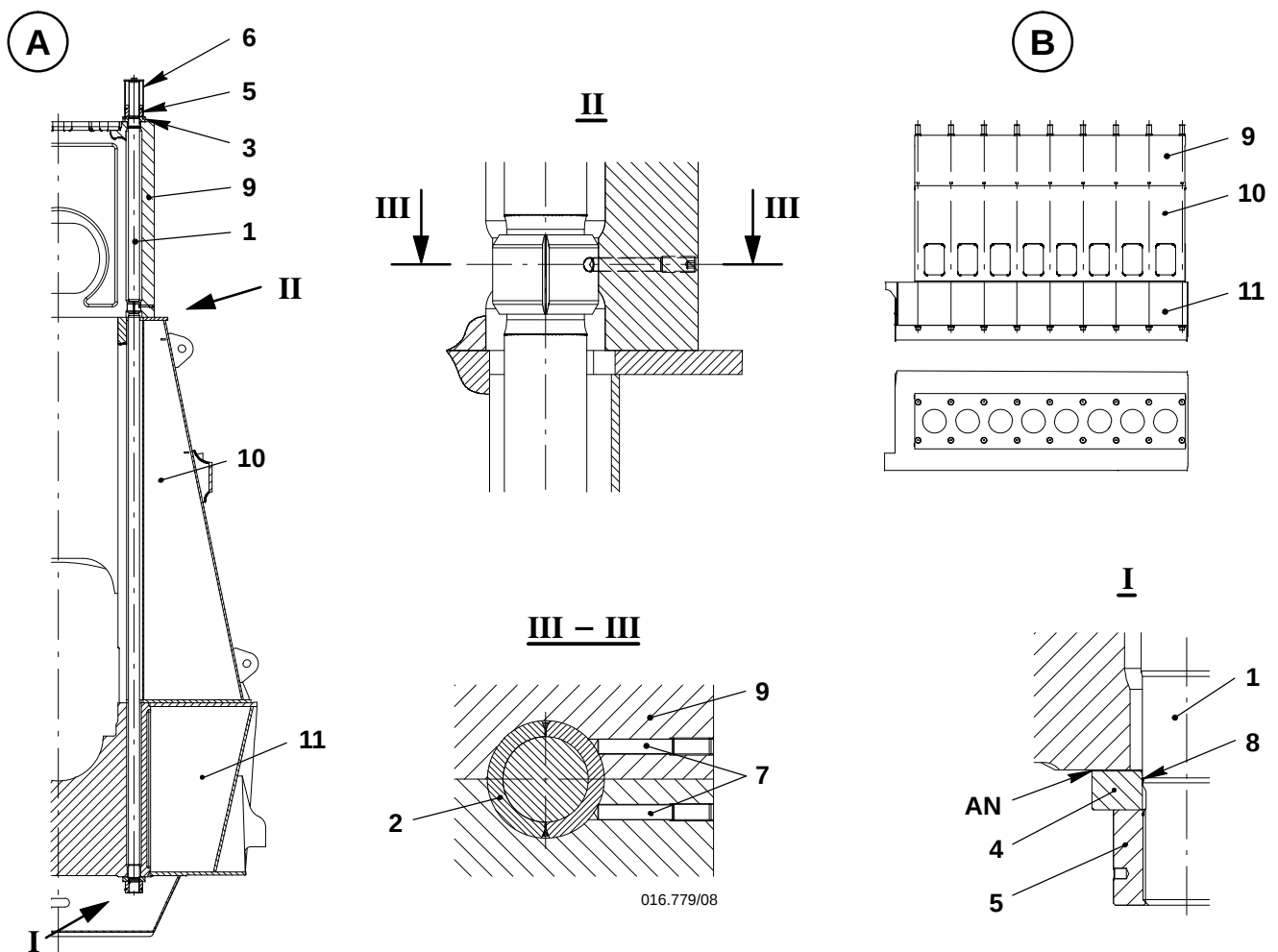
- |                                          |                          |
|------------------------------------------|--------------------------|
| 1 Bearing cover                          | 13 Flywheel              |
| 2 Thrust pads (driving end)              | 14 Lubricating oil pipe  |
| 3 Thrust pads (free end)                 | 15 Spray nozzle          |
| 4 Waisted stud for bearing cover         | 16 End casing            |
| 5 Round nut                              | 17 Lower bearing shell   |
| 6 Crankshaft                             | 18 Upper bearing shell   |
| 7 Gear wheel on crankshaft               | 19 2-part oil baffle     |
| 8 Intermediate wheel for fuel pump unit  |                          |
| 9 Intermediate wheel for servo pump unit |                          |
| 10 Bedplate                              |                          |
| 11 Column                                | DF Thrust bearing flange |
| 12 Arbor support                         | OE Bearing oil inlet     |

**Tie Rod****1. General**

Tie rods 1 fasten cylinder jacket 9, column 10 and bedplate 11 together at four points around the cylinder (see Fig. 'B').

Each tie rod is equipped with a two-part bush 2 which is firmly fastened by the two clamp screws 7 (see detail II) located at the bottom of the cylinder jackets 9. These guide bushes prevent the tie rod from vibrating. For additional vibration damping the space around the lower part of the tie rod till mid-column is filled with oil which enters through a filling bore in way of the crosshead guide plate.

The lower thread (detail I) of the intermediate ring is provided with a drain groove 'AN'. Through this drain groove some oil and possible condensate water can always drain away (in case of engine standstill).



**Key to Illustrations:** 'A' Tie rod  
'B' Tie rod arrangement (8 cylinder engine)

- |                           |                                      |
|---------------------------|--------------------------------------|
| 1 Tie rod                 | 7 Clamp screw                        |
| 2 Two-part bush           | 8 O-ring                             |
| 3 Upper intermediate ring | 9 Cylinder jacket                    |
| 4 Lower intermediate ring | 10 Column                            |
| 5 Round nut               | 11 Bedplate                          |
| 6 Protective cap          | AN Drain groove in intermediate ring |

## Cylinder Liner

---

### 1. General

Cylinder liner 1 is fitted into the cylinder jacket 4 with screws 12 and holders 6. The nuts of the waisted studs fasten the cylinder cover 9, the cylinder liner 1, the upper and lower water guide jackets 2, 3 onto the cylinder jacket 4.

### 2. Cooling

At connection 'KE' the cooling water enters into water space 'WR'.

The cooling water rising around the cylinder liner and lower water guide jacket flows into annular space 'RR' via pipe connections 7 and pipe pieces 8, and then cools the cylinder cover and the exhaust valve cage via cooling bores 'KB'.

To optimize the cylinder liner wall temperature an insulating band 14 has been applied on the cylinder liner.

An antipolishing ring 15 fitted in the cylinder liner is used for removing too heavy coke formations at the piston crown during operation.



**Remark: Automatic cooling water temperature control**

In order to avoid undue tensions in the upper part of the cylinder liners, the cooling water temperature must be maintained under all load conditions as steady as possible. The maximum admissible temperature fluctuations are:

- $\pm 2$  °C at constant load
- $\pm 4$  °C during load changes (transient conditions).

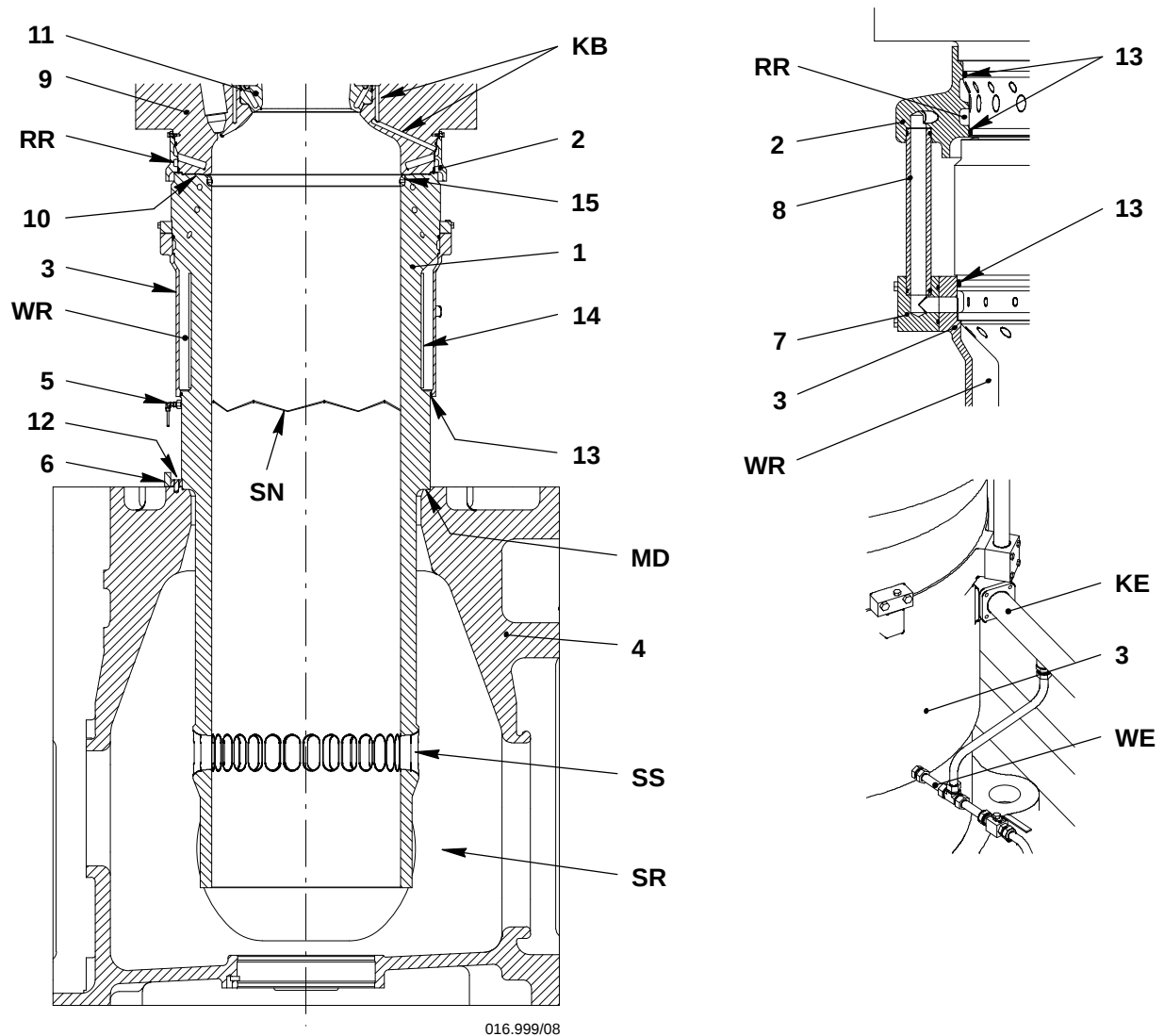
O-rings 13 are used to seal water space 'WR' and annular space 'RR'. Should water leak then the O-rings must be replaced at the next opportunity. The surface 'MD' of the cylinder liner seals metallically combined with a non-hardening sealing compound.

### 3. Lubrication

Cylinder lubricating oil is delivered to the running surface of the cylinder liner through eighth lubricating quills 5. Around the circumference of the cylinder liner a row of lubricating grooves 'SN' is milled into the running surface. The cylinder lubricating oil is equally distributed through this row of lubricating grooves.

The arrangement and function of the pulse lubrication are described in [7218-1](#).

## Cylinder Liner

**Key:**

- |                                 |                                              |
|---------------------------------|----------------------------------------------|
| 1 Cylinder liner                | 14 Insulating band                           |
| 2 Upper water guide jacket      | 15 Antipolishing ring                        |
| 3 Lower water guide jacket      |                                              |
| 4 Cylinder jacket               | KB Cooling bores in cylinder cover           |
| 5 Lubricating quill             | KE Cooling water inlet                       |
| 6 Holder                        | MD Metallic sealing                          |
| 7 Pipe connection               | RR Annular space in upper water guide jacket |
| 8 Pipe piece                    | SN Row of lubricating grooves                |
| 9 Cylinder cover                | SR Scavenge space (piston underside)         |
| 10 Joint ring                   | SS Scavenge ports                            |
| 11 Valve seat for exhaust valve | WE Water space drain                         |
| 12 Screw                        | WR Water space                               |
| 13 O-ring                       |                                              |

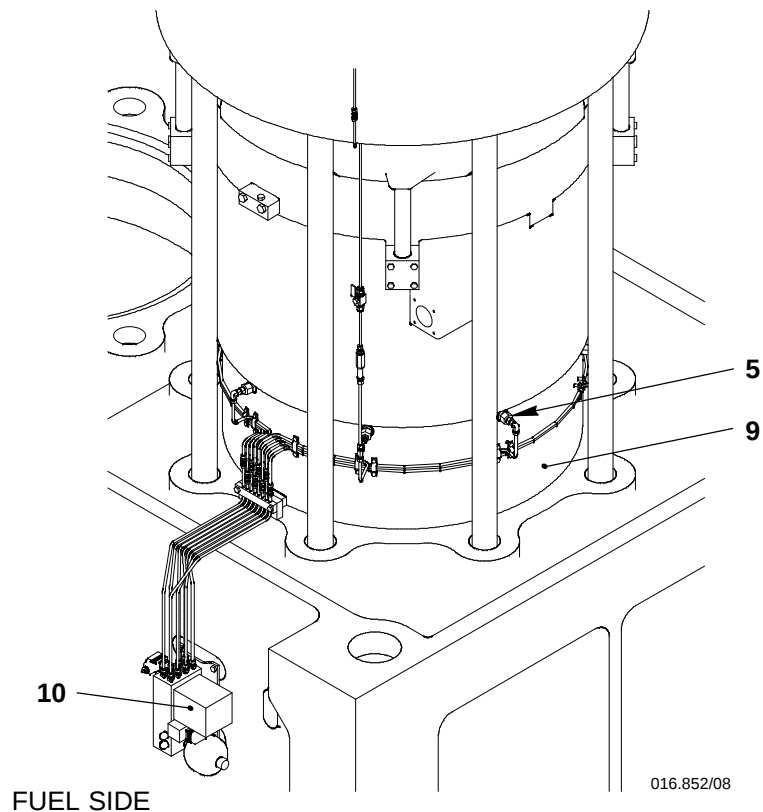
## Lubricating Quills on Cylinder Liner

### 1. General

Eight lubricating quills are screwed-in around the circumference of the cylinder liner 9. The lubricating oil is fed in separate pipes from lubricating pump 10 to every lubricating quill.

The lubricating quill 5 is extended in length by the passage 6 to deliver the cylinder oil through cylinder liner 9 to lubricating point 'SA'.

**A**

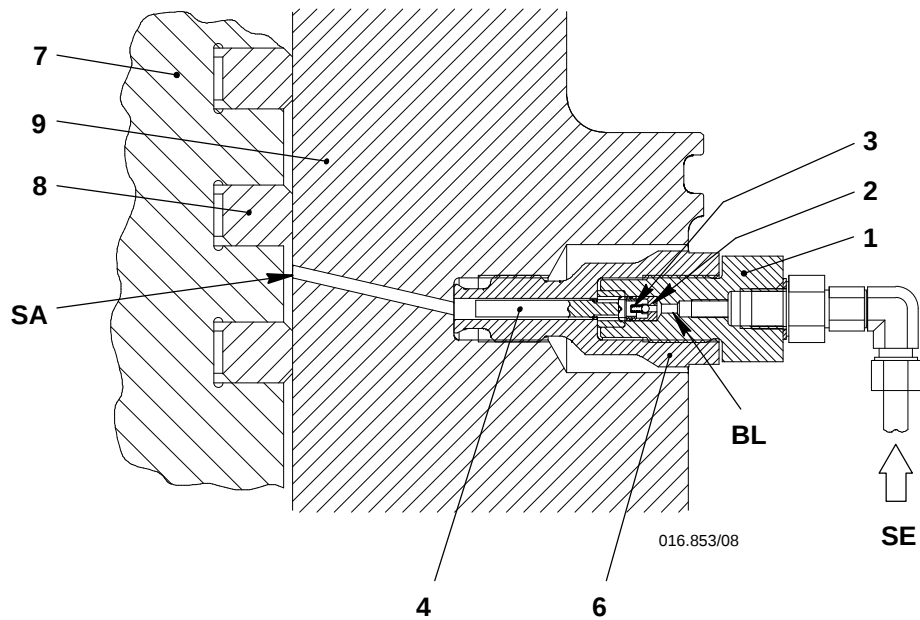


### 2. Function

Lubricating pump 10 deliver the required feed rate of lubricating oil at high pressure through connection 'SE' into the lubricating quills 5. Non-return valve 2 opens and the lubricating oil is fed to the lubricating grooves via filling pin 4, and then it is equally distributed on the cylinder liner wall (see also Cylinder Liner [2124-1](#) and Cylinder Lubrication [7218-1](#)).

When the oil pressure drops after feeding, the non-return valve is closed by the force of pressure spring 3.

## Lubricating Quills on Cylinder Liner

**B**

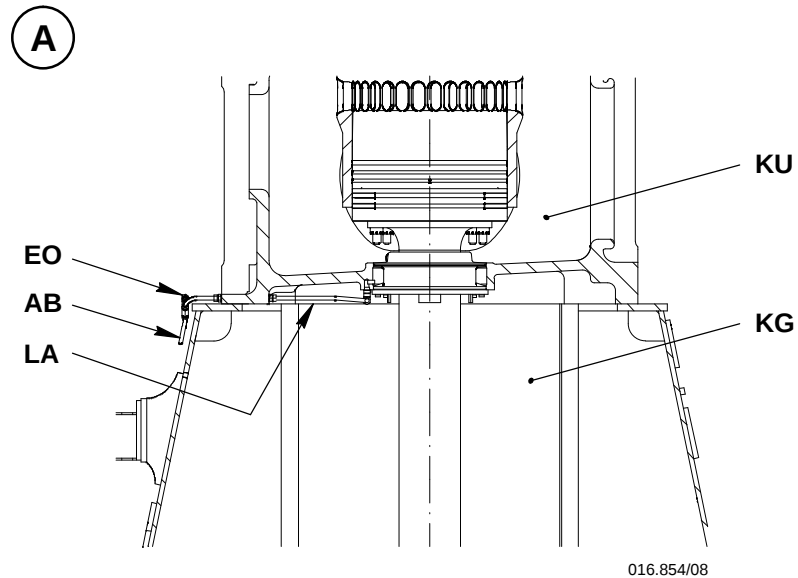
**Key to Illustrations:** 'A' Arrangement of lubricating quills  
 'B' Lubricating quill

- |                                 |                     |                                        |
|---------------------------------|---------------------|----------------------------------------|
| 1 Screw                         | } Lubricating quill | 8 Piston ring                          |
| 2 Non-return valve              |                     | 9 Cylinder liner                       |
| 3 Pressure spring               |                     | 10 Lubricating pump                    |
| 4 Filling pin                   |                     |                                        |
| 5 Lubricating quill             |                     | BL Orifice                             |
| 6 Passage for lubricating quill |                     | SA Lubricating point in cylinder liner |
| 7 Piston                        |                     | SE Lubricating oil inlet               |

## Piston Rod Gland

### 1. General

The piston rod gland prevents the contamination of the bearing oil by combustion residues and seals scavenge space 'KU' against crankcase 'KG' (see Fig. 'A').



### 2. Function

Both scraper rings 3 and sealing ring 6 scrape dirty oil from piston rod 10. This oil flows through bores 'OB', is collected on the bottom of the scavenge space 'KU' and then it is discharged via the drain 'SO' on fuel side.



**Attention!** The dirty oil drain from scavenge space 'KU' must always be free (see 0240-1). A major fire risk exists, if the dirty oil does not flow off (see 0450-1)!

The two 4-part sealing rings 6 and 6a prevent the escape of scavenge air into the crankcase. The low air pressure caused by gap losses is released via a vent in the plant.

The oil accumulated via relief passages 'EB' in the neutral space 'NR' flows back through oil leakage drain 'LA' and leakage oil pipe 'AB' (see Fig. 'A' and 'B').

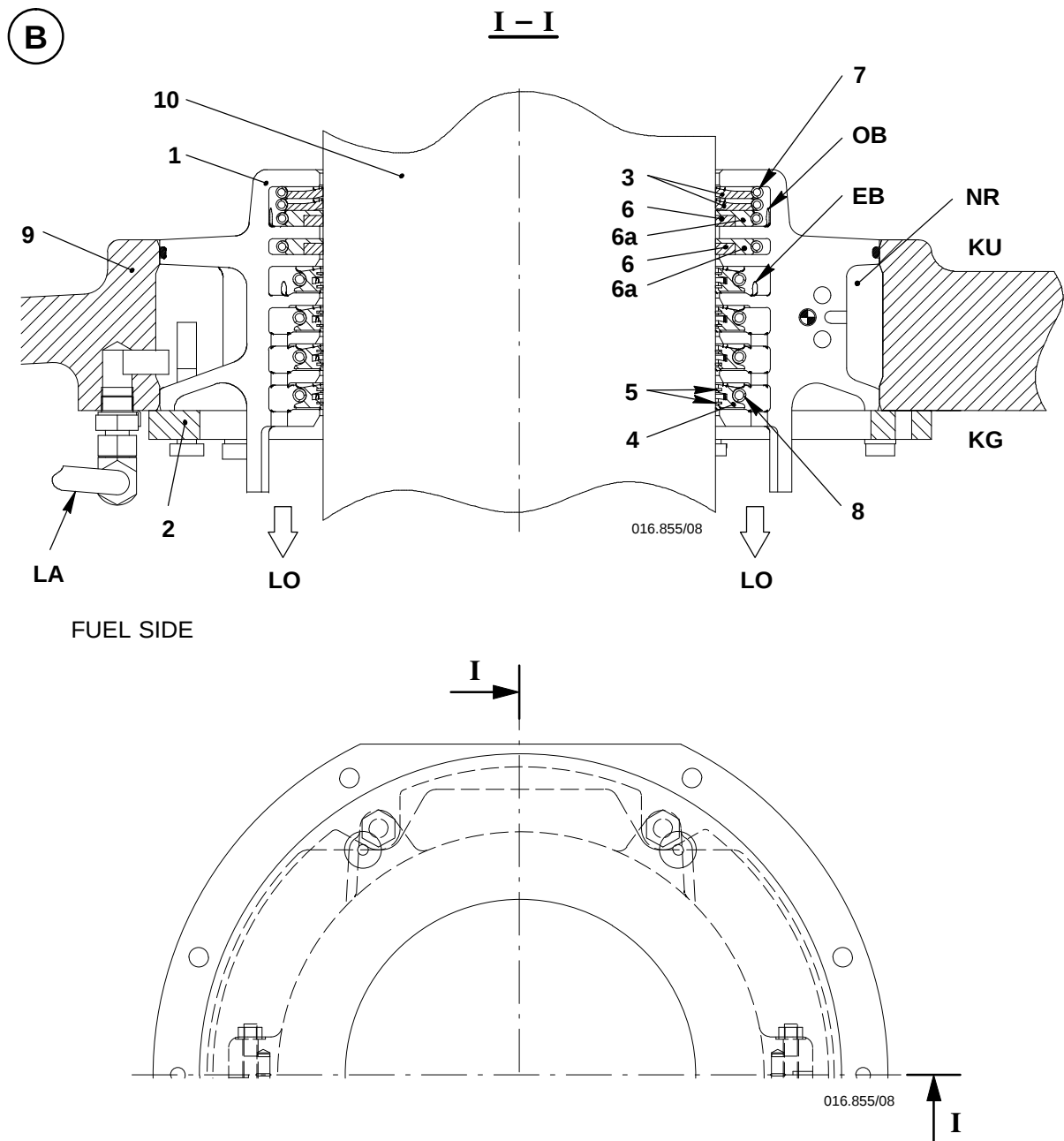


**Remark:** Increased oil drain is a symptom of leaky sealing rings 6 and 6a. Providing device 'EO' the oil drain quantity can be measured or a sample for laboratory analysis be taken.

The four ring supports 4 carry two scraper rings 5 each and these scrape bearing oil off the piston rod and lead it back to crankcase 'KG' via oil bore 'LO'.

All ring types are pressed against the piston rod by tension springs 7 and 8.

## Piston Rod Gland

**Key to Illustrations: 'A' Arrangement of piston rod gland****'B' Piston rod gland**

- |                             |                                                               |
|-----------------------------|---------------------------------------------------------------|
| 1 Housing (2-part)          | AB Leakage oil pipe                                           |
| 2 Support                   | EB Relief passage                                             |
| 3 Scraper ring (4-part)     | EO Device for taking oil sample                               |
| 4 Ring support (3-part)     | KG Crankcase                                                  |
| 5 Scraper ring (3-part)     | KU Piston underside (scavenge space)                          |
| 6, 6a Sealing ring (4-part) | LA Relief of air pressure from space 'NR' (leakage oil drain) |
| 7 Tension spring            | LO Bearing oil drain                                          |
| 8 Tension spring            | NR Neutral space                                              |
| 9 Cylinder jacket           | OB Oil bore                                                   |
| 10 Piston rod               |                                                               |

## Injection Valve

### 1. General

Three injection valves 1 are fitted in each cylinder cover.

Fuel oil which leaks in consequence of nozzle needle clearance is drained through the fuel leakage pipe 13 via connection 'LA' to the fuel leakage collecting pipe from the injection valves (see Fig. 'B' and Fuel Oil System 8019-1).

Fuel oil which possibly leaks between nozzle body 3, intermediate piece 8 and nozzle holder 2 (leakage) rises and appears at the upper edge of the cylinder cover at 'LB'.



**Remark:** In this case the parts concerned should be overhauled at the next opportunity. If the sealing face 'DF' is leaky, exhaust gas passes through gap 'LB'.

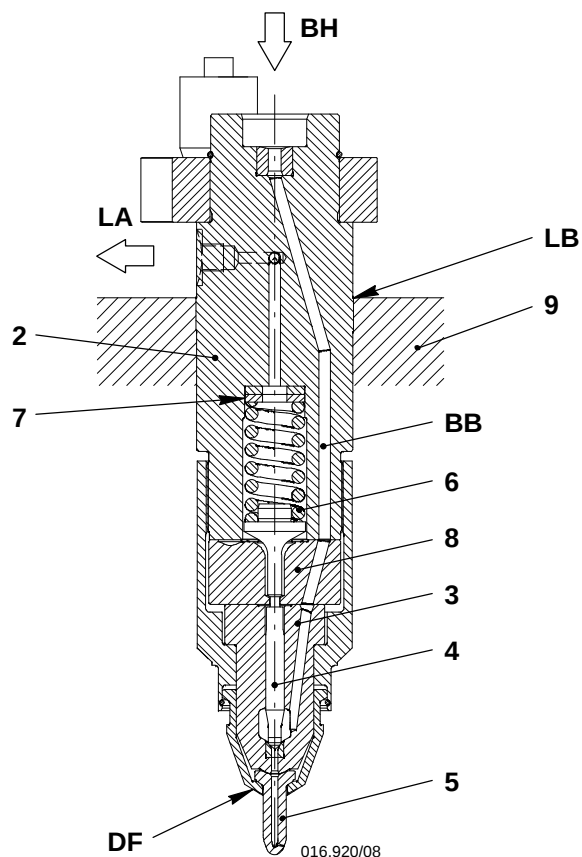
For testing, dismantling, assembling and setting of injection valves see 2722-1 in the Maintenance Manual.



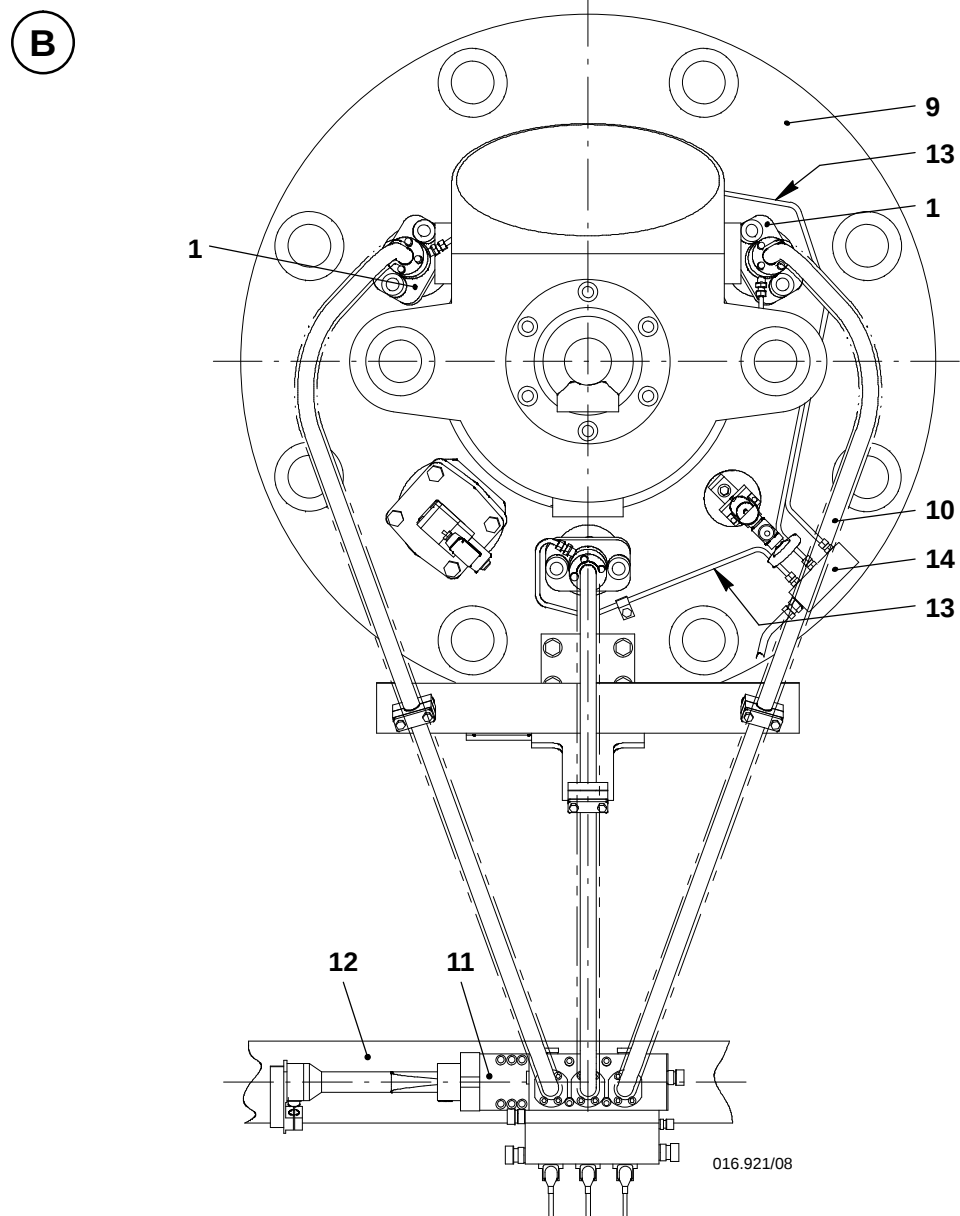
**Attention!** Fuel leakage pipes 13 are under pressure. Before removing them, they must be depressurized by means of drain valve 3.65 (see 'Fuel leakage system').

### 2. Function

Fuel oil is led at high pressure to the three injection valves via injection control unit 11. The fuel quantity required for injection flows through connection 'BH' and the bore 'BB' to nozzle body 3. The high fuel pressure lifts nozzle needle 4 off its seat against the force of compression spring 6, and finely atomized fuel is injected into the combustion chamber.



## Injection Valve



**Key to Illustrations:** 'A' Injection valve  
 'B' Arrangement at cylinder cover

- |                                |                                |
|--------------------------------|--------------------------------|
| 1 Injection valve 3.01         | 11 Injection control unit 3.02 |
| 2 Nozzle holder                | 12 Fuel rail 3.05              |
| 3 Nozzle body with needle seat | 13 Fuel leakage pipe 3.49      |
| 4 Nozzle needle                | 14 Collecting piece            |
| 5 Nozzle tip                   |                                |
| 6 Compression spring           | BB Fuel bore                   |
| 7 Shim ring                    | BH Fuel feed (high pressure)   |
| 8 Intermediate piece           | DF Sealing face                |
| 9 Cylinder cover               | LA Leakage fuel drain          |
| 10 Injection pipe 3.47         | LB Leakage fuel outlet (gap)   |

## Starting Valve

---

### 1. General

Every cylinder cover 6 is provided with a starting valve, which is controlled electrically by the FCM-20 (Flex Control Module-20). With that the engine can be started and when reversing it can be slowed down (see also Manoeuvring [0260-1](#)). I.e. at certain piston positions starting air streams into the cylinder during these processes.

The parameter settings, i.e. opening and closing of the starting valve with regard to the crank position, are adjusted in the WECS-9520 (engine control system).

In the schematic diagram [4003-2](#) the starting valve bears number 2.07.

### 2. Function

#### ***Ready for operation:***

Space 'P<sub>2</sub>' is charged with starting air pressure. Compression spring 4 keeps the valve closed. Connection 'SL' at cover 1 is under starting air pressure.

#### ***Starting:***

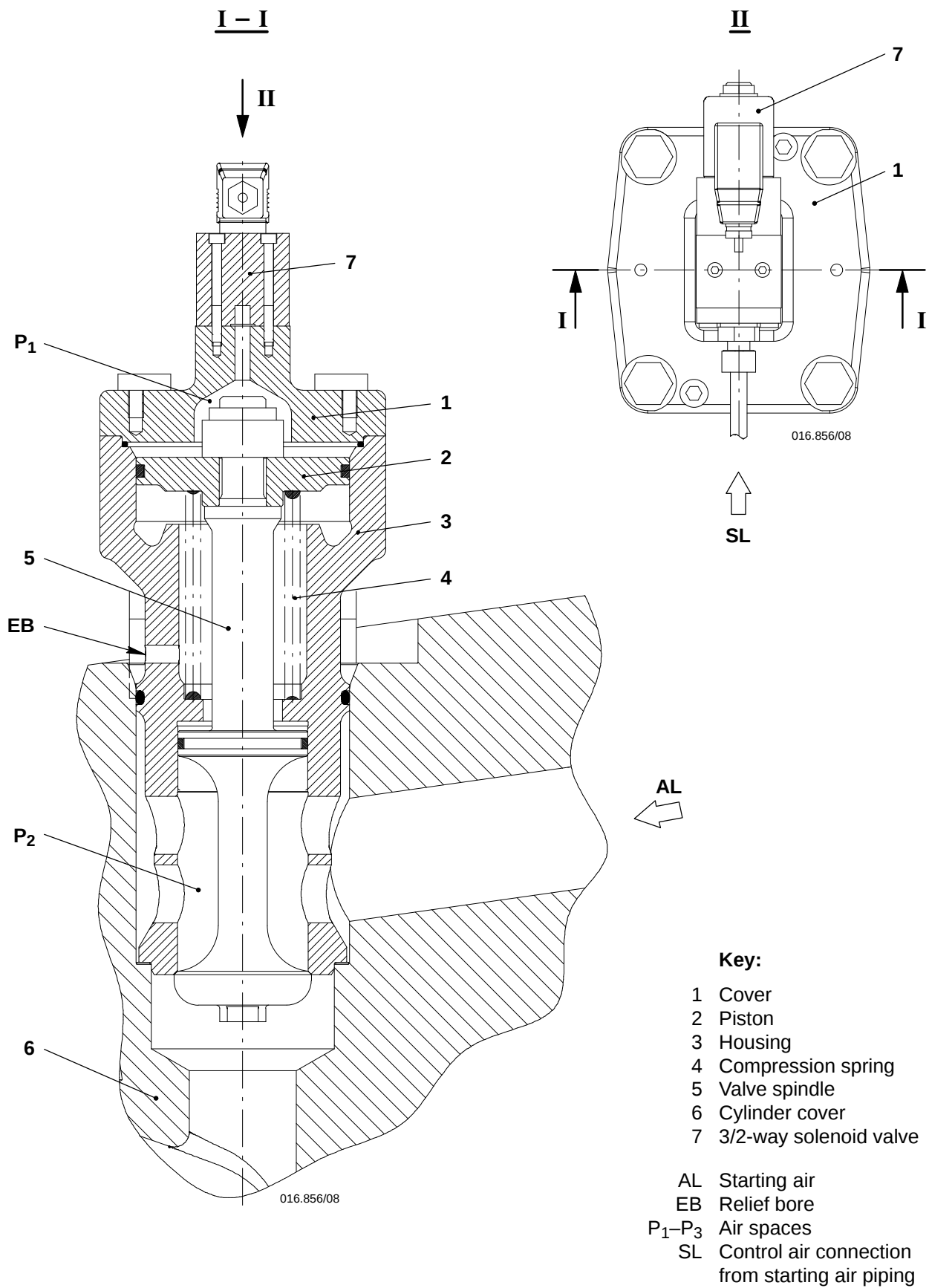
The 3/2-way solenoid valve 7 is controlled by the FCM-20. Space 'P<sub>1</sub>' is pressurized, the valve opens and starting air flows to the cylinder space. The piston is moved downwards and the engine begins to turn.

When the engine begins firing, a higher pressure (firing pressure) exists in the combustion space and therefore the starting valve remains closed during this high pressure phase.

#### ***Slow-down of engine for reversing:***

During reversing, when the ship is still in motion, the engine is 'dragged' by the propeller in the wrong direction of rotation. The starting valve opens by approx. 100° before TDC and starting air fills the cylinder space. By compressing this air the engine is braked in order to be re-started in the new direction of rotation. Depending on the ship speed (dragging of the engine by the propeller) this manoeuvre must be delayed (this may take several minutes). I.e. as soon as the engine speed falls below the set limit, the starting valve will be operated via the engine control system in order to release braking air / starting air and thereby initiating a successful engine start.

## Starting Valve



## Exhaust Valve

---

### 1. General

The exhaust valve is screw fastened in the centre of cylinder cover 21. The exhaust valve generally consists of the following parts: Upper housing 3 and lower housing 2, valve cage 1, valve spindle 6, valve seat 20 and air spring 'LF'.

The stroke sensor 19 monitors and transmits the positions OPEN and CLOSED of the valve spindle 6 to the WECS-9520 engine control system (see Fig. 'B').

For safety reasons disc springs 16 are provided as a damping element to prevent the exhaust valve from being damaged, if the balance of valve opening and the air spring force are disturbed.



**Remark:** The lubricating oil pump and servo oil service pump must only be switched on after air spring air supply is ensured and with closed exhaust valves. Therefore, the engine can not be started if the exhaust valves are not fully closed.

### 2. Function

#### Opening:

Controlled by the piston in the exhaust valve control unit, hydraulic oil 'HO' is pressed through the connection 14 into the upper housing 3, moving the step piston downwards. The valve spindle 6, with air spring piston 10 fastened to it, is also pushed downwards against the pressure in the air spring 'LF'. The exhaust valve opens. The exhaust gas outflow hits rotation wings 17, thereby rotating the valve spindle.

#### Closing:

When the hydraulic oil pressure from the exhaust valve control unit diminishes (i.e. the corresponding relief passages have been opened by the control rod in the exhaust valve control unit) valve spindle 6 is pressed upwards by the pressure in the air spring 'LF' acting on the air spring piston. The exhaust valve closes. The hydraulic oil in the upper housing 3 is pressed back to the exhaust valve control unit.

#### 2.1 Venting of hydraulic system (see Fig. 'B' and 'C')

Through the orifice 15 hydraulic oil and any air present in the system is continuously drained into the leakage oil drain 'LO' via bores in the housing 3, outside and inside pistons (items 4, 5) and leakage oil collecting space 'LS'. This oil loss is continuously made up to the hydraulic system by the oil which is led to the exhaust valve control unit (internal bores).

#### 2.2 Air supply to air spring (see Fig. 'C')

Compressed air enters the air spring 'LF' through connection 'LE' and inlet bore 'EB'. When the exhaust valve opens, air spring piston 10 is pushed downwards compressing the air in the air spring housing. Some air flows back into connection 'LE' through inlet bore 'EB'. After the exhaust valve closes, the air spring space 'LF' fills up again.

## Exhaust Valve

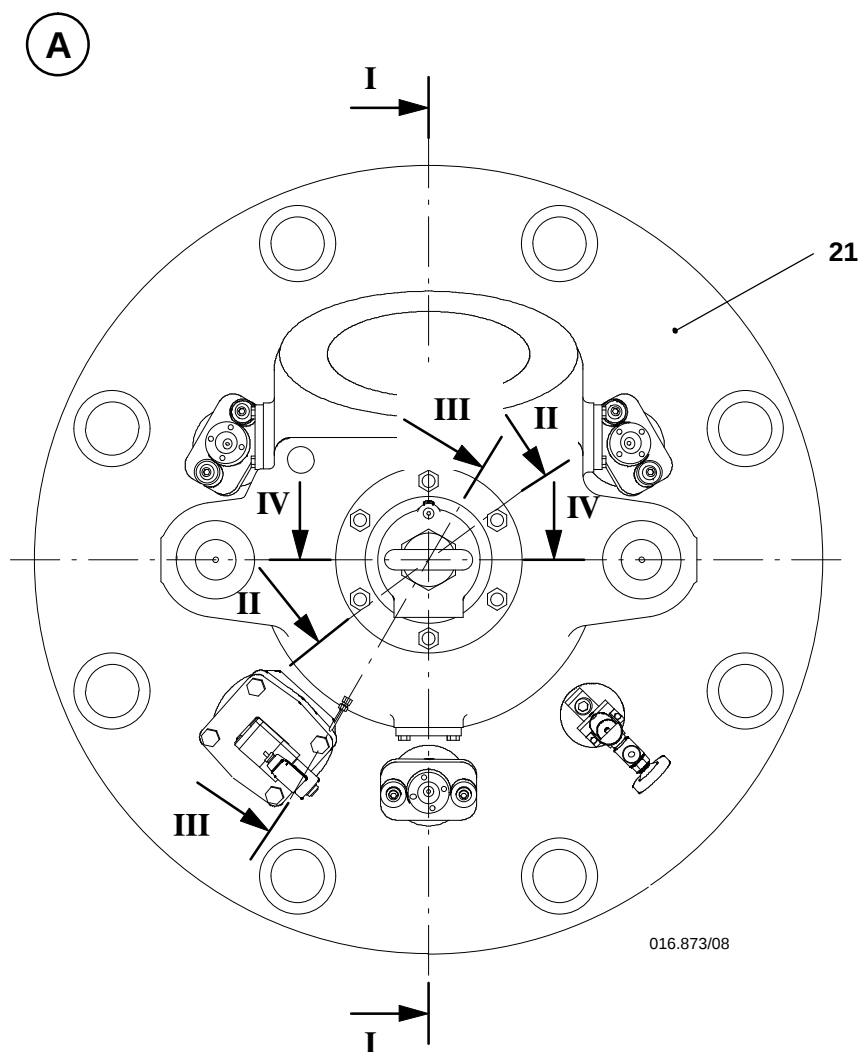
**3. Lubrication** (see Fig. 'B' to 'D')

Leak oil from step piston is used to lubricate air spring piston 10. Surplus oil in space 'LS' is drained to leakage oil drain 'LO'. While the exhaust valve closes oil enters the air spring 'LF' via the air spring piston. The oil accumulating on the bottom of the air spring (inlet bore 'EB') is atomized by the in-flowing air. This oil mist lubricates the upper part of the valve spindle. Excess oil is pressed out of air spring 'LF' when the exhaust valve opens, and is led to an accumulator via the air spring pipe. From time to time the content of the accumulator is automatically drained to the plant via the leakage oil pipe DE (driving end) of the exhaust valves.

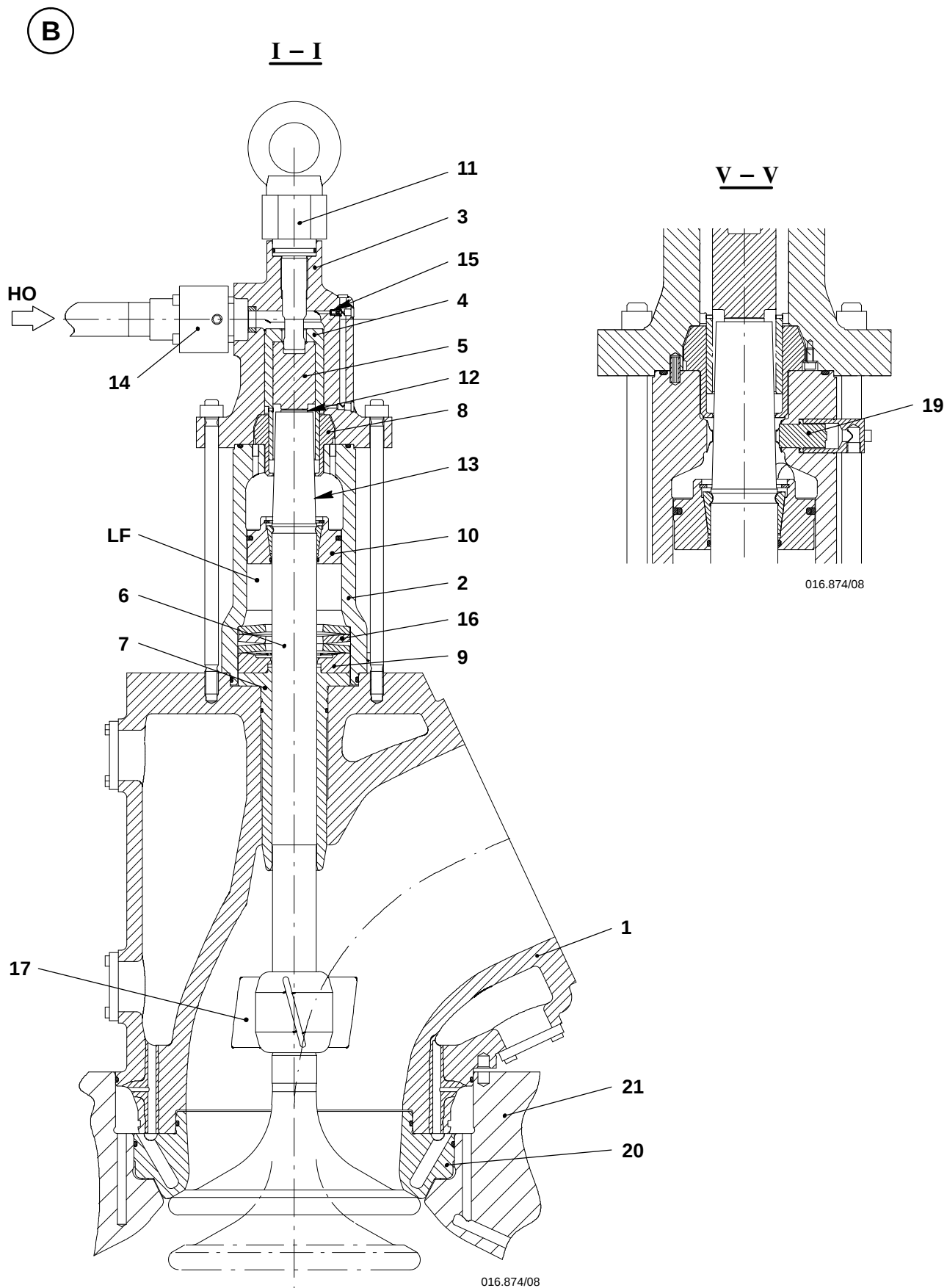
The valve spindle 6 is lubricated by means of oil bath 'OB' (see Fig. 'D').



**Remark:** During the first operating hours or after an exhaust valve overhaul the valve spindle is additionally lubricated via the separate oil supply 'OV' from the cylinder lubrication (see Fig. 'D' and 7218-1 'Additional lubrication of exhaust valve spindle').

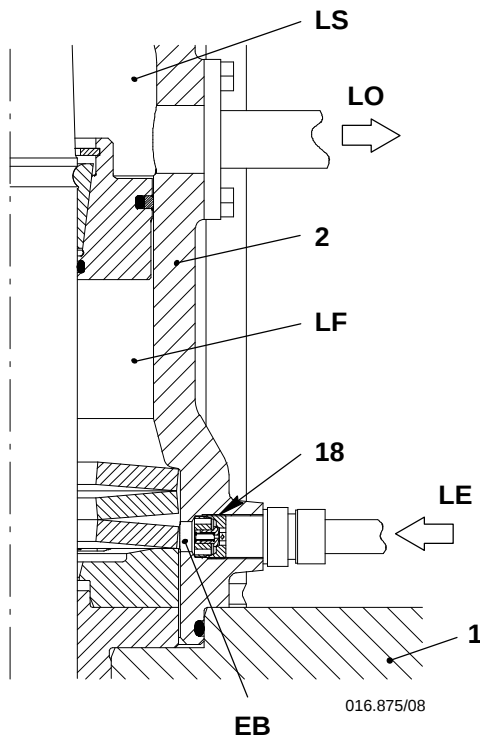


## Exhaust Valve

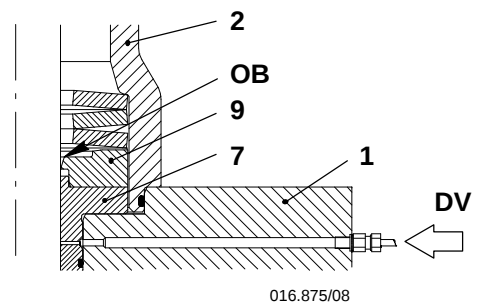


## Exhaust Valve

C

II – II

D

III – III

**Key to Illustrations:**

- 'A' Arrangement in cylinder cover
- 'B' Exhaust valve
- 'C' Leakage oil drain and Air inlet to air spring
- 'E' Oil supply to valve guide

- |                                   |                                  |
|-----------------------------------|----------------------------------|
| 1 Valve cage                      | 16 Disc spring                   |
| 2 Lower housing                   | 17 Rotation wing                 |
| 3 Upper housing                   | 18 Non-return valve              |
| 4 Outside piston                  | 19 Valve stroke sensor           |
| 5 Inside piston                   | 20 Valve seat                    |
| 6 Valve spindle                   | 21 Cylinder cover                |
| 7 Guide bush                      |                                  |
| 8 Piston guide                    | EB Inlet bore to air spring      |
| 9 Distance ring                   | HO Hydraulic oil (high pressure) |
| 10 Air spring piston              | LE Air inlet to air spring       |
| 11 Damper                         | LF Air spring                    |
| 12 Thrust piece                   | LO Leakage oil drain             |
| 13 Measuring cone (shaft outline) | LS Leakage oil collecting space  |
| 14 Hydraulic oil connection       | OB Oil bath                      |
| 15 Orifice                        | OV Oil supply to valve guide     |

## Axial Damper

---

### 1. General

The engine is equipped with an integrated axial damper. The duty of the axial damper is the reduction of axial vibrations.

The damper consists of an upper 1, and a lower cylindrical part 2, which are both screw fastened to the last bearing girder, and of a damping flange 'FK' which is a part of the crankshaft. The oil quantity required for the damping is adjusted by means of a throttling valve.

### 2. Function

Bearing oil 'OE' is supplied via orifices 8 into the spaces 'OR' to both sides of flange 'FK' on crankshaft 10. The bigger part of the oil, thus imprisoned, can only circulate in case of axial crankshaft movements through throttle valve 3 from one space 'OR' to the other. The remaining part of the oil is drained due to the radial and axial clearance of the sealing rings as well as the venting screws.

The optimum damping effect can be adjusted by spindle 4.



**Remark:** The adjustment has to be carried out during sea-trials, with the application of special measuring instruments. After the adjustment the setting screws are secured with locking device 5 against unintentional mis-adjustment.

The setting value of the spindle has to be engraved on a nameplate in the immediate vicinity of the throttle valve.

In order to exceptionally permit taking readings at different throttle positions of the spindle during sea-trials, an opening has been provided at the top side of the casing. Through this opening, normally closed by a cover, the spindle position can be altered using a special spanner.

**Any displacement of this spindle must be avoided!**



The engine must **not** be operated with the spindle 4 removed or with the oil supply to the axial damper interrupted!

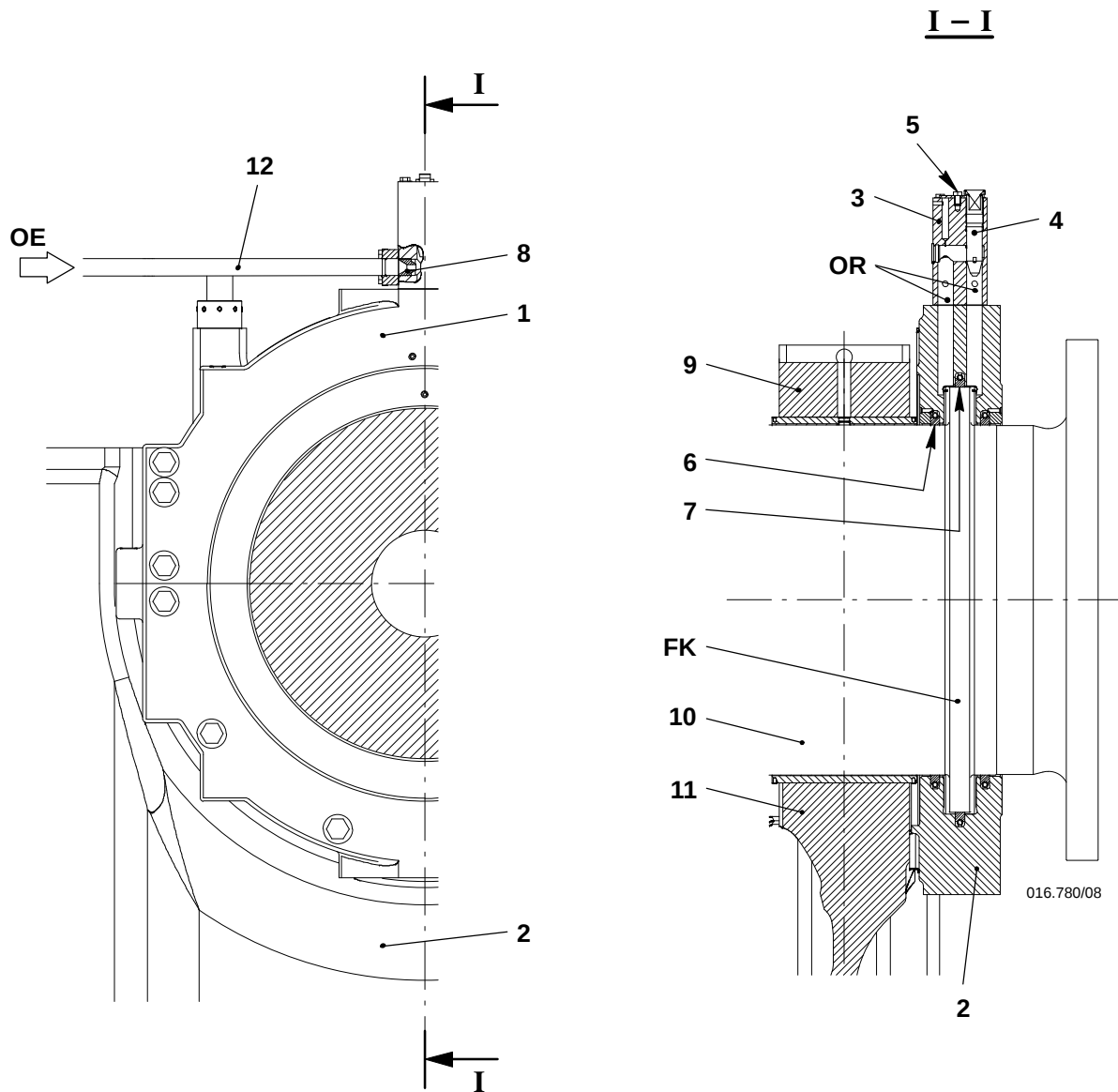
### 3. Monitoring system

The engine is equipped with an axial damper monitoring system arranged above the end casing at the free end. The oil pressure in the aft side and fore side chamber of the axial damper is monitored, and in case of oil pressure drop an alarm is triggered (setting values see Alarms and Safeguards [0250-2](#)).

The reason for this alarm must be investigated and remedied:

- Orifices in the pressure gauge pipes clogged
- Shut-off valves closed in the pressure gauge pipes
- Low oil pressure and / or high oil temperature in the bearing oil system
- Throttle valve mal-adjusted
- Excessive wear of the sealing rings, e.g. caused by dirt particles (clearance too big).

## Axial Damper

**Key:**

- |                          |                                      |
|--------------------------|--------------------------------------|
| 1 Upper part of cylinder | 9 Bearing cover                      |
| 2 Lower part of cylinder | 10 Crankshaft                        |
| 3 Throttle valve         | 11 Bearing girder (part of bedplate) |
| 4 Spindle                | 12 Oil pipe                          |
| 5 Locking device         |                                      |
| 6 Small sealing ring     | FK Flange on crankshaft              |
| 7 Large sealing ring     | OE Oil inlet                         |
| 8 Orifices               | OR Oil spaces                        |

## Connecting Rod and Connecting Rod Bearing

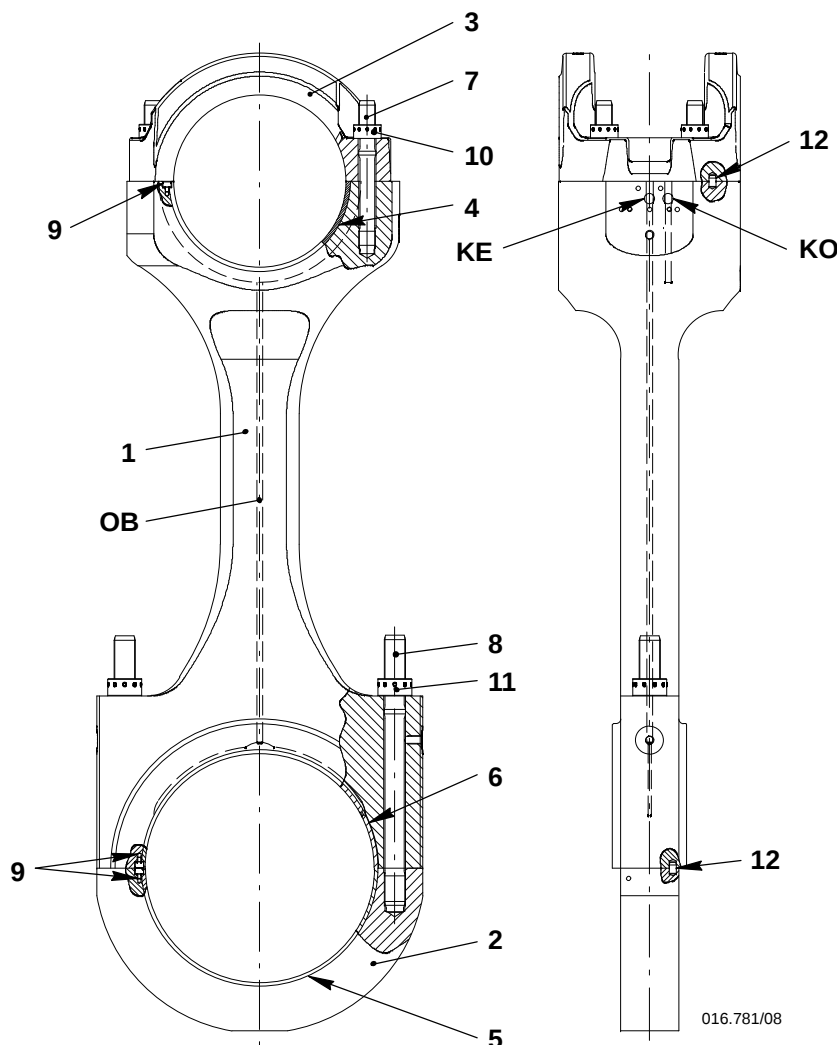
### 1. General

The connecting rod connects the crosshead with the crankshaft and converts the linear stroke movement of the piston into a turning movement. Replaceable bearing shells are fitted on the connecting rod 1 for the bottom end bearing (items 5 and 6) and for the top end bearing (item 4). The bearing cover for the top end bearing (item 3) is lined with white metal.

### 2. Lubrication

Crosshead lubricating oil reaches the top end bearing through the connection 'KE', and drillings in the crosshead pin admit lubricating oil to the guide shoes. Crosshead lubricating oil reaches the bottom end bearing through the drilling 'OB' in the connecting rod 1.

Bearing lubricating oil is fed through connection 'KO' for piston cooling through corresponding drillings in the crosshead pin and piston rod.



#### Key:

- 1 Connecting rod
- 2 Lower bearing cover
- 3 Upper bearing cover
- 4 Bearing shell for top end bearing (crosshead)
- 5 Lower bearing shell for bottom end bearing
- 6 Upper bearing shell for bottom end bearing
- 7 Studs to top end bearing
- 8 Studs to bottom end bearing
- 9 Allen screw
- 10 Round nut
- 11 Round nut
- 12 Cylindrical pin
- KE Crosshead lube oil inlet
- KO Piston cooling oil inlet
- OB Oil bore in connecting rod

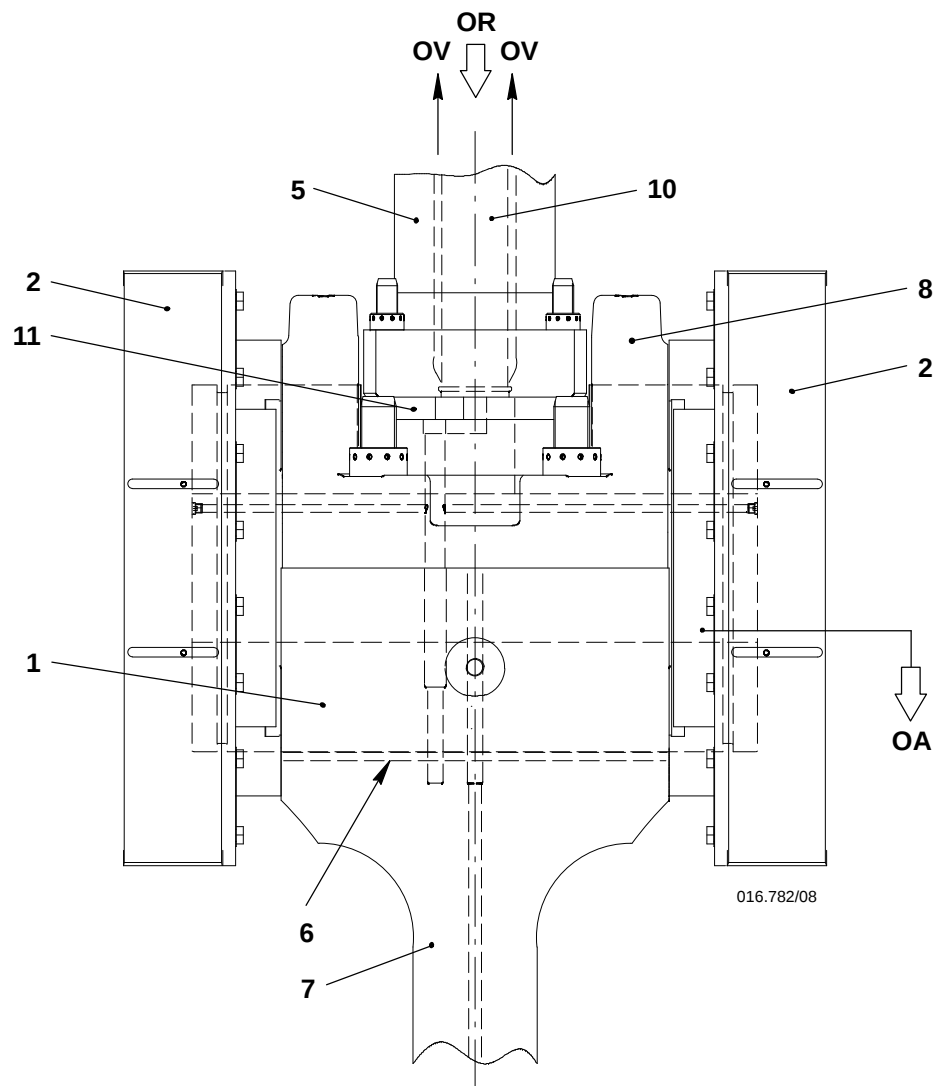
## Crosshead and Guide Shoe

### 1. General

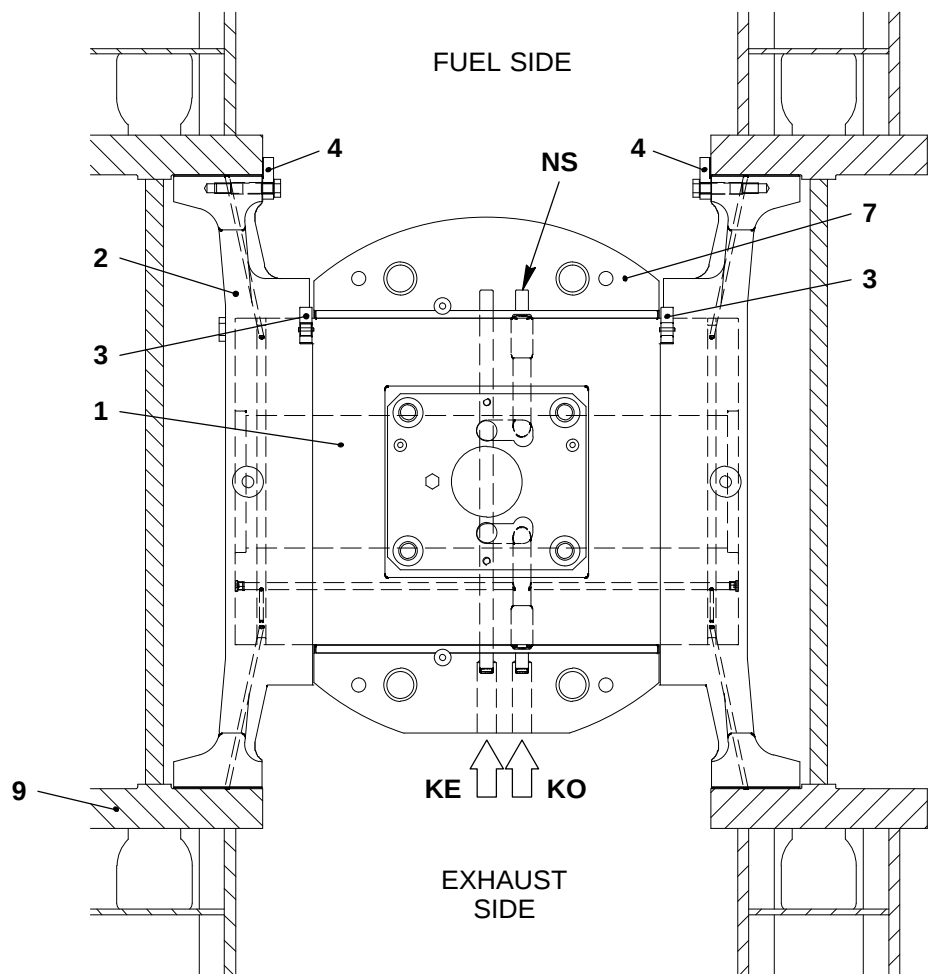
The crosshead guides piston rod 5 and absorbs the lateral forces originating from connecting rod 7.

The piston rod 5 is screw fastened to the crosshead pin 1. The bearing lubricating oil required for cooling the piston is led through the slot 'NS' and the bore 'OV' to the piston. The oil 'OR' flows back to the crosshead pin through the oil pipe 10 and returns to the crankcase through the drain 'OA'.

The guide shoes 2 rest on the crosshead pin 1 and are kept in their axial position with the holding plates 3. They are guided in the guide ways of column 10 by guide rails 4.



## Crosshead and Guide Shoe



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**Key to Illustrations:**

- |                                                 |                                           |
|-------------------------------------------------|-------------------------------------------|
| 1 Crosshead pin                                 | 10 Oil pipe to piston                     |
| 2 Guide shoe                                    | 11 Compression shim                       |
| 3 Holding plate                                 |                                           |
| 4 Guide rail                                    |                                           |
| 5 Piston rod                                    |                                           |
| 6 Bearing shell for top end bearing (crosshead) | KE Crosshead lubricating oil inlet        |
| 7 Connecting rod                                | KO Oil inlet for piston cooling oil inlet |
| 8 Upper bearing half for top end bearing        | NS Slot (groove) in connecting rod        |
| 9 Column                                        | OA Oil drain into crankcase               |
|                                                 | OR Oil return from piston                 |
|                                                 | OV Oil approach in piston rod             |

## Piston

## 1. General

The piston consists basically of: Piston crown 1, piston skirt 3, piston rod 5, the oil cooling components and piston rings 2. The piston crown and piston rod are fixed by means of hydraulically tightened waisted studs 9 and round nuts 10. Piston skirt 3 is directly screw fastened to piston rod 5.

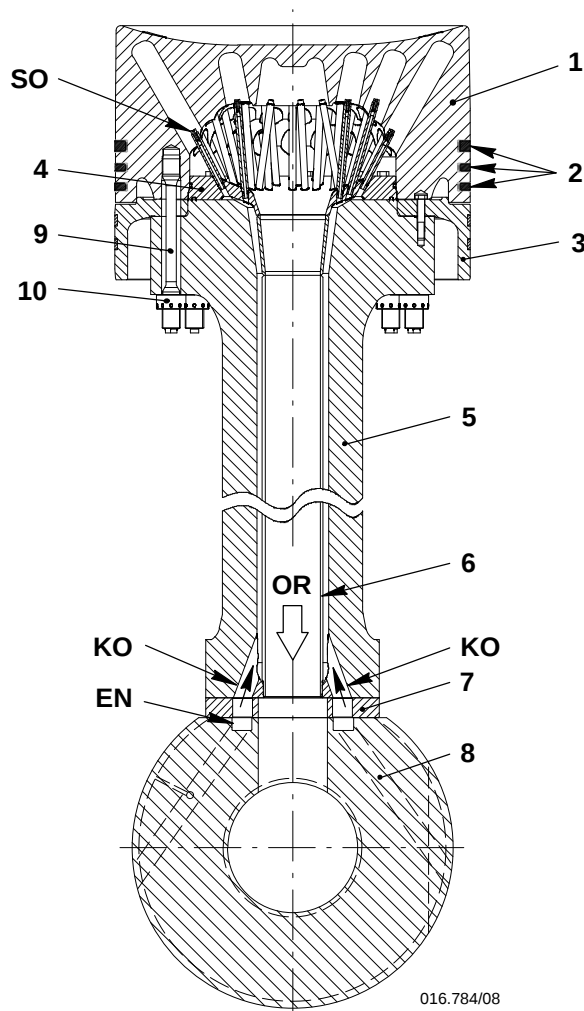
Piston rod 5 is fastened to crosshead pin 8 in a particular position. A compression shim 7 is fitted between them, its thickness being adapted to the compression ratio.



**Remark:** All piston rings have to be fitted with the marking 'TOP' upwards. Equipment of the piston rings see Maintenance Manual [3425-1](#).

## 2. Piston cooling

The piston crown 1 is cooled by bearing lubricating oil. The piston cooling oil 'KO' is fed from crosshead pin 8 into the two inlet slots 'EN'. From here it flows outside the oil pipe 6 (arranged in the piston rod 5) till spray plate 4. The cooling oil is sprayed into the cooling bores of the piston crown through nozzles in the spray plate. From there the oil 'OR' flows through oil pipe 6 into the crosshead pin from where it emerges sideways.



## Key:

- 1 Piston crown
- 2 Top piston rings
- 3 Piston skirt
- 4 Spray plate
- 5 Piston rod
- 6 Oil pipe to spray plate
- 7 Compression shim
- 8 Crosshead pin
- 9 Waisted stud
- 10 Round nut

- EN Inlet slot (groove)
- KO Piston cooling oil
- OR Oil return from piston
- SO Spray oil

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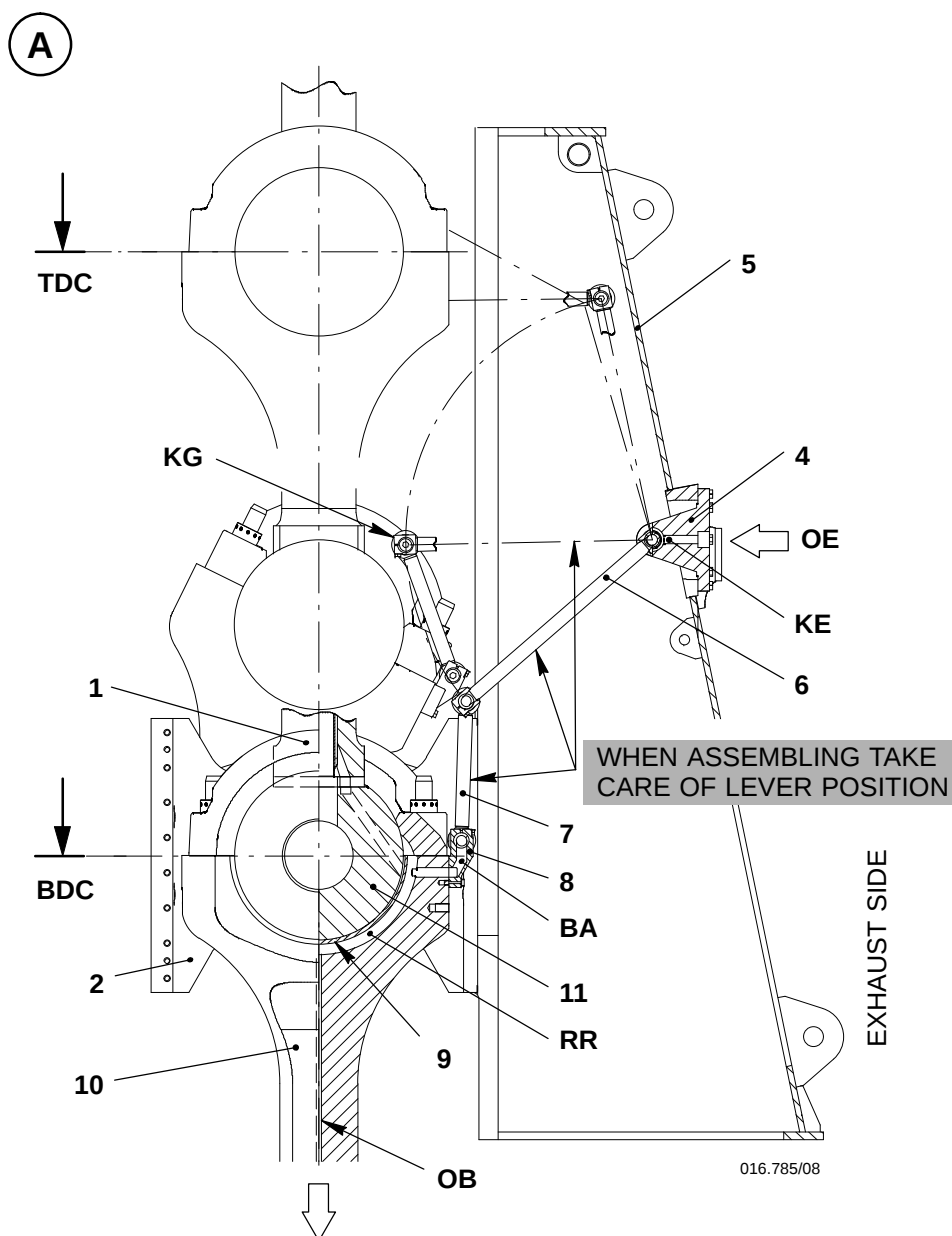
## Crosshead Lubrication and Piston Cooling

### 1. General

Main bearing oil is used to cool the pistons and also to lubricate the crossheads. Both oil systems are led to the crosshead via a double articulated lever with separate oil supplies.

### 2. Crosshead lubrication

The crosshead lubricating oil 'KE' reaches the connecting piece 8, which is fitted to the connecting rod 10, by-passing through the support 4, the lower lever 6 and the upper lever 7. The oil enters the ring space 'RR' through bore 'BA'. The crosshead pin is lubricated through drillings in the top end bearing shell 9 (see Fig. 'A'). A drilling 'OB' through the connecting rod 10 leads the oil to the bottom end bearing.



## Crosshead Lubrication and Piston Cooling

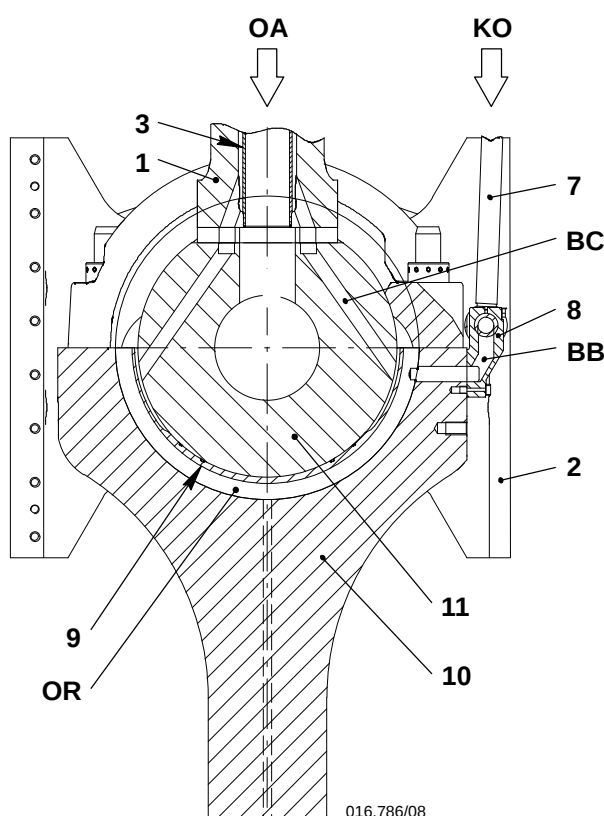
## 3. Piston cooling

Bearing oil 'KO' passes through the support 4, the lower lever 6 and the upper lever 7 to the connecting piece 8, which is fitted to the connecting rod 10. The cooling oil is led to the working piston through the bore 'BB', the ring space 'OR', drillings in the top end bearing shell 9 and the bores 'BC', then outside the oil pipe 3 through the piston rod 1. The oil then flows through the oil pipe 3 to the central bore in the crosshead pin 11 and returns to the crankcase. Part of the piston cooling oil is used to lubricate the guide shoes 2 (see 3326-1).



**Attention!** When fitting the upper lever 7 to connecting piece 8 great care must be taken that the toggle lever (knee) 'KG' buckles upwards as per Fig. 'A'. Wrongly fitted, this would certainly lead to very grave damage to the toggle lever, the crosshead and the column. Besides this it will cause interruption of the lubricating oil supply with further heavy damage resulting.

(B)



## Key to Illustrations:

'A' Articulated lever arrangement

'B' Cross section through crosshead

- 1 Piston rod
- 2 Guide shoe
- 3 Oil pipe
- 4 Support
- 5 Column
- 6 Lower lever
- 7 Upper lever
- 8 Connecting piece
- 9 Top end bearing shell
- 10 Connecting rod
- 11 Crosshead pin
- BA Bore for crosshead lubricating oil
- BB Bore for piston cooling oil
- BC Bore in crosshead pin
- KE Inlet for crosshead lubricating oil
- KO Inlet for piston cooling oil
- KG Toggle lever (knee)
- OA Piston cooling oil return
- OB Bore for crosshead lubricating oil to bottom end bearing
- OE Oil inlet
- OR Ring space for piston cooling oil
- RR Ring space for crosshead lubricating oil

## Engine Control System WECS-9520

## Overview

|     |                                                            |       |
|-----|------------------------------------------------------------|-------|
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## 1. General

The WECS-9520 (Wärtsilä Engine Control System) has been specially designed for two-stroke engines with Wärtsilä Common Rail technology, covering all engine-related ([section 3](#)) and cylinder-related ([section 4](#)) control functions.

**Engine-related control functions:**

- Fuel rail pressure
- Servo oil pressure for exhaust valve drive
- Cylinder lubricating system

**Cylinder-related control functions:**

- Volumetric injection control (including VIT)
- Exhaust valve control (including VEO and VEC)
- Starting valve control
- Crank angle sensor

The 'Common Function' to the external systems is ensured by data buses to the propulsion control system and to the ship alarm and monitoring system ([section 5](#)). They serve as interface between operator and engine control.

## 2. Components

[Fig. 'A'](#) is a schematic representation of the related components and their interconnections.

Main components of WECS-9520:

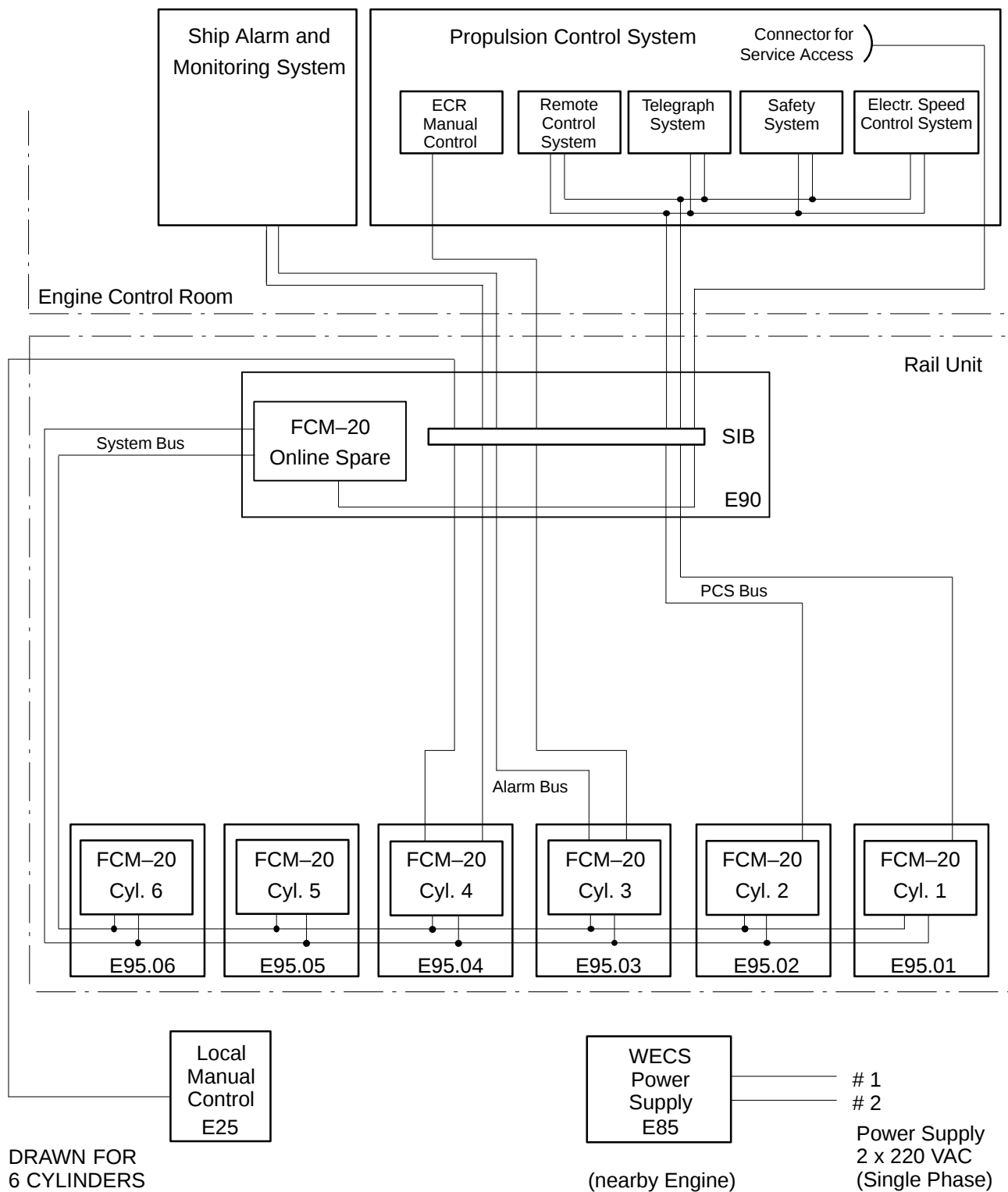
- Control box E90 (SIB) as communication to the external systems, containing a FCM-20 module as 'Online Spare'.
- Per cylinder a control box E95.xx, containing a FCM-20 module each for engine and cylinder-related control functions.

All modules are connected by the system bus.

All control boxes (E90, E95.xx) are arranged on the rail unit, and power supply box (E85) is placed nearby the engine.

## Engine Control System WECS-9520

A



## Engine Control System WECS-9520

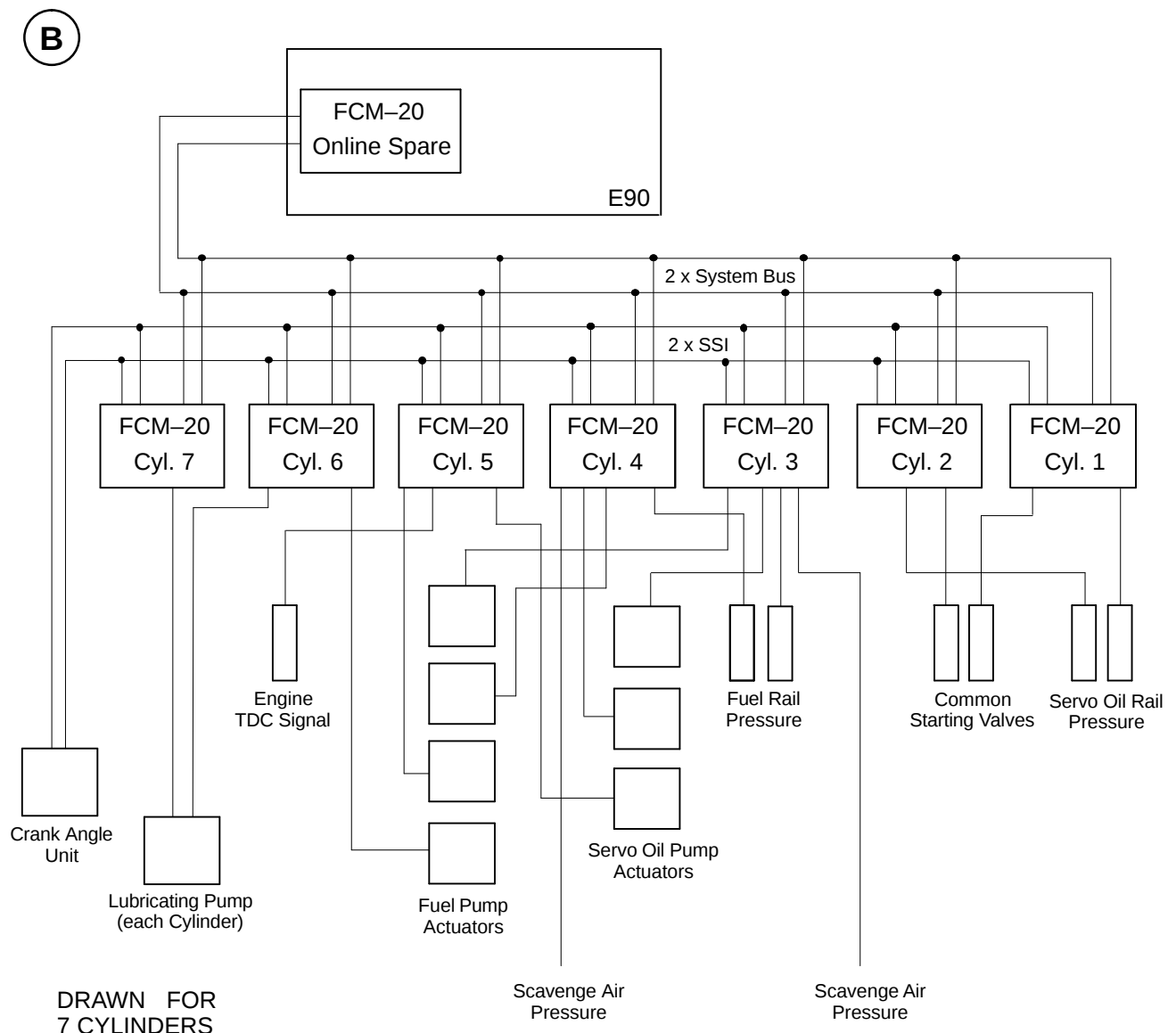
**3. Engine-related control functions****3.1 General**

All engine-related control functions are distributed within six FCM-20 modules (cylinders 1–6) for 6 to 8 cylinder engines, however, there are eight modules for 9 to 12 cylinder engines. The last and penultimate modules are provided for the control functions of the cylinder lubricating system.

For safety reasons all important functions, input and output signals of the modules are redundant. The engine remains in operation if one module fails. The power supply is also redundant (see Fig. 'B').

A defective module has to be replaced with the 'Online Spare' module.

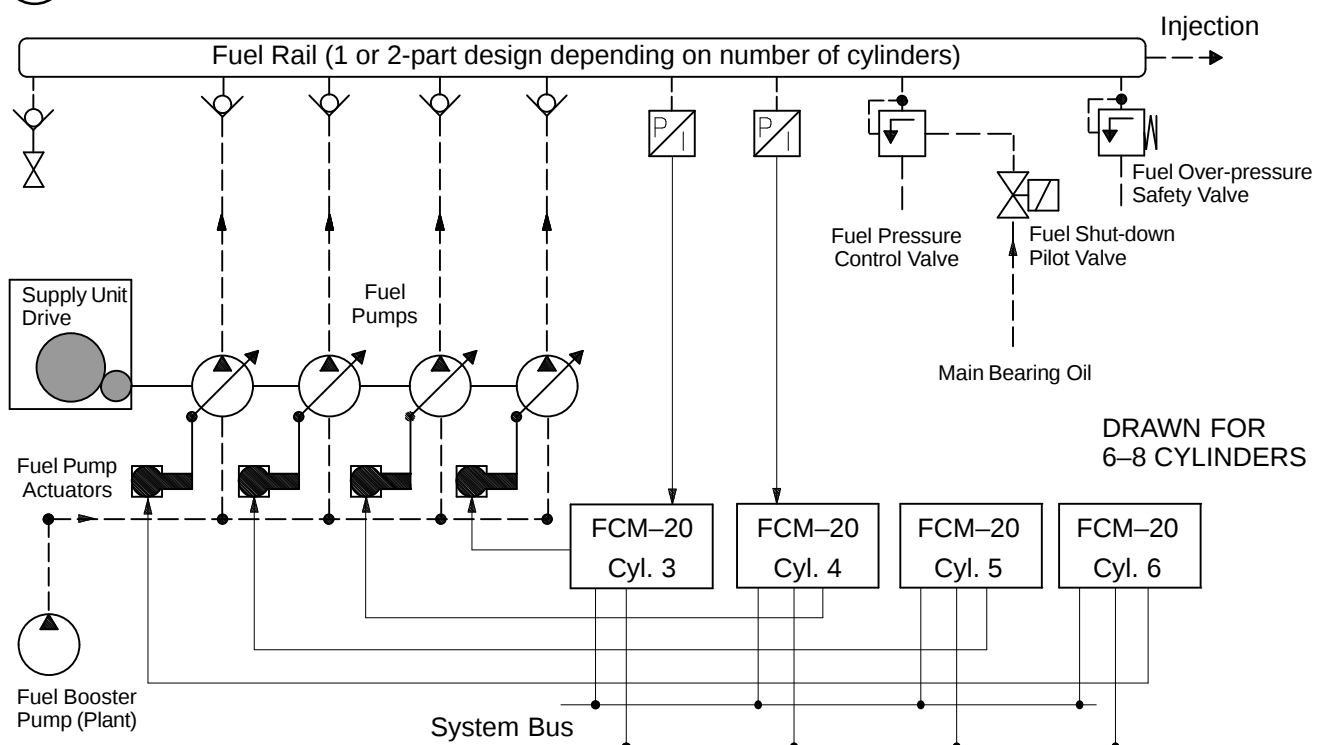
The control box E90 must subsequently be completed with a new module as 'On-line Spare' which will receive a download of all application data.



## Engine Control System WECS-9520

**Functions:**

- Fuel pressure control
- Servo oil pressure control
- Monitoring and triggering functions
- Servo oil pumps
- Fuel pump actuators
- Cylinder lubricating system control

**3.2 Fuel pressure control****C****Starting:**

At starting, the fuel pump actuators are set to start position.

**Engine running:**

The fuel pressure is dependent on the engine load.

The control loop for the fuel rail pressure can basically be described as follows:

- WECS-9520 generates a control signal based on engine speed and 'fuel command'.
- Signals from FCM-20 modules control the fuel pump actuators. There is one actuator provided for one fuel pump.
- The resulting fuel rail pressure is measured by two pressure transmitters as feedback to the FCM-20 modules of cylinders 3 & 4.

**Shut-down:**

At shut-down the fuel pump actuators are set to position 'zero' and the fuel shut-down pilot valve is activated by the safety system.

## Engine Control System WECS-9520

**3.2.1 Emergency mode*****One actuator breakdown:***

If an actuator fails, its regulating output remains in position or turns slowly to zero delivery.

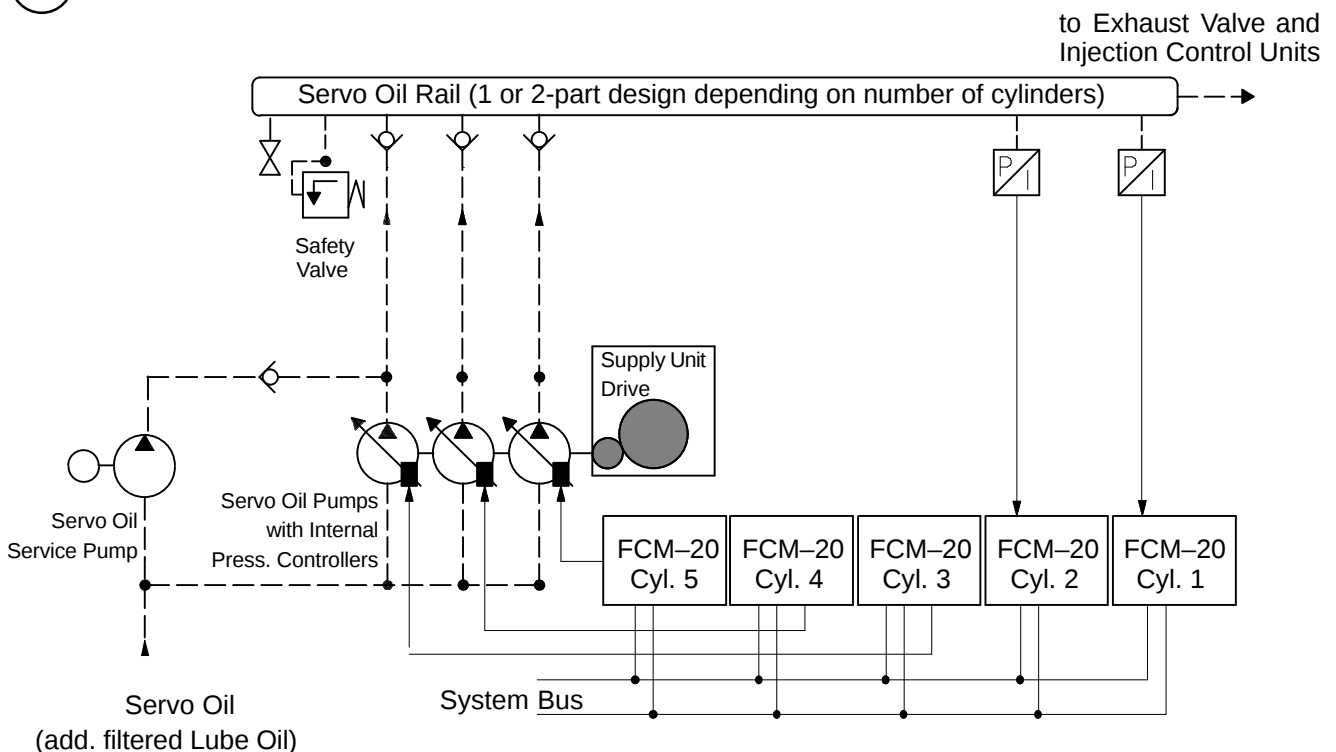
The other actuators still control the fuel pressure. In the lower load range any surplus fuel is released by the fuel pressure control valve.

**3.2.2 Monitoring*****Pressure:***

The pressure is monitored. If out of tolerance, a failure is indicated.

***Sensors:***

The sensors are monitored. If out of range or exceeding difference, a failure is indicated, and it can furthermore be observed with blinking LEDs on FCM-20 modules of cylinders 3 & 4 (see [0850-1](#) 'Failures and Defects of WECS Components').

**3.3 Servo oil pressure setpoint**

Engine Control System WECS–9520

---

**3.3.1 Pressure setpoint**

An internal mechanical pressure controller with an electrical setpoint is provided for each servo oil pump. This setpoint is determined by a pulse width modulation (PWM) signal.

The setpoint is mainly dependent on the engine load and generated in FCM–20.

A closed loop control compensates pressure losses in the pipes between the servo oil pumps and the servo oil rail.

Every pressure controller of the three pumps is connected to a FCM–20 module (cylinders 3, 4 & 5). This decentralization increases the availability of the servo oil system.

**3.3.2 Emergency mode**

One servo oil pump may fail, however, the system keeps running. The load is taken over by the other pumps.

**3.3.3 Sensor monitoring*****Pressure:***

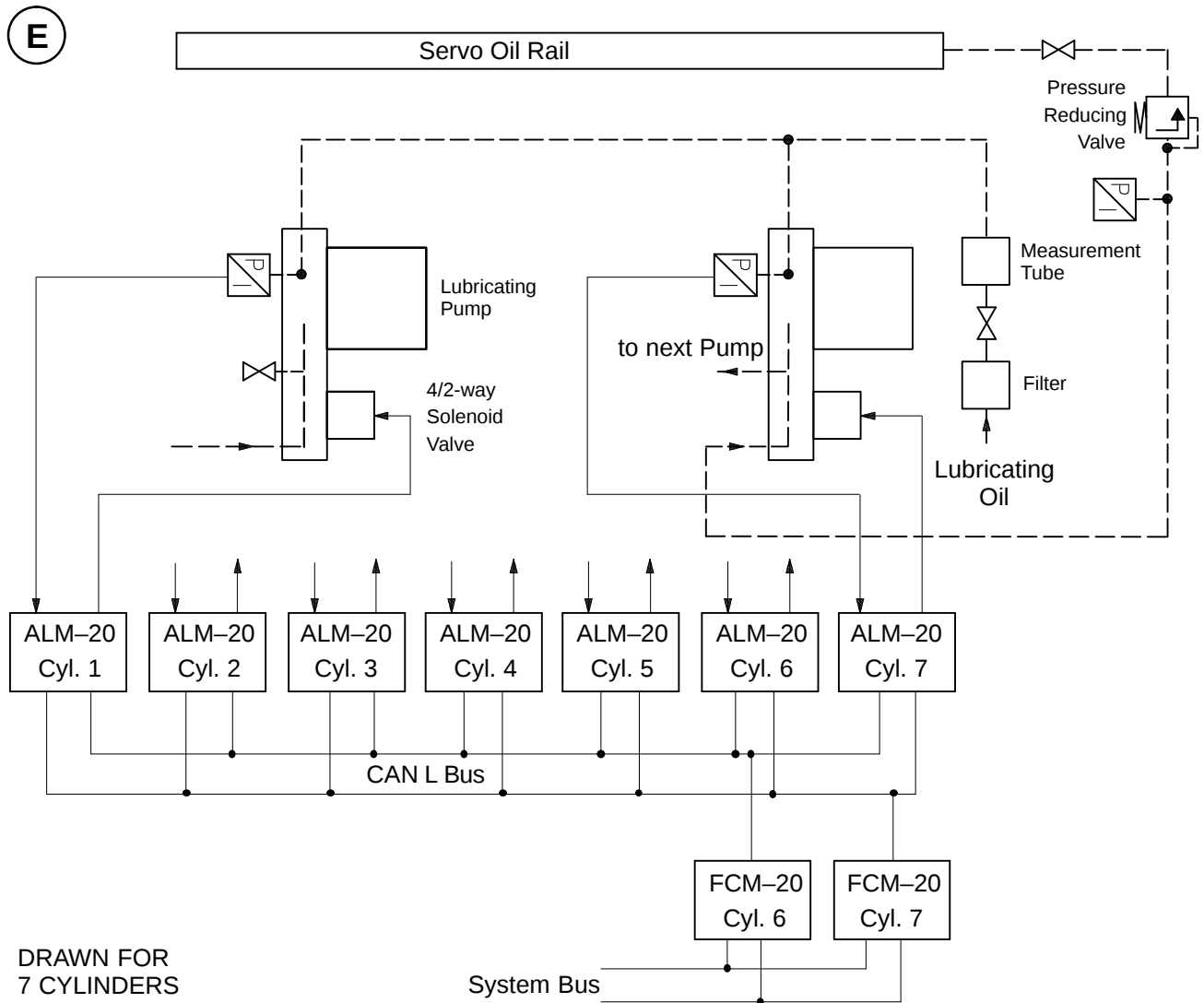
The pressure is monitored. If out of tolerance, a failure is indicated.

***Sensors:***

The sensors are monitored. If out of range or exceeding difference, a failure is indicated, and it can furthermore be observed with blinking LEDs on FCM–20 modules of cylinders 1 & 2 (see [0850–1](#) 'Failures and Defects of WECS Components').

## Engine Control System WECS-9520

## 3.4 Cylinder lubricating system control



## 3.4.1 General

The last and penultimate FCM-20 modules are provided for the control functions of the cylinder lubricating system. Each ALM-20 (control unit) actuates a lubricating pump when receiving the corresponding control signal from the FCM-20. The dual execution of the system bus, CAN bus and power supply ensures the redundancy.

## 3.4.2 Emergency mode

Upon failure of a FCM-20 module or bus the second FCM-20 module or bus ensures the control of the cylinder lubricating system, however, a passive failure is indicated in WECS-9520 (see also 0850-1).

## Engine Control System WECS-9520

## 4. Cylinder-related control functions

### 4.1 General

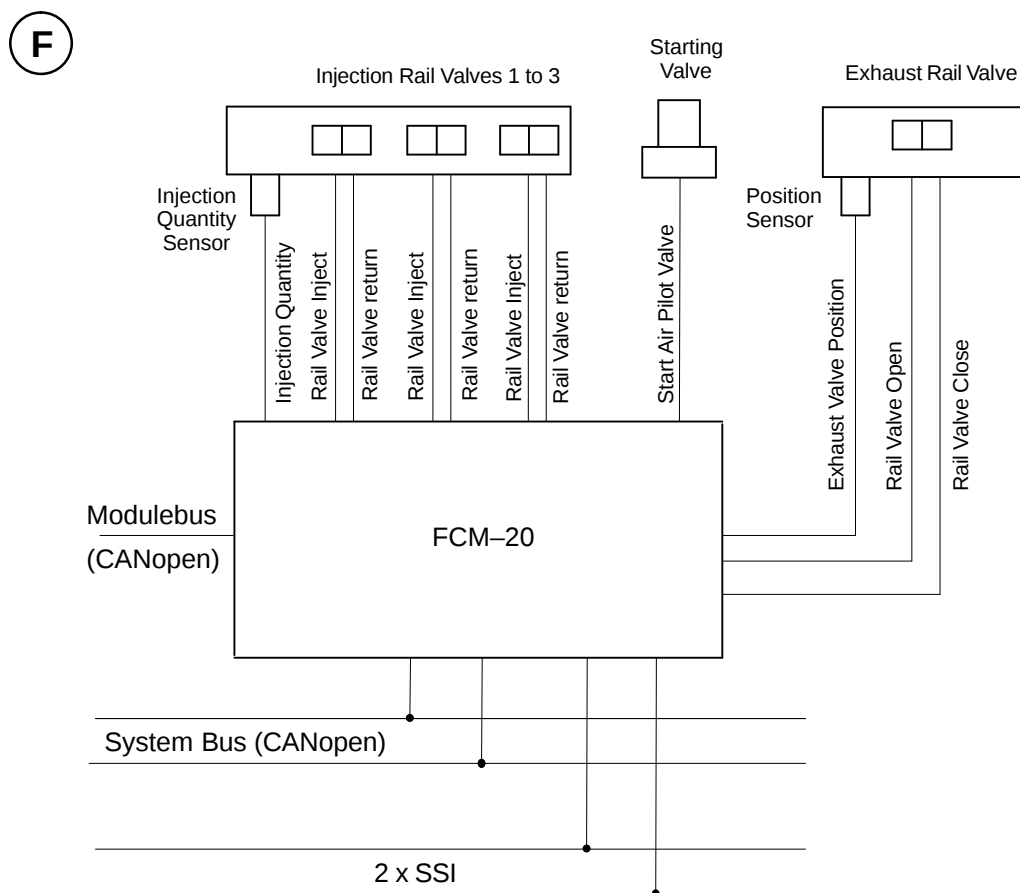
Every cylinder is equipped with an FCM-20 module. A redundant system bus provides communication between the FCM-20 modules.

The FCM-20 modules receive the crank angle signal via a redundant SSI bus.

If a FCM-20 module breaks down, the respective cylinder is cut out. The other FCM-20 modules remain in operation.

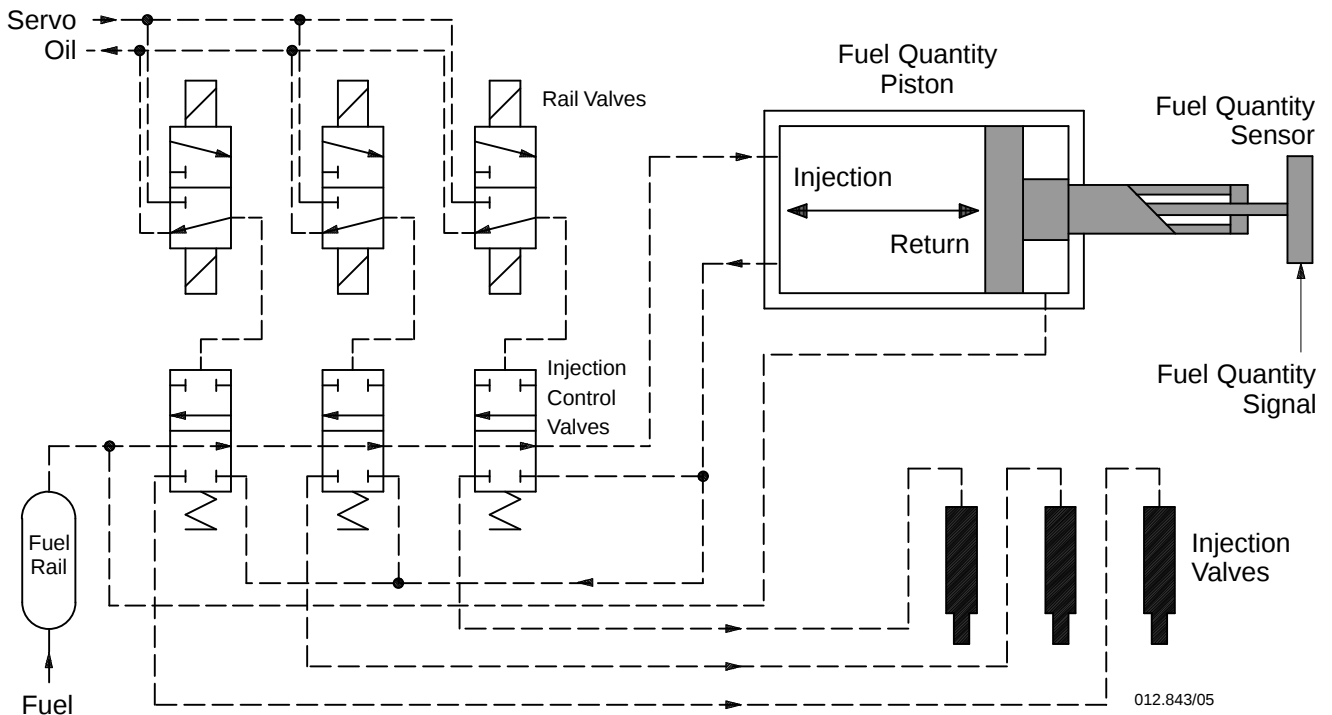
#### Functions:

- Volumetric injection control (including VIT)
- Exhaust valve control (including VEO/VEC)
- Starting valve control



## Engine Control System WECS-9520

## 4.2 Injection control

**G**

All components are shown  
in position NO INJECTION

**Injection valve control function:**

All injection valves, respectively the injection rail valves of a cylinder, are controlled individually, but with one common feedback signal for the injected fuel quantity.

Normally all injection valves are activated at the same time. Special operation modes enable injection with only one or two injection valve(s) or with spray interruption (multi-shooting patterns), (see also [0280-1](#) 'WECS-9520 Injection control').

In order to improve atomizing at low load one or two injection valves are cut out automatically.

The FCM-20 is used to amplify control outputs up to the required signal level for the rail valves.

**Rail valve ON-time measurement:**

The rail valve's supply is cut off as soon as the valve piston has moved. This is measured 'ON-time' and indicated in the remote control.

It allows a certain interpretation of the rail valve condition.

**Initial setpulse:**

Since the rail valves are bistable, their initial position is undefined. Therefore, at engine standstill, setpulses are periodically applied to the rail valves to obtain a defined position.

## Engine Control System WECS-9520

\*

**Injection control:**

Fuel injection is controlled as follows:

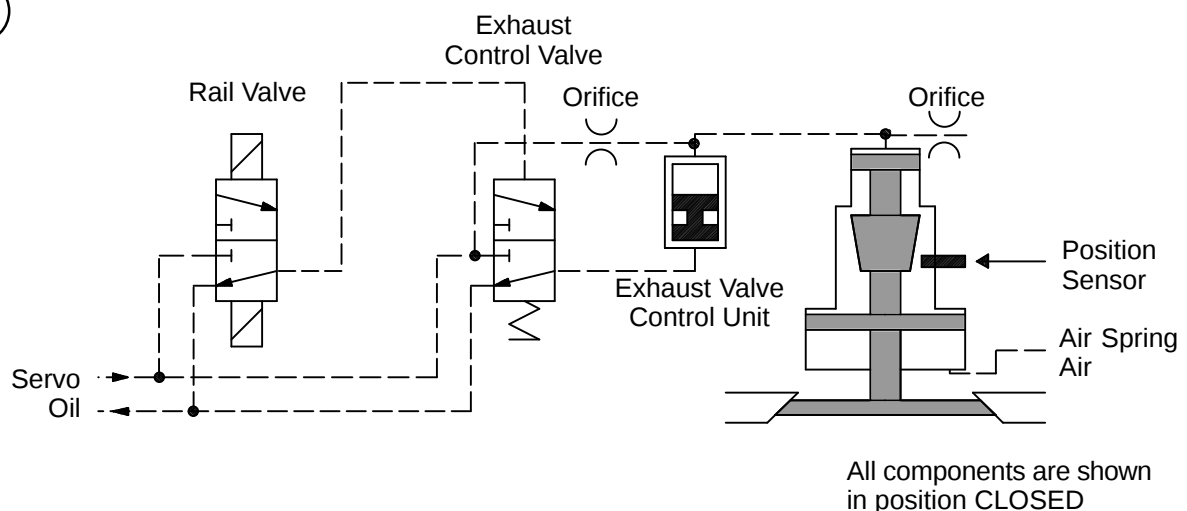
- Calculation of injection begin with reference to crank angle and VIT.
- Releasing the injection by actuating the rail valves.
- The time difference between injection start signal and injection begin is called 'injection deadtime'. The injection begin is detected with the movement of the fuel quantity piston.
- The actual injection quantity is determined by the stroke of the fuel quantity piston. The injection is stopped when the fuel quantity piston reaches the calculated stroke.
- Based on the control signal the injection quantity is calculated by the governor.
- On the following injection cycle, the calculation of the correct injection time includes the measured injection deadtime.
- The functionality of the injection system is monitored at each cycle.

**Reversing:**

For running the engine ASTERN, the crank angle is mirrored.

**Emergency mode:**

If the fuel quantity sensor is broken, the control system converts the 'fuel command' signal from the corresponding FCM-20 module into a time period. This cylinder is then controlled with timed injection.

**4.3 Exhaust valve control****H****Exhaust valve function:**

The exhaust valve opens and closes once per crankshaft revolution.

Its movement is measured by the position sensor.

The FCM-20 is used to amplify control outputs up to the required signals for the rail valves.

Engine Control System WECS-9520

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***Rail valve ON-time measurement:***

The time between start signal and moving the valve piston is measured and indicated in the remote control.

***Initial setpulse:***

Since the rail valves are bistable, their initial position is undefined. Therefore, at engine standstill, setpulses are periodically applied to the rail valves to obtain a defined position.

***Exhaust valve control:***

The exhaust valve movement is controlled as follows:

- The opening command of the exhaust valve is calculated with reference to crank angle and VEO.
- Triggering of the opening rail valve.
- Measuring opening deadtime: Displacement time from 0–15% valve stroke.
- The closing command is calculated with reference to crank angle and VEC.
- Triggering of the closing rail valve.
- Measuring closing deadtime: Displacement time from 100–15% valve stroke.
- After a completed crankshaft revolution the timing for the next cycle is corrected according to the deadtime of the previous one.

***Reversing:***

For running the engine ASTERN, the crank angle is mirrored.

***Emergency mode:***

In case of a broken position sensor the process continues with time control for the affected cylinder.

**4.4 Starting valve control**

The starting valve is opened and closed directly by the FCM-20 once per crankshaft revolution at a certain crank angle until the engine is running.

***Reversing:***

For starting the engine ASTERN, the crank angle is mirrored.

**4.5 Crank angle sensor**

Two crank angle sensors are mounted at the free end; they are driven by the crankshaft via a coupling. They provide an absolute angle signal (not an incremental signal).

Both signals are transmitted to each FCM-20, however, excluded is the 'Online Spare' module.

Following works on the crank angle sensors or their associated drives, the signals must be compared to the reading on the flywheel. If necessary the offset must be readjusted on the remote control.

***Crank angle signal monitoring:***

Both crank angle signals and the TDC signal are compared with each other.

An alarm, slow-down or shut-down is indicated if the three signals do not correspond within a certain tolerance.

## 5. Communication between WECS–9520 and external systems

WECS–9520 provides the following data communications to:

- Propulsion control system
- Ship alarm and monitoring system
- Control panel at local manoeuvring stand
- BACKUP control box in control room.

The standard version of WECS–9520 covers the following external communications:

- 2 redundant data cables to remote control
- 2 redundant data cables to ship alarm and monitoring system
- 1 data cable to local control panel
- 1 data cable to BACKUP control box in control room
- 1 data cable to a connector at BACKUP control box of remote control for connecting a notebook of the service personnel.

Schematic diagrams see [Fig. 'I'](#) and ['A'](#).



**Remark:** The communications between the systems may differ slightly depending on approved system manufacturer (see therefore the relevant documentation).

### 5.1 Propulsion control system

The propulsion control system is divided into the following subsystems:

- Remote control system (RCS)
- Electronic speed control system
- Safety system
- Telegraph system



**Remark:** The safety and telegraph systems work independently and are fully operational also at failure of the remote control functions.

### 5.2 Remote control system

Main functions:

- Start, stop, reversing
- Automatic slow turning
- Auxiliary blower control
- Transfer control
- Speed setting
- Automatic speed setting program

Information about current WECS–9520 status is available in the remote control.

This includes measured values of sensors, alarm indications, parameter settings and trendlines (see documentation of remote control manufacturer).

## Engine Control System WECS–9520

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User parameters e.g. maximum fuel limit, running-in mode and FQS can be adjusted by the engine operator.

All commands to run the engine, e.g. AHEAD or ASTERN, are generated in the RCS according to operator requirements.

On the other hand, the corresponding FCM–20 generates a load signal to the RCS out of the average from the measured fuel quantity signals.

Two charge (scavenge) air signals are transmitted to RCS via WECS–9520, therefore, the signal is redundant.

If WECS–9520 detects a failure, it sends an alarm signal to the ship alarm system or a slow-down / shut-down signal to the safety system.

### **Parameter setting:**

The parameters are divided into two groups:

- User parameters, access without password
- Expert parameters, access with password only

User parameters e.g. maximum fuel limit, running-in mode and FQS can be adjusted by the engine operator.

Expert parameters are changed only by service personnel, mainly during commissioning. A typical expert parameter is the firing order of the engine, which is set only once. A connector for service access is provided in the engine control room.

### **5.3 BACKUP control box**

It is part of the propulsion control system and arranged in the ECR console. The same control functions can be carried out as at the local control panel (see also [4618–1](#)).

### **5.4 Electronic speed control system**

- Maintains engine speed at required value from remote control
- Transfers 'fuel command' to WECS–9520
- Fuel quantity limitation depending on charge (scavenge) air pressure and engine protection

The speed control system for the engine is an independent electronic device and not part of WECS–9520.

WECS–9520 receives a 'fuel command' signal from the speed governor.

This signal is distributed to all FCM–20 modules. This is the setpoint for the fuel quantity to be injected.

In case of a speed control system failure, the engine can be run either in:

- LOCAL mode by manually adjusted fuel quantity at local control panel, or
- ECR BACKUP mode from BACKUP control box in control room.



**Attention!** In BACKUP mode an engine with controllable pitch propeller (CPP) shall be operated with blocked propeller pitch to avoid overspeed.

## Engine Control System WECS–9520

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### 5.5 Safety system

Main functions:

- Emergency stop
- Overspeed protection
- Automatic shut-down
- Automatic slow-down

Each irregularity generates within WECS–9520 a request to the safety system.

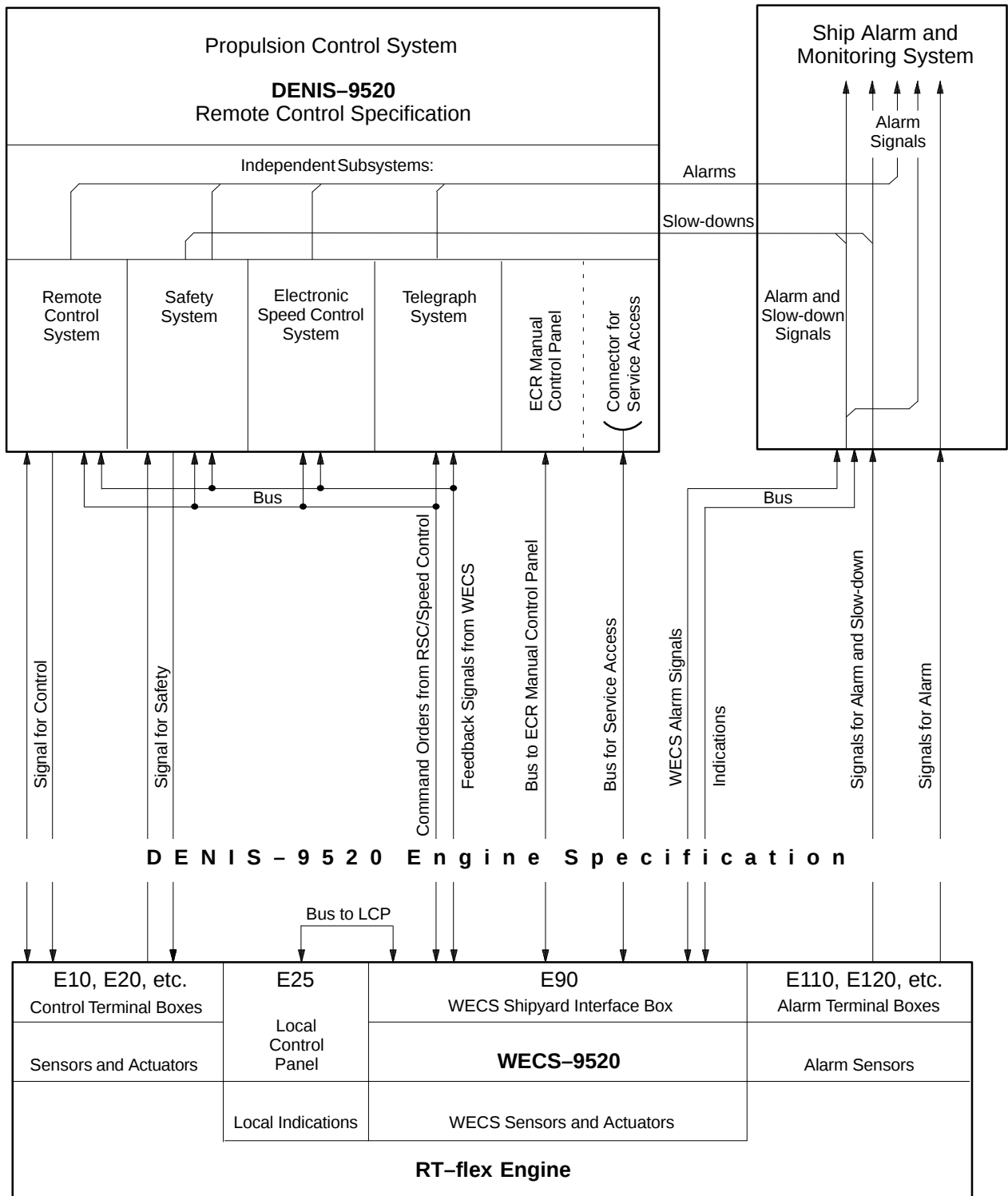
See detailed failure description in [0850–1](#) 'Failures and Defects of WECS Components'.

### 5.6 Telegraph system

- Used for transmission of manoeuvring orders from the wheelhouse to the control room and local control panel.

## Engine Control System WECS-9520

I



## User Parameters and Maintenance Settings

### 1. General

'User parameter settings' are accessible to the operator without password.

'Maintenance settings' are accessible to the operator with password or key only depending on remote control manufacturer!

Setting or altering the parameters listed in WECS-9520 can be carried out using the 'Operator interface' of the remote control as follows:

- 'User parameters' in USER
- 'Maintenance settings' in ADJUST.

How to reach these areas in order to alter the corresponding values is described in the manual of the remote control manufacturer.

#### 1.1 Overview of user parameters

| Parameter                                                                 | Purpose and effect                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>FQS</b><br>(Fuel quality setting)                                      | FQS can be set to adjust maximum firing pressure to nominal value.<br>A negative correction angle will <b>advance</b> the injection begin and increase max. pressure.<br>A positive correction angle will <b>retard</b> the injection begin and reduce max. pressure.                      |
| <b>VIT on/off</b>                                                         | VIT is normally switched on (shown as ON).<br>It can be switched off (shown as OFF) for running-in. OFF means injection begins at nominal angle independent of the engine power.                                                                                                           |
| <b>Inj. cut off</b><br>(Injection cut off)                                | Can be used to stop fuel injection to individual cylinders if necessary (e.g. in case of liner/piston ring problems or damaged injection system). The exhaust valve remains in normal operation.                                                                                           |
| <b>Inj. venting</b><br>(Injection venting)                                | Injection units of individual cylinders or all of them can be vented. Rail valves of cylinders will be rhythmically activated for some time. Servo oil service pump must be switched on.<br>This should be done preferably before every engine start after a stop of some hours.           |
| <b>Exv. A/M Cmd</b><br>(Exhaust valve auto/manual command)                | Use it to manually open and close single exhaust valve at <b>stopped engine</b> . Useful for testing and venting, e.g. after maintenance works.<br>Preconditions: Servo oil service pump must be switched on, building up some pressure in servo oil rail. Air spring pressure must be up. |
| <b>Start Valves Checking</b><br>(Common start valves 1/2, enable/disable) | For function checks of control valves on shut-off valve for starting air.<br>Switch off a valve in order to check the other one.                                                                                                                                                           |
| <b>Heavy Sea Mode</b>                                                     | Can be switched on in case of heavy sea. This function sets the fuel rail pressure to a constant value, independent of the engine power. Pressure control becomes more stable. Switch off when weather conditions have normalized and before manoeuvring.                                  |
| <b>Lubrication</b> (Feed rate)                                            | Adjusting required feed rate in steps of 0.1 g/kWh.                                                                                                                                                                                                                                        |

User Parameters and Maintenance Settings

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**1.2 Overview of maintenance settings**

| Parameter                                                                                  | Purpose and effect                                                                                                                                                                                                                                           |
|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Crank Angle (PARA3)</b><br>Crank angle offset, engine<br>TDC offset                     | Crank angle settings and checks after maintenance or replacement of crank angle sensor unit.<br>Input of crank angle deviations (mean values) and checking of measured values.                                                                               |
| <b>Exv. closing offset</b><br>(Exhaust valve closing<br>offset)                            | Cylinder pressure fine tuning in service:<br>Permits adjusting of compression pressure.                                                                                                                                                                      |
| <b>Inj. begin offset</b><br>(Injection begin offset)                                       | Cylinder pressure fine tuning in service:<br>Permits adjusting of maximum firing pressure.                                                                                                                                                                   |
| <b>Inj. correction factor</b><br>(Injection correction factor)                             | Injected fuel quantity for each cylinder can be reduced individually to 80 %. Useful to run in single cylinders or in case of running troubles on single cylinders.                                                                                          |
| <b>Servo oil pump,<br/>Pr. setp. tun.</b><br>(Servo oil pump,<br>pressure setpoint tuning) | Should be done at initial adjusting of engine at shop trial.<br>In case of exchange of a servo oil pump it could become necessary to readjust if one pump at low load gives indication of No Flow. In this case, increase pressure value by trial and error. |

## Regular Checks and Recommendations for WECS-9520

---

### 1. General

For safety reasons redundant control systems and the components in standby mode should be checked periodically for trouble-free functioning.

### 2. Monthly checks

#### 2.1 LOCAL MANUAL CONTROL (Local Control)

⇒ Carry out an engine start in LOCAL MANUAL CONTROL mode.

### 3. Quarterly checks

#### 3.1 Level switch

See [8016-1](#) 'Servo oil leakage system' and [8019-1](#) 'Fuel leakage system'.

⇒ Check electric cable junctions.

⇒ Remove the terminals cover from the sensor and change the selector switch from MAX to MIN.

- An alarm should be triggered and the LED display on the sensor shows red.

⇒ Set the selector switch back to the original position and fit the terminals cover.

#### 3.2 Power supply to FCM-20 & ALM-20 modules and fuel pump actuators

⇒ Check in power supply box E85 if all of the corresponding circuit breakers are cut in (see also Location of flex Electronic Components [9362-1](#) and block diagram in box E85).

⇒ Check the main supply switch-over functions by cutting out and in the AC #1 at the main switch board (plant side). WECS-9520 must remain in full operation.



**Remark:** Carry out the above check only at engine standstill, e.g. during the start preparations.

#### 3.3 Pressure switch PS5017C on shut-off valve



**Remark:** If the pressure switch PS5017C on the shut-off valve is defective, starting in LOCAL MANUAL CONTROL mode (Local Control) is not possible.

⇒ At engine standstill, push LOCAL MANUAL CONTROL (Local Control) at WECS-9520 manual control panel (see [4618-1](#)).

⇒ Check the indications of the turning gear:

- engaged = switch open
- disengaged = switch closed

## Regular Checks and Recommendations for WECS-9520

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### 3.4 Starting air control valves

- ⇒ Switch off one of the starting air control valves activated by FCM-20 of cylinder 1 or 2 in the remote control (user parameter, function 'Start Valves Checking').
- ⇒ Carry out an engine start with starting air (AIR RUN) only or slow turning.
- ⇒ Repeat the test procedure with the second control valve.



**Remark:** After every start attempt, WECS-9520 reactivates both control valves automatically.

### 4. Recommendations for replacing FCM-20 modules

- Carry out at engine standstill if possible.
- Cut out the power supply to the modules concerned and control box E90.
- Insert 'Online Spare' module from control box E90.
- The control box E90 must subsequently be completed with a new module as 'Online Spare' which will receive a download of all application data.

### 5. Recommendations for replacing ALM-20 modules

- Can be carried out during engine operation or at standstill.
- Replace defective ALM-20 module.
- Check function of new ALM-20 module (outer LEDs), see [7218-1](#) 'ALM-20 module'.

## Engine Control

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### Overview

|      |                                               |       |
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### 1. General

The DENIS-9520 (**D**iesel **E**ngine **C**ontrol and **O**ptimizing **S**pecification) and the WECS-9520 (**W**ärtsilä **E**ngine **C**ontrol **S**ystem) have been designed in such a manner, that various remote controls can be used. To this end all nodes are exactly defined. Terminal boxes are mounted on the engine, to which the cable ends from the control room or from the bridge (depending on remote control) can be connected.

The engine control comprises all parts which are necessary for operation, monitoring and safety of the engine.

#### **Synopsis of engine control (4003-2):**

The **Control Diagram** is a schematic synopsis of all control components and of their functional connections.

All code numbers and designations used in the following description are found in the control diagram and summary 4003-2.

#### **Detailed control diagram with interfaces in the plant (4003-3):**

On these pages individual diagram sections of the engine control connected by function are shown in detail.

They provide a general view of:

- Connection of the individual systems.
- Interfaces from engine to plant or to remote control respectively.
- Monitoring and safeguard instrumentation.
- Code designations for the identification of external connectors.

## Engine Control

**2. Function of control**

The engine control permits carrying out the following functions:

- Starting, operation, manoeuvring and shutting down.
- Regulating the engine speed.
- Partly safeguarding and monitoring the engine.

All the functions can be checked (see [paragraph 4](#). 'Checking the engine control system before commissioning the engine').

Interlocks protect against and prevent manoeuvring errors.

| Media of control                                | Pressures                      |
|-------------------------------------------------|--------------------------------|
| Control air from board system                   | 7 – 9 bar <sup>1)</sup>        |
| Control air from starting air system            | max. 25 / 30 bar <sup>2)</sup> |
| Starting air from starting air bottle           | max. 25 / 30 bar               |
| Main & crosshead bearing and piston cooling oil | 4.5 – 6.0 bar                  |
| Servo oil                                       | 100 – 200 bar                  |

1) Adjusted to 6.5 bar with pressure reducing valve 23HA

2) Adjusted to 6 bar with pressure reducing valve 19HA

**3. Engine local control**

The engine can be operated at the local control panel (see also [4618–1](#)).

This mode of operation can be chosen e.g. in case of electronic speed control system or remote control failures. The operator may under no circumstances leave the local manoeuvring stand. He must regularly observe the engine speed enabling him to immediately adjust the fuel supply when the speed varies to some extent.

**Additional preparation:**

- ⇒ At WECS–9520 manual control panel (see [4618–1](#)), press button LOCAL MANUAL CONTROL (Local Control) for mode transfer to local manual control.

**Starting:**

- ⇒ Press button AUX. BLOWER PRESEL.
- ⇒ Press button FUEL CONTROL MODE.
- ⇒ Turn rotary knob for fuel injection quantity to approx. 15% start fuel charge (see display).
- ⇒ Press requested button START AHEAD or START ASTERN until the engine runs.
- ⇒ Slowly adjust rotary knob for fuel injection quantity until the engine runs at the required speed. The corresponding value can be read on display and speed indicator.

Engine Control

---

**Reversing:**

- ⇒ Turn rotary knob to 15% fuel injection quantity (see display).
- ⇒ Press requested button START AHEAD or START ASTERN until the engine runs in the correct direction.



**Remark:** On ships under way this procedure may under certain circumstances take rather a long time (several minutes), as the propeller is "dragged" in the "wrong" sense of rotation.

**Stopping:**

- ⇒ Reduce engine speed / load with rotary knob.
- ⇒ Press button STOP.



**Remark:** The above mentioned starting procedure may also be carried out on ECR manual control panel.

However, buttons and rotary knob function only in the corresponding mode of operation, i.e. with active control stand (see 4618–1 'WECS–9520 manual control panel').

## 4. Checking the engine control system

Should elements of the pneumatic control system have been dismantled, removed or replaced during an overhaul, then a general operational check must be made before recommissioning. The following passages describe how to proceed.

The item numbers of the following mentioned valves and designations correspond to those in the schematic engine control diagram 4003–2 and detailed control diagrams 4003–3.



**Attention!** Any detected leakages must be eliminated during checking the control system!

### 4.1 General preparatory works

- ⇒ Open indicator valves.
- ⇒ Close shut-off valves on the starting air bottles. Close shut-off valve for starting air 2.03 with handwheel 2.10. Vent starting air supply pipe with venting valve 2.21.
- ⇒ Vent starting air distributor main using venting valve 2.27.
- ⇒ Vent control air bottle 287HA.
- ⇒ Engage turning gear.
- ⇒ Remove roller lifting tools if fitted.
- Servo oil service pump 4.88 must be switched off (main switch).

### 4.2 Control air supply unit **A**

- ⇒ Open 30 bar feed to control air supply unit using shut-off cock 36HC at connection A2.
- ⇒ Adjust air for air spring and control air to **6 bar** with reducing valve 19HA. For this shut-off cock 36HA must be open. The pressure can be checked on pressure gauges PI4341M and PI4412M.
- ⇒ Open 8 bar feed from board supply system to control air supply unit using shut-off cock 36HB at connection A1.
- ⇒ Adjust air for air spring and control air to **6.5 bar** with reducing valve 23HA. The pressure can be checked on pressure gauges PI4341M and PI4412M.
- ⇒ Make sure that air is fed to blocking valve 2.13.

## Engine Control

**4.3 Starting up of WECS–9520 control system**

- ⇒ Switch on all breakers in the power supply box E85.
- ⇒ Check that both green indication LEDs light up on all FCM–20 modules.
- The FCM–20 modules are able to function if no red LEDs light up after the countdown process.

**4.4 Safety and alarm system**

- ⇒ WECS–9520, RCS, safety system, alarm and monitoring system must be switched on.
- ⇒ Actuate EMERGENCY STOP on the control room console as well as on the local control panel. Check each time if fuel shut-down pilot valve 3.08 is electrically activated (i.e. the coil is energized).
- For the safety system the setting of the pressure switches must be carried out with falling pressures by means of the compressed air pump (tool), in accordance with the following table:

| Medium                 | Code No.   | Pressure | Action | Time delay |
|------------------------|------------|----------|--------|------------|
| Cylinder cooling water | PS1101S    | 2.5 bar  | Stop   | 60 sec.    |
| Main bearing oil       | PS2002S    | 3.8 bar  | Stop   | 60 sec.    |
| Piston cooling oil     | PS2541–xxS | 0.4 bar  | Stop   | 15 sec.    |
| Air spring             | PS4341S    | 4.5 bar  | Stop   | 0 sec.     |



**Remark:** The above setpoints are for reference only. Valid settings see Operating Data Sheet [0250–2](#).

- For the passive failure monitoring a resistor must be inserted in the plug of the following pressure switches between connections 2 and 3:
  - PS1101S
  - PS2002S
  - PS4341S
- For passive failure monitoring a resistor must be inserted in the plug of pressure switches PS2541S–PS25xxS between connections 1 and 3.

The value of the resistors depends on the remote control supplier:

| Supplier           | Resistor [kOhm] | Power [W] |
|--------------------|-----------------|-----------|
| KONGSBERG Maritime | 10              | 0.6       |
| NABTESCO           | 3.9             | 0.6       |
| SAM / Lyngsø       | 8.2             | 0.6       |

## Engine Control

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- ⇒ Trigger a system alarm in the oil mist detection system by means of:
  - removing a plug from the junction box or
  - starting the 'Test Menu' in the control unit.
- ⇒ Connect smoke testing instrument (tool) to test connection on a sensor. Simulate oil mist and with that trigger an alarm in the safety system.
- ⇒ Check pick-ups for speed measurement:
  - Turn crankshaft with turning gear. LEDs on speed pick-ups go on and off in the pattern of passing teeth.
- ⇒ Check level switch in the condensate collectors. Release a high-level alarm by manual actuating of the floater.
- ⇒ Check level switch in the leakage oil return. Release a high-level alarm by manual actuating of the floater.

### 4.5 Automatic filter

- ⇒ Ensure pressure air at the automatic filter. Check whether stop valves 4.37 and 4.80 are open in the oil pipe before and after automatic filter, and stop valve is closed in the pressure compensating pipe near the oil outlet.
- ⇒ Ensure power supply at control box and turn on main switch.
- ⇒ Bring selector switch in the control box to 'Adjust' ( II ). On the display the parameters can be adjusted as follows:  
(see also instructions of filter manufacturer)

| Function                             | Parameter | Adjustment |
|--------------------------------------|-----------|------------|
| Flushing interval in h               | PA2       | 1          |
| Flushing interval in min.            | PA3       | 0          |
| Flushing interval in sec.            | PA4       | 20         |
| Flushing interval monitoring (alarm) | PA8       | ON         |

- ⇒ Bring selector switch in the control box back to 'Operation' ( I ).
- ⇒ Touch 'Flushing' button on the display. A flushing cycle of 20 seconds duration must now be initiated.
- ⇒ Observe whether the motor of the rotating device turns in the indicated direction (clockwise viewed from top).

## Engine Control

## 4.6 Auxiliary blowers

- ⇒ Switch on electric power supply for both auxiliary blowers.
- ⇒ Press button LOCAL MANUAL CONTROL at WECS–9520 manual control panel (see 4618–1) in order to takeover the control.
- ⇒ Press button AUX. BLOWER PRESEL.
- Auxiliary blower 1 must start immediately.
- Auxiliary blower 2 must start with a delay of four to six seconds.
- ⇒ This delay period can be set on time relay in the auxiliary blower control box.
- ⇒ Repeat this test at ECR manual control panel.
- ⇒ Check rotation direction of both auxiliary blowers.
- ⇒ Connect compressed air pump (tool) to pressure transmitters PT4043C and PT4044C, simulating scavenge air pressure (0–4 bar). Disconnect cables from terminal 18 (PT4043C) resp. terminal 20 (PT4044C) and connect an ammeter between terminal and corresponding cable in terminal box E12. Check that transmitter output (4–20 mA) corresponds with simulated pressure (0–4 bar). If necessary adjust or replace transmitter(s). Reconnect cables to terminals after test.  
Auxiliary blower start/stop hysteresis (0.35/0.45 bar) is adjusted in remote control.
- ⇒ Remove compressed air pump.

## 4.7 Servo oil system

- ⇒ Start main bearing oil pump and check whether the operating pressure is properly adjusted.
- ⇒ Start servo oil service pump 4.88.
- The pressure in servo oil rail 4.11 should be approx. 100 bar. The corresponding value can be read off on display of WECS–9520 manual control panel.

## 4.8 Exhaust valve drive

- ⇒ Open exhaust valve 4.01 of cylinder 1 manually in remote control (user parameter, function 'Exv. A/M Cmd').
- ⇒ Simultaneously with opening the exhaust valve, note indicated value (mA) in remote control, EXV of field 'Open position sensor'.



**Remark:** This value must be noted immediately after opening the exhaust valve, since the valve will automatically close slowly.

- ⇒ Shut exhaust valve 4.01 of cylinder 1.
- ⇒ With exhaust valve closed, note indicated value (mA) in remote control, EXV of field 'Open position sensor'.
- ⇒ Repeat procedure above for each exhaust valve.
- The shown values shall be approximately the same for all cylinders. If not, the valve is not fully open or the sensors are defective.
- ⇒ Set parameters of each exhaust valve drive to AUTO in remote control (user parameter, function 'Exv. A/M Cmd').

Engine Control

---

**4.9 Cylinder lubrication**

- ⇒ Check whether all ALM-20 modules are electrically connected. The display (upper LED part) lights up green with power supply switched on and correctly working lubricating system software.
- ⇒ Open stop valves 4.30-5 and 4.30-6.
- ⇒ Check servo oil pressure of 60 bar. If necessary adjust it by means of pressure reducing valves 8.11-1 and 8.11-2. The value can be read off on pressure gauges PI2041L and PI2042L.
- ⇒ Ensure lubricating oil supply and cleanness of piping filter 8.17.
- ⇒ Put shut-off valves and relief valves in the lubricating pumps to operating position (to stop fully turned out).
- ⇒ Check whether stop valve is closed in oil pipe to exhaust valves.



**Remark:** However, stop valve is to be opened for 24 hours after an exhaust valve overhaul (see [7218-1](#) 'Additional lubrication of exhaust valve spindle').

- ⇒ Vent lubricating oil filter 8.17, measurement tube 8.19 and all lubricating pumps 8.06.
- ⇒ Select corresponding cylinder number in field MANUAL LUBRICATION ON CYL. in the operator interface or actuate MANUAL EMERGENCY on 4/2-way solenoid valve, checking whether lubricating oil is fed to the row of lubricating grooves in the cylinder liner through the lubricating quills.



**Remark:** According to requirements number of lube pulses can be altered (e.g. 200 lube pulses for checking feeding or for venting) LUBRICATION → in field MANUAL LUB. NR. OF CYCLES in the operator interface.

- ⇒ Set parameter for feed rate, e.g. 1.4 g/kWh for running-in (see Cylinder Lubrication [7218-1](#) and [0410-1](#) 'Cylinder lubricating oil feed rate').

**4.10 Regulating linkage**

- ⇒ Verify if the connections to the fuel pumps have been fitted according to Maintenance Manual [5583-1](#) 'Adjusting the regulating linkage'.
- ⇒ Ensure that the regulating linkage moves freely over the entire stroke.



**Newer switch on actuators which are disconnected from the regulating linkage, nor disconnect the regulating linkage of already powered up actuators! This leads to actuator damages!**

Engine Control

---

**4.11 Fuel oil system**

- ⇒ Start fuel booster pump 3.15.
- ⇒ Check if pressure retaining valve 3.53 has been set to a pressure difference of 3–5 bar. The pressures before and after the pressure retaining valve can be read off pressure gauges PI3421L and PI3431L (setting values see also Operating Data Sheet [0250–1](#)).
- ⇒ Check whether knurled screw is adjusted and tightened at its lower stop corresponding to the opening pressure on fuel pressure control valve 3.06.
- ⇒ Remove plug 3.39 and the nut with conical plug on stop valve 3.40 and connect tool 94583 (pipe) between fuel rail 3.05 and servo oil rail 4.11.
- ⇒ Start main bearing oil pump and servo oil service pump 4.88.
- ⇒ Open stop valve 3.40 between fuel rail 3.05 and servo oil rail 4.11. Fuel rail must now be pressurized with 70–100 bar.
- ⇒ Start the venting function of the injection system in remote control (user parameter, functions 'Inj. Venting' and 'Venting all').
- The fuel pressure shall not drop too much, then the venting function is completed.
- ⇒ Press all EMERGENCY STOP buttons, triggering a shut-down.
- Fuel pressure control valve 3.06 must open at once, and the pressure in fuel rail 3.05 must drop to '0' bar. This pressure drop can be watched on display of WECS–9520 manual control panel ([4618–1](#)).
- ⇒ Close stop valve 3.40.
- ⇒ Relieve pressure in fuel rail 3.05. Remove tool 94583 (pipe) between fuel rail 3.05 and servo oil rail 4.11. Refit and tighten plug 3.39 and the nut with conical plug.
- ⇒ Reset the EMERGENCY STOP so that the system is operative again.

**4.12 Starting system and start interlock*****Start interlock:***

- Shut-off valve for starting air 2.03 is closed and starting air supply piping vented.
- Turning gear is engaged.
- ⇒ Loosen the piping to valve unit **E** at connection E6. **No** air must come out of the pipe.
- ⇒ Slowly disengage turning gear. As long as the pinion of the turning gear is engaged, and as long as the clearance between the tooth of the flywheel and the pinion of the turning gear does not exceed 10 mm, no air must issue from the piping. This check has to be made when engaging and disengaging the turning gear.
- ⇒ Reconnect the piping to connection E6. Disengage the turning gear.

Engine Control

---

**Shut-off valve for starting air:**

- ⇒ Remove shuttle valve 115HA from valve unit **E**.  
(pay attention not to lose the three O-rings!)
- ⇒ Press button LOCAL MANUAL CONTROL at WECS-9520 manual control panel (see [4618-1](#)) in order to takeover the control.
- ⇒ Press button AIR RUN.
- ⇒ Check that both solenoid valves ZV7013C and ZV7014C are energized (using screwdriver or magnet tester), and control air comes out at both outer bores at shuttle valve place in valve unit **E**.
- Shut-off valve for starting air 2.03 manually closed, no active shut-downs released, turning gear disengaged and auxiliary blowers switched off by means of AUX. BLOWER STOP button.
- ⇒ Press button START AHEAD at WECS-9520 manual control panel.
- Indications 'No Aux. Blower Running' and 'Start Interlock' must be displayed on WECS-9520 manual control panel. No start command is released.
- ⇒ Carry out same test with START ASTERN button.
- ⇒ Press button AUX. BLOWER PRESEL. and carry out both tests START AHEAD and START ASTERN.
- The auxiliary blowers start and control air comes out at both outer bores at shuttle valve place in valve unit **E**.
- ⇒ Refit shuttle valve 115HA with O-rings in valve unit **E**.

**Turning gear interlocks:**

- Turning gear is engaged.
- ⇒ Check whether pressure switch PS5017C (switching point 2 bar) and switch ZS5016C are not activated (open contact).
- Indication 'Turning Gear Engaged' must be displayed on both WECS-9520 manual control panels, i.e. at the control room console and local manoeuvring stand.



**Attention, very important!** It must be ensured that the engine is ready for service, shut-off valve for starting air 2.03 is closed and starting air supply piping vented.

- ⇒ Press button LOCAL MANUAL CONTROL at WECS-9520 manual control panel (see [4618-1](#)) in order to takeover the control.
- ⇒ Press button START AHEAD.
- Indication 'Start Interlock' must be displayed on both WECS-9520 manual control panels. No start command is released.
- ⇒ Repeat test also from ECR manual control panel and with remote control.
- ⇒ Disengage turning gear.
- Indication 'Start Interlock' disappears from both WECS-9520 manual control panels. Start command is cleared in remote control.

## Engine Control

---

### 4.13 Overspeed system and start preparations

- ⇒ Close venting valves 2.21 and 2.27. Put handwheel 2.10 of shut-off valve for starting air 2.03 in position AUTOMAT and open shut-off valves at the starting air bottles.
- Turning gear is disengaged.
- ⇒ Set overspeed safeguard monitoring to approx. 30 rpm.
- ⇒ Make absolutely sure that the safety system checks have been carried out successfully and fuel shut-down pilot valve 3.08 functions properly.
- ⇒ Switch on main bearing oil pump.
- ⇒ Switch off servo oil service pump 4.88.
- ⇒ Switch on cooling water pumps.
- ⇒ Press button LOCAL MANUAL CONTROL at WECS-9520 manual control panel (see [4618-1](#)) in order to takeover the control.
- ⇒ Start the engine with air only by pressing AIR RUN button.
- When the engine reaches a speed of 30 rpm, overspeed monitoring should respond, activating a shut-down.
- Fuel pressure control valve 3.06 must open, and existing pressure in fuel rail 3.05 must drop at once. This can be watched on display of WECS-9520 manual control panel.
- At the same time the fuel pump actuators move the toothed racks in the fuel pumps to position '0'.
- ⇒ Reset the overspeed monitoring so that the system is operative again.
- If these overspeed tests have been successfully completed, the overspeed monitoring in the safety system can be set to the nominal speed +10%.

### 4.14 Start on fuel oil

- The engine is ready for service (see [0110-1](#) 'Checks and preparations').
- ⇒ Turn the engine with air by pressing AIR RUN button.
- ⇒ Press button FUEL CONTROL MODE.
- ⇒ Set fuel injection quantity to 25% with rotary knob on local control panel.
- ⇒ The engine can now be started by pressing START AHEAD button on WECS-9520 manual control panel. Regulate the speed by means of rotary knob for fuel injection quantity. Run the engine until all cylinders fire regularly.
- ⇒ Press button STOP. The engine stops.
- ⇒ At WECS-9520 manual control panel, press button REMOTE AUTO. CONTROL for mode transfer to remote control.
- ⇒ After takeover the engine can be started via remote control.

**Control Diagram**Designations (Description to [4003-1](#), [4003-2](#) and [4003-3](#))**1. Summary of part code numbers**

|          |                                             |
|----------|---------------------------------------------|
| <b>A</b> | Control air supply unit                     |
| <b>B</b> | Fuel supply                                 |
| <b>C</b> | Fuel injection                              |
| <b>D</b> | Servo oil supply                            |
| <b>E</b> | Valve unit for start                        |
| <b>F</b> | Exhaust valve drive                         |
| <b>H</b> | Instrument panel                            |
| <b>I</b> | Pressure switches and pressure transmitters |
| <b>K</b> | Local control panel                         |

|           |                                 |      |                                |
|-----------|---------------------------------|------|--------------------------------|
| <b>1.</b> | <b>Speed setting system</b>     | 27   | Ball valve                     |
| 01        | Crank angle sensor unit         | 29   | Fuel rising pipe               |
| 04        | Speed pick-ups                  | 33-3 | Stop valve                     |
| <b>2.</b> | <b>Starting system</b>          | 33-4 | Stop valve                     |
| 03        | Shut off valve for starting air | 33-5 | Stop valve                     |
| 04        | Non-return valve                | 33-6 | Stop valve                     |
| 05        | Control valve                   | 38   | Ball valve                     |
| 06        | Drain and test valve            | 39   | Plug                           |
| 07        | Starting valve                  | 40   | Stop valve                     |
| 08        | Flame arrester                  | 41   | Injection control valve        |
| 09        | Relief valve                    | 42   | Fuel quantity piston           |
| 10        | Handwheel for shut-off valve    | 43   | Actuator piston                |
| 13        | Blocking valve on turning gear  | 46   | Fuel leakage pipe              |
| 21        | Venting valve                   | 47   | Injection pipe                 |
| 27        | Venting valve                   | 48   | Fuel leakage pipe pressurized  |
|           |                                 | 49   | Fuel leakage pipe injector     |
| <b>3.</b> | <b>Fuel system</b>              | 52   | Fuel overpressure safety valve |
| 01        | Fuel injection valve            | 53   | Pressure retaining valve       |
| 02        | Injection control unit          | 55   | Camshaft                       |
| 03        | Fuel quantity sensor            | 65   | Drain valve                    |
| 05        | Fuel rail                       | 67   | Non-return valve               |
| 06        | Fuel pressure control valve     | 76   | Rail valve                     |
| 08        | Fuel shut down pilot valve      | 77-1 | Pressure transmitter           |
| 10        | Level switch                    | 77-2 | Pressure transmitter           |
| 12        | Leakage inspection device       | 81-1 | Non-return valve               |
| 14        | Fuel pumps                      | 81-2 | Non-return valve               |
| 15        | Fuel booster pump (plant)       | 81-3 | Non-return valve               |
| 17        | Leakage inspection point        | 81-4 | Non-return valve               |
| 19        | Cut-out device (tool)           | 81-5 | Non-return valve               |
| 21        | Fuel pump actuator              | 81-6 | Non-return valve               |
| 22        | Non-return valve                | 82   | Drain screw                    |
| 24        | Fuel inlet pipe                 |      |                                |

## Designations (Description to 4003–1, 4003–2 and 4003–3)

|           |                                          |           |                                           |
|-----------|------------------------------------------|-----------|-------------------------------------------|
| <b>4.</b> | <b>Exhaust valve drive</b>               | 51        | Supply pipe                               |
| 01        | Exhaust valve                            | 53        | Non-return valve                          |
| 02        | Air spring                               | 54        | Flow sensor                               |
| 03        | Valve drive                              | 55        | Servo oil rising pipe                     |
| 06        | Non-return valve with throttle           | 63        | Servo oil return piping                   |
| 08        | Air spring venting                       | 66        | Actuator pipe                             |
| 10        | Exhaust valve control unit               | 68        | Disc spring                               |
| 11        | Servo oil rail                           | 69        | Two-stage piston                          |
| 15        | Servo oil pump                           | 70–1      | Stroke sensor                             |
| 16        | Pressure control valve                   | 71        | Stroke measuring device                   |
| 17        | Leakage inspection point                 | 76        | Rail valve                                |
| 18        | Level switch                             | 77–1      | Pressure transmitter                      |
| 19        | Throttle                                 | 77–2      | Pressure transmitter                      |
| 20        | Automatic filter                         | 80        | Stop valve                                |
| 22        | Crankcase                                | 82        | Drain screw                               |
| 23        | Safety valve                             | 88        | Servo oil service pump                    |
| 24–1      | Non-return valve                         | <b>7.</b> | <b>Monitoring</b>                         |
| 24–2      | Non-return valve                         | 18        | Collector for leakage oil from air spring |
| 24–3      | Non-return valve                         | <b>8.</b> | <b>Cylinder lubricating system</b>        |
| 26–3      | Stop valve                               | 06        | Cylinder lubricating pump                 |
| 26–4      | Stop valve                               | 09        | Lubricating quill with non-return valve   |
| 26–5      | Stop valve                               | 11–1      | Pressure reducing valve                   |
| 26–6      | Stop valve                               | 11–2      | Pressure reducing valve                   |
| 30–5      | Stop valve                               | 17        | Cyl. lube oil filter                      |
| 30–6      | Stop valve                               | 19        | Measurement tube                          |
| 37        | Stop valve                               | <b>9.</b> | <b>Engine room</b>                        |
| 39        | Gear wheel crankshaft                    | 01        | Starting air bottles                      |
| 41–1      | Intermediate wheel servo oil supply      | 02        | Oil pump (low pressure)                   |
| 41–2      | Intermediate wheel fuel supply           | 04        | Oil filter                                |
| 42        | Gear wheel                               | 05        | Oil cooler                                |
| 44        | Gear wheel                               |           |                                           |
| 45        | Pinion                                   |           |                                           |
| 50        | Shaft with shearable overload protection |           |                                           |

Designations (Description to 4003–1, 4003–2 and 4003–3)

|            | Sensors                                      |              | Actuators                            |
|------------|----------------------------------------------|--------------|--------------------------------------|
| PS3121A    | Cyl. lube oil filter diff. pres.             | CV7231–36C   | Fuel pump actuator No. A1–B3         |
| PT2041A    | Cyl. lubr. servo oil free end                | CV7221–23C   | Servo oil pump actuator No. 1–3      |
| PT2042A    | Cyl. lubr. servo oil driving end             |              |                                      |
| PT2046A    | Cyl. lubr. servo oil leakage free end        | ZV7201–12A/B | Exhaust valve control unit Cyl. 1–12 |
| PT2047A    | Cyl. lubr. servo oil leakage driving end     | ZV7201–12C–H | Injection control unit Cyl. 1–12     |
| PT2051A    | Servo oil unit inlet pressure                | ZV7241–52C   | Start air pilot valve Cyl. 1–12      |
| PT2071C    | Servo oil rail pressure                      | ZV7061S      | EM. STOP (Fuel Shd pilot valve)      |
| PT2072C    | Servo oil rail pressure                      | ZV7013C      | Common start valve 1                 |
| PT3421A    | Fuel before supply unit                      | ZV7014C      | Common start valve 2                 |
| PT3461C    | Fuel rail pressure                           |              |                                      |
| PT3462C    | Fuel rail pressure                           |              |                                      |
|            |                                              |              | <b>Local indications</b>             |
| LS2055A    | Servo oil supply unit, leak                  | PI2041L      | Cylinder lubr. servo oil free end    |
| LS3426A    | Fuel supply unit, leak (fuel side)           | PI2042L      | Cylinder lubr. servo oil driving end |
| LS3427A    | Fuel supply unit, leak (exhaust side)        | PI2051L      | Servo oil unit (inlet pressure)      |
| LS3444A    | Rail unit general leak (DE)                  | PI2071M      | Servo oil rail pressure              |
| LS3445A    | Rail unit general leak (FE)                  | PI3421L      | Fuel pressure supply unit inlet      |
| LS3446A    | Injection control unit or fuel pipe leak     | PI3431L      | Fuel pressure supply unit outlet     |
| LS2076A    | Servo oil leak rail unit (DE)                | PI3462M      | Fuel rail pressure                   |
| LS2077A    | Servo oil leak rail unit (FE)                |              |                                      |
| FS2061–63A | Servo oil pump 1–3 (flow)                    | SI5101M      | Engine speed                         |
| GT5126C    | Crank angle sensor 1                         |              |                                      |
| GT5127C    | Crank angle sensor 2                         |              |                                      |
| TE3431–36A | Fuel pump A1–B3 outlet temp.                 |              |                                      |
| ZS5016C    | Turning gear disengaged                      |              |                                      |
| ZS5018C    | Start air shutoff valve man. closed          |              |                                      |
| ZS5123C    | Engine TDC signal                            |              |                                      |
| ZT5421–32C | Exhaust valve 1–12, open and close positions |              |                                      |
| ZT5461–72C | Fuel injection quantity cylinder 1–12        |              |                                      |

**Remark:** Systems are drawn for engines in STOP position, reversed AHEAD with unpressurised circuits.

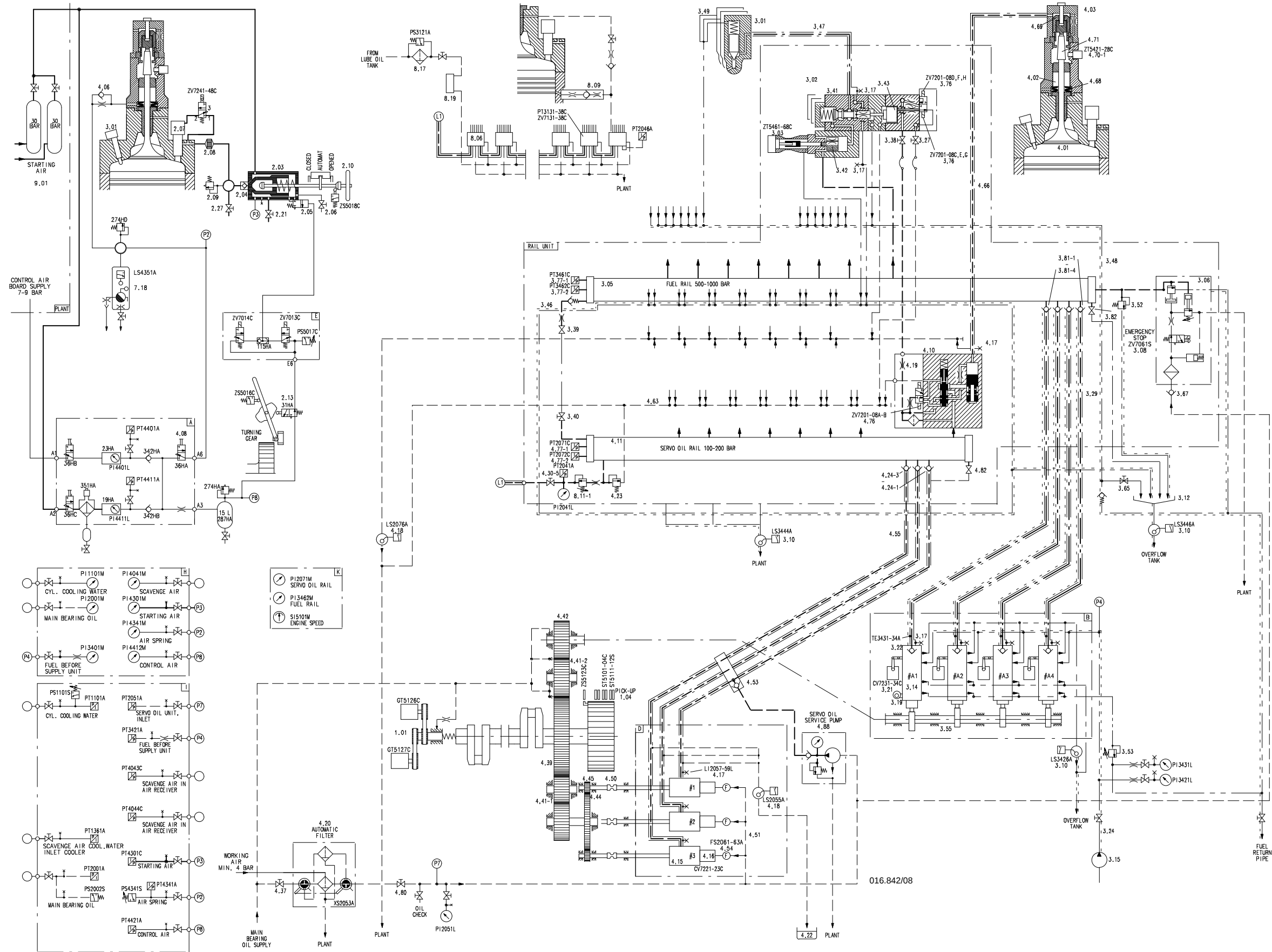
**Circuits:**

|           |                                |           |                    |
|-----------|--------------------------------|-----------|--------------------|
| —————     | Starting air and cooling water | — - - - - | Low pressure fuel  |
| —————     | Control air                    | — - - - - | High pressure fuel |
| - - - - - | Low pressure oil               | - - - - - | Heating            |
| - - - - - | High pressure oil              |           |                    |



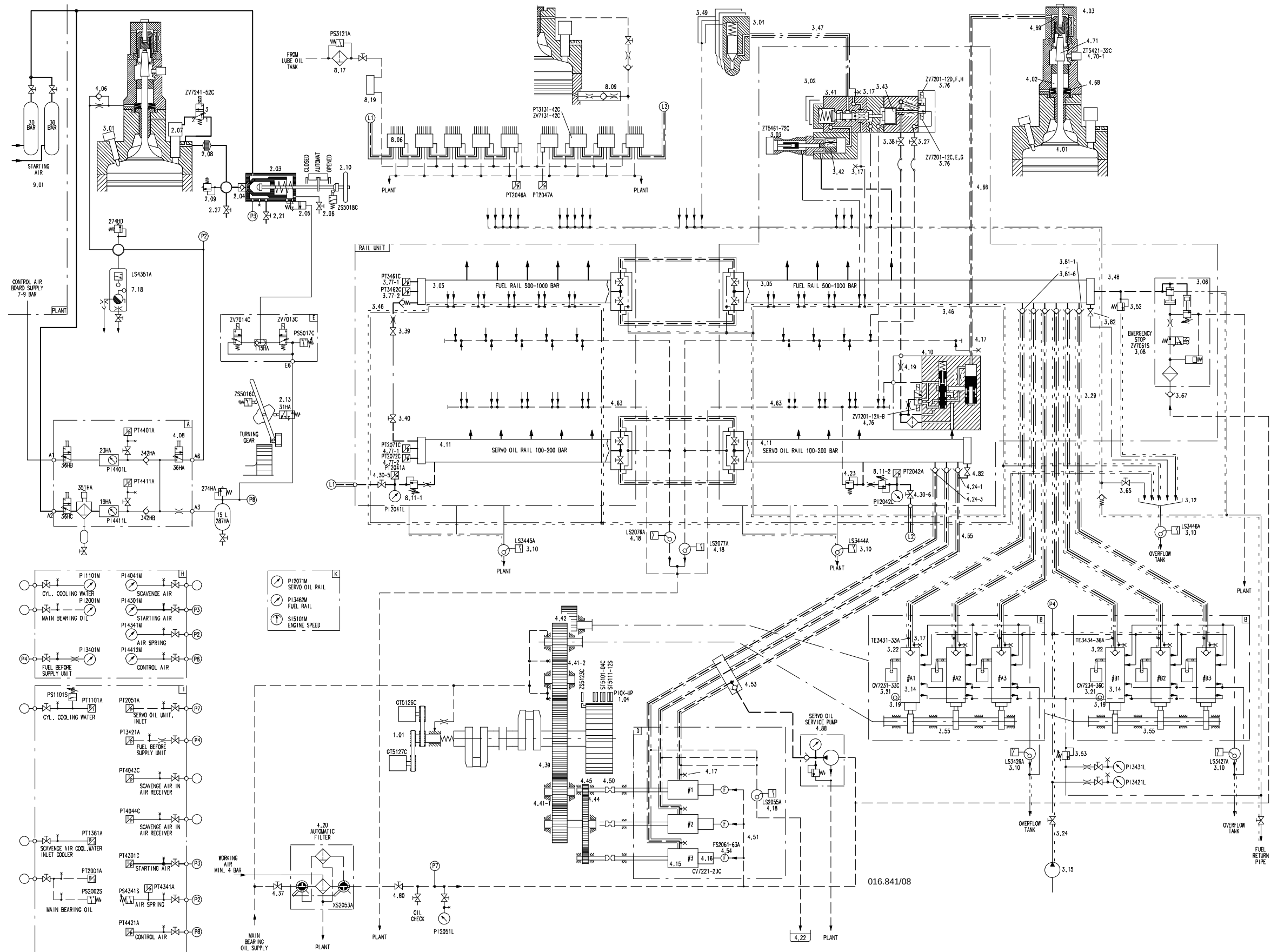
Control Diagram

6 to 8 Cylinders



### Control Diagram

## 9 to 12 Cylinders



**Control and Auxiliary Systems**

## Detailed Control Diagrams with Interfaces to the Plant

On the following pages 3 to 20 the complete engine control with the auxiliary systems, split up into their various functions, has been precisely represented. It includes all interfaces to the plant and remote control with clear designations for the identification of internal and external connectors.

| Overview of the systems                                                                                          | Path No.<br>range | Page |
|------------------------------------------------------------------------------------------------------------------|-------------------|------|
| Air supply                                                                                                       | 30                | 3    |
| Bearing and cooling oil supply                                                                                   | 40                | 4    |
| Servo oil supply (2 pumps)*                                                                                      | 50                | 5    |
| Servo oil supply (3 pumps)*                                                                                      | 50                | 6    |
| Fuel supply (4 pumps)*                                                                                           | 60                | 7    |
| Fuel supply (6 pumps)*                                                                                           | 60                | 8    |
| Starting system                                                                                                  | 110               | 9    |
| Speed control                                                                                                    | 150               | 10   |
| Cylinder lubrication pulse (6 to 8 cylinders)*                                                                   | 170               | 11   |
| Cylinder lubrication pulse (9 to 12 cylinders)*                                                                  | 170               | 12   |
| Exhaust gas / turbocharger type TPL, MET and NA / scavenge air / auxiliary blower (1-stage scavenge air cooler)* | 300               | 13   |
| Exhaust gas / turbocharger type TPL, MET and NA / scavenge air / auxiliary blower (2-stage scavenge air cooler)* | 300               | 14   |
| Exhaust valve drive, air spring (6 to 8 cylinders)*                                                              | 310               | 15   |
| Exhaust valve drive, air spring (9 to 12 cylinders)*                                                             | 310               | 16   |
| Fuel injection (6 to 8 cylinders)*                                                                               | 330               | 17   |
| Fuel injection (9 to 12 cylinders)*                                                                              | 330               | 18   |
| Cooling water                                                                                                    | 340               | 19   |
| Main bearing lubrication, piston cooling, oil mist detector (OMD)                                                | 350               | 20   |

\* Design execution alternative

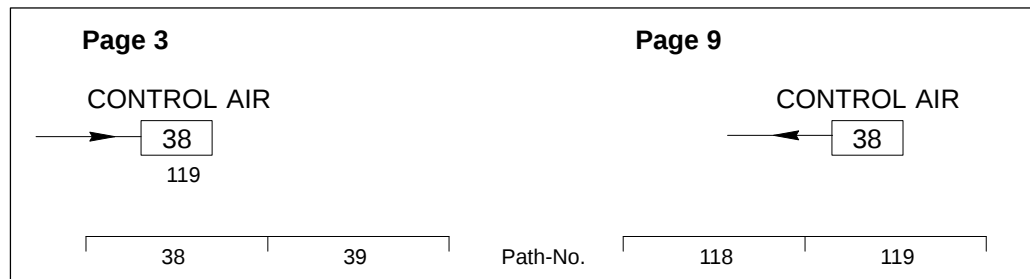
*(continuation on [page 2](#))*

## Detailed Control Diagrams with Interfaces to the Plant

**Remarks for easier understanding of the individual diagrams:**

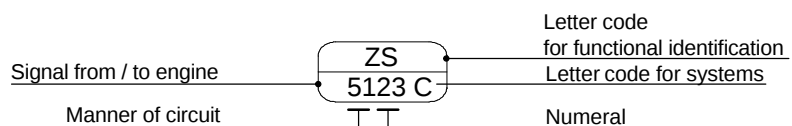
Each diagram has a path No. range allotted to the system part, which is subdivided at the page edge (on the right) into 10 sections. These **path numbers** designate the junctions from one diagram to the other.

One piping leading away in the direction of the arrow is marked with the path No. (framed) which lies above this No. in the section part. The number below the rectangle is the target path number.

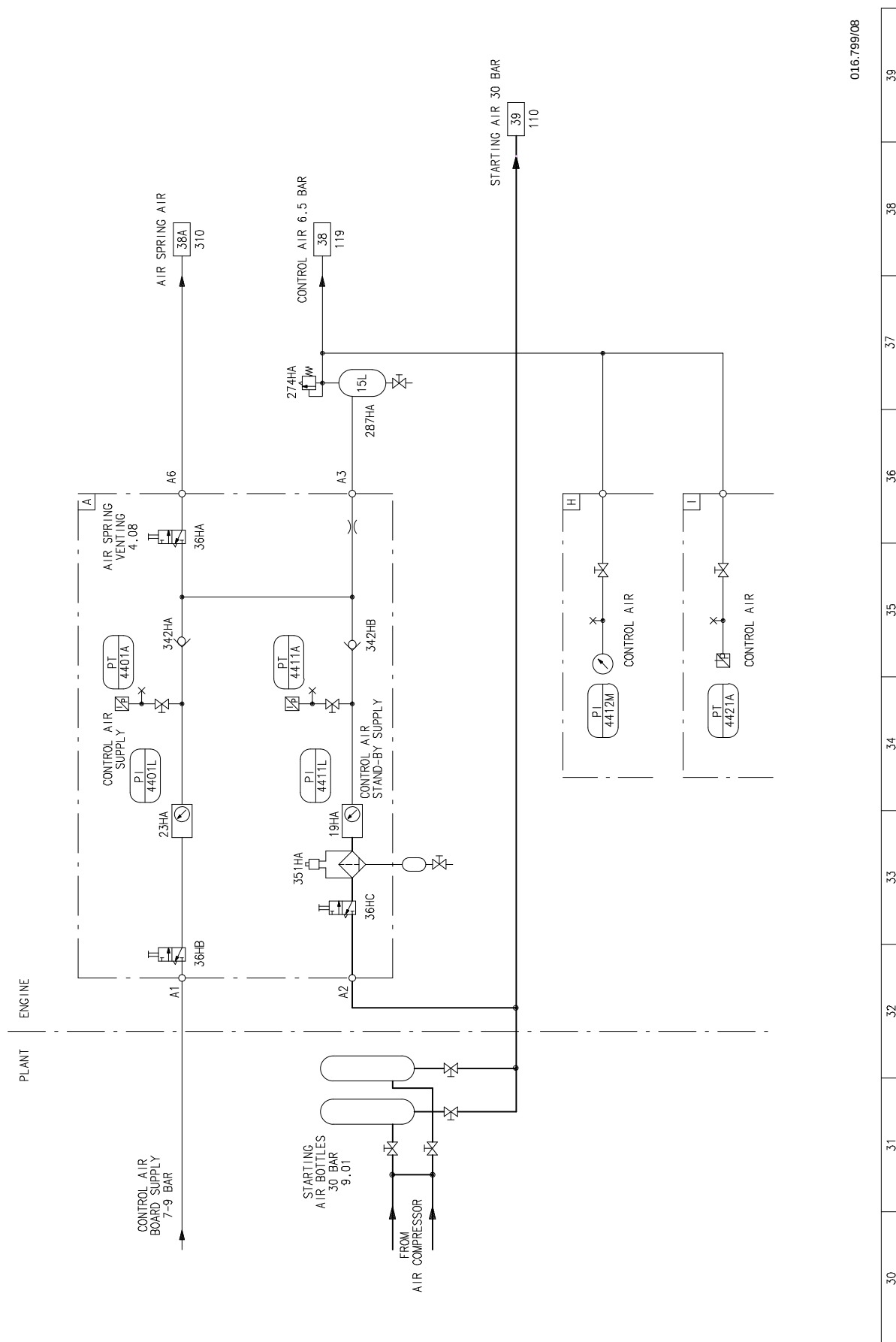
**Example:**

In this example the control air tube carrying number 38 (page 3) leads to target path No. 119 (page 9). Where two equal path numbers appear additional letter indications are used for identification, e.g. on page 3 No. 38 and 38A.

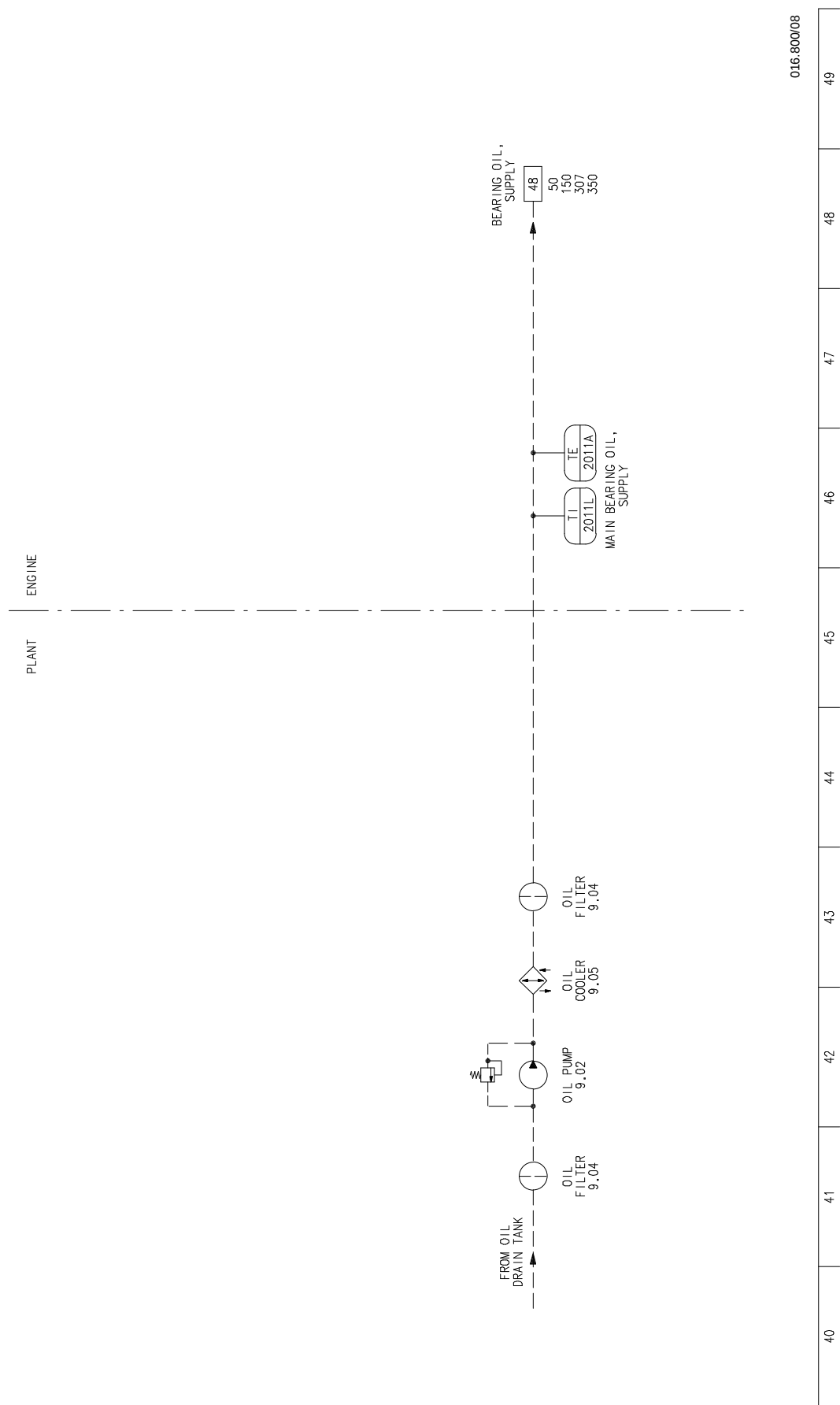
The **interfaces** to the remote control as well as local alarm and monitoring instruments have been designated by expressive symbols (box with rounded corners).



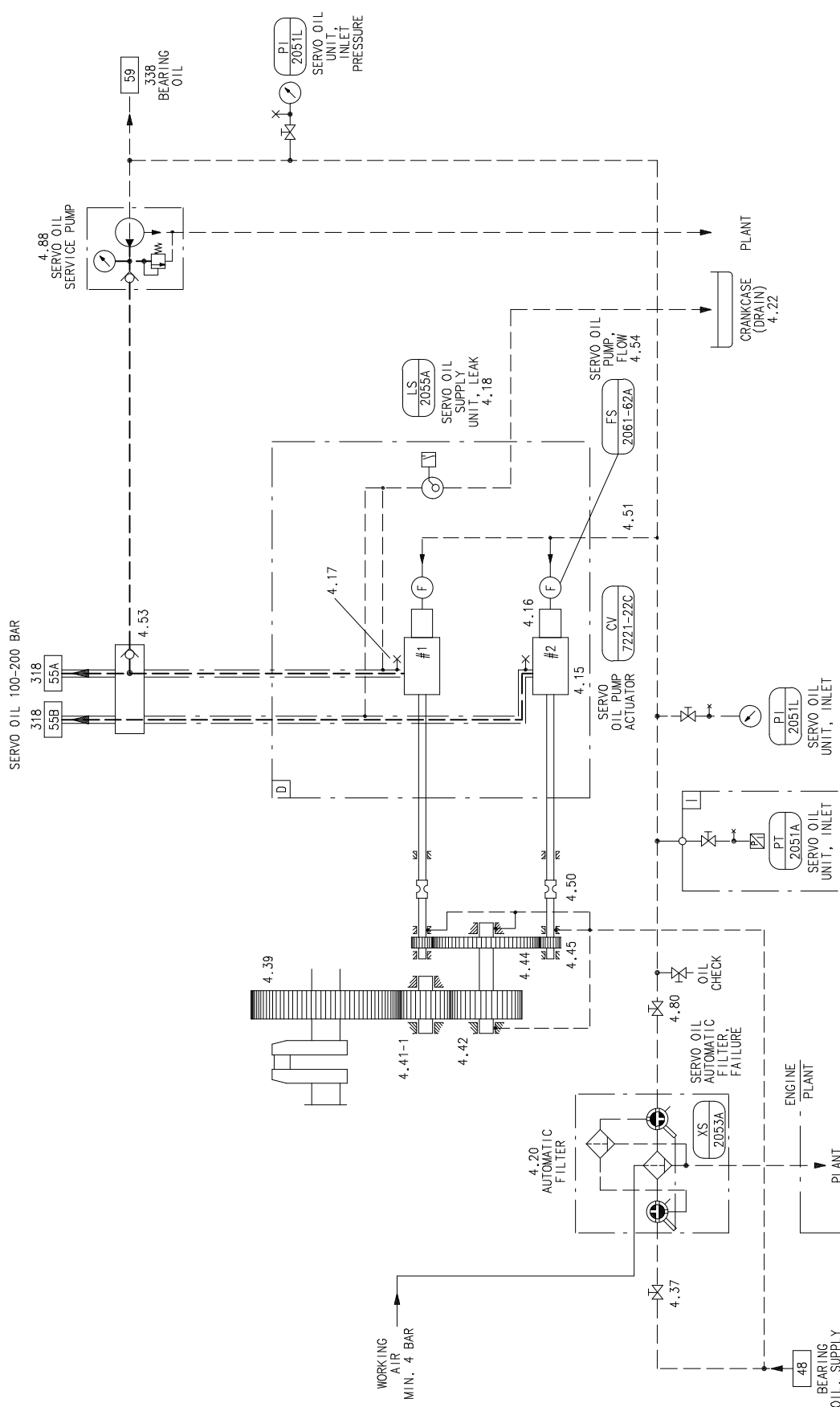
# Air Supply



Bearing and Cooling Oil Supply



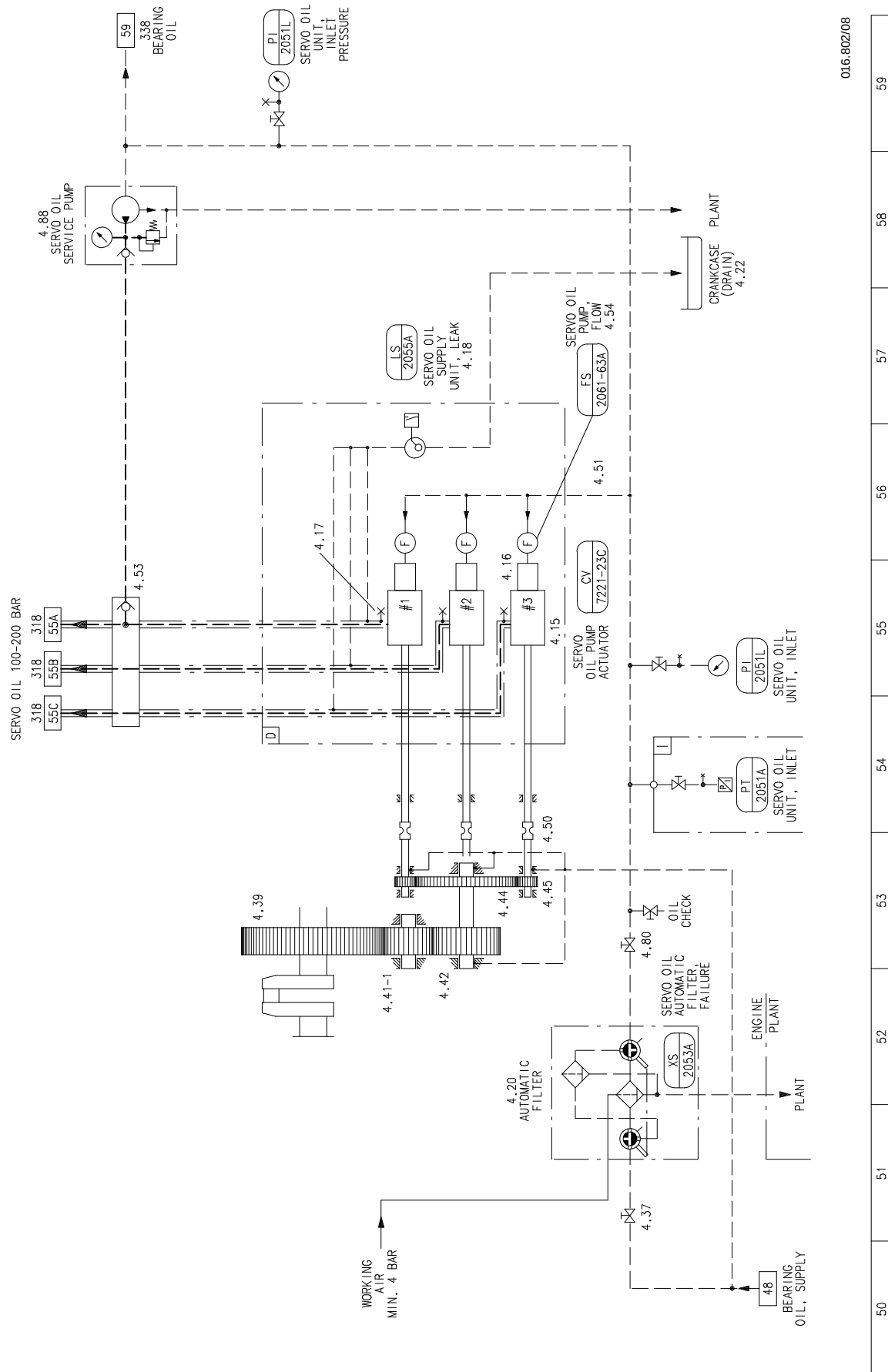
(2 Pumps)



016.801/08

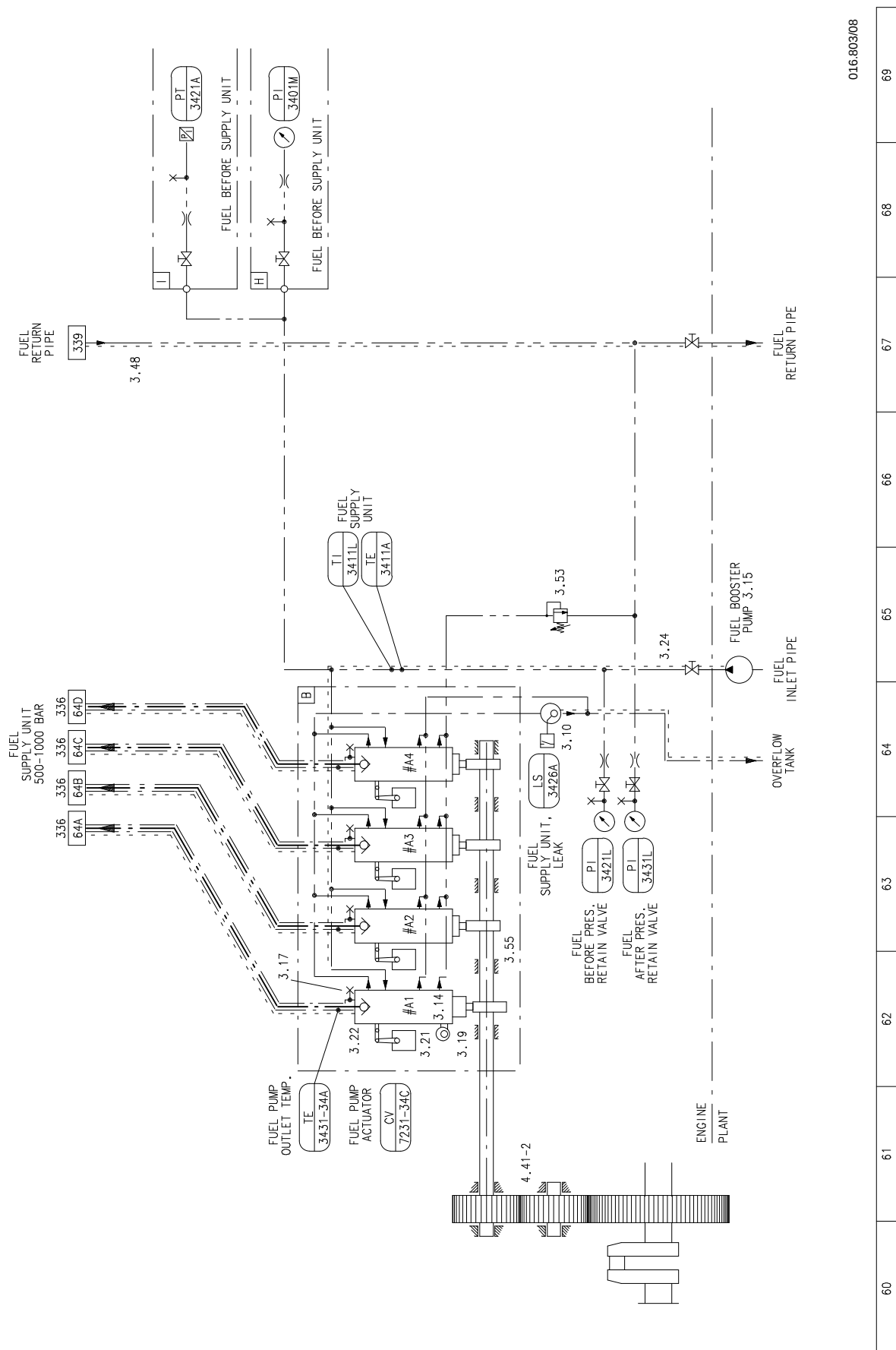
## Servo Oil Supply

(3 Pumps)



# Fuel Supply

(4 Pumps)

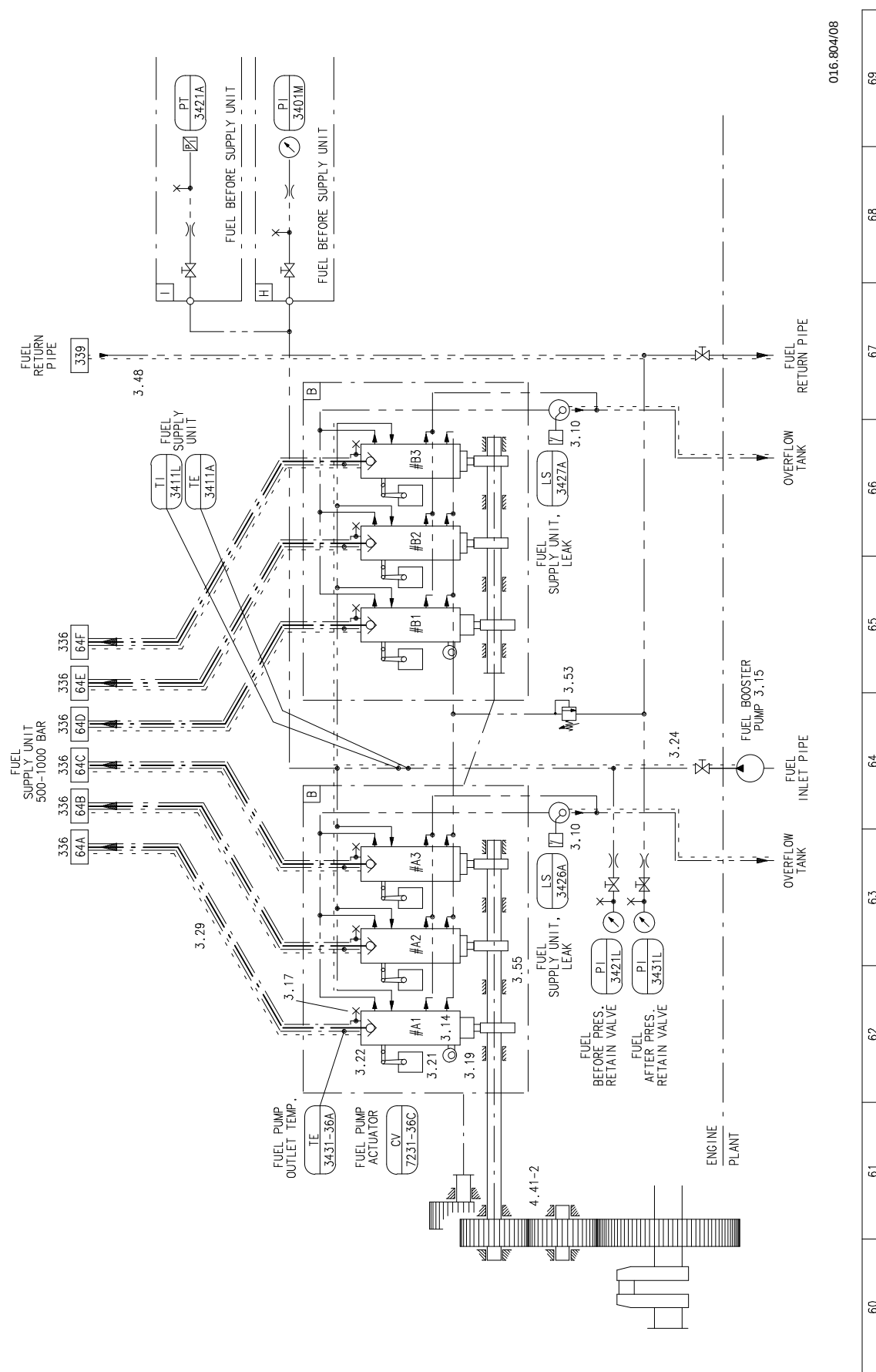


016.803/08

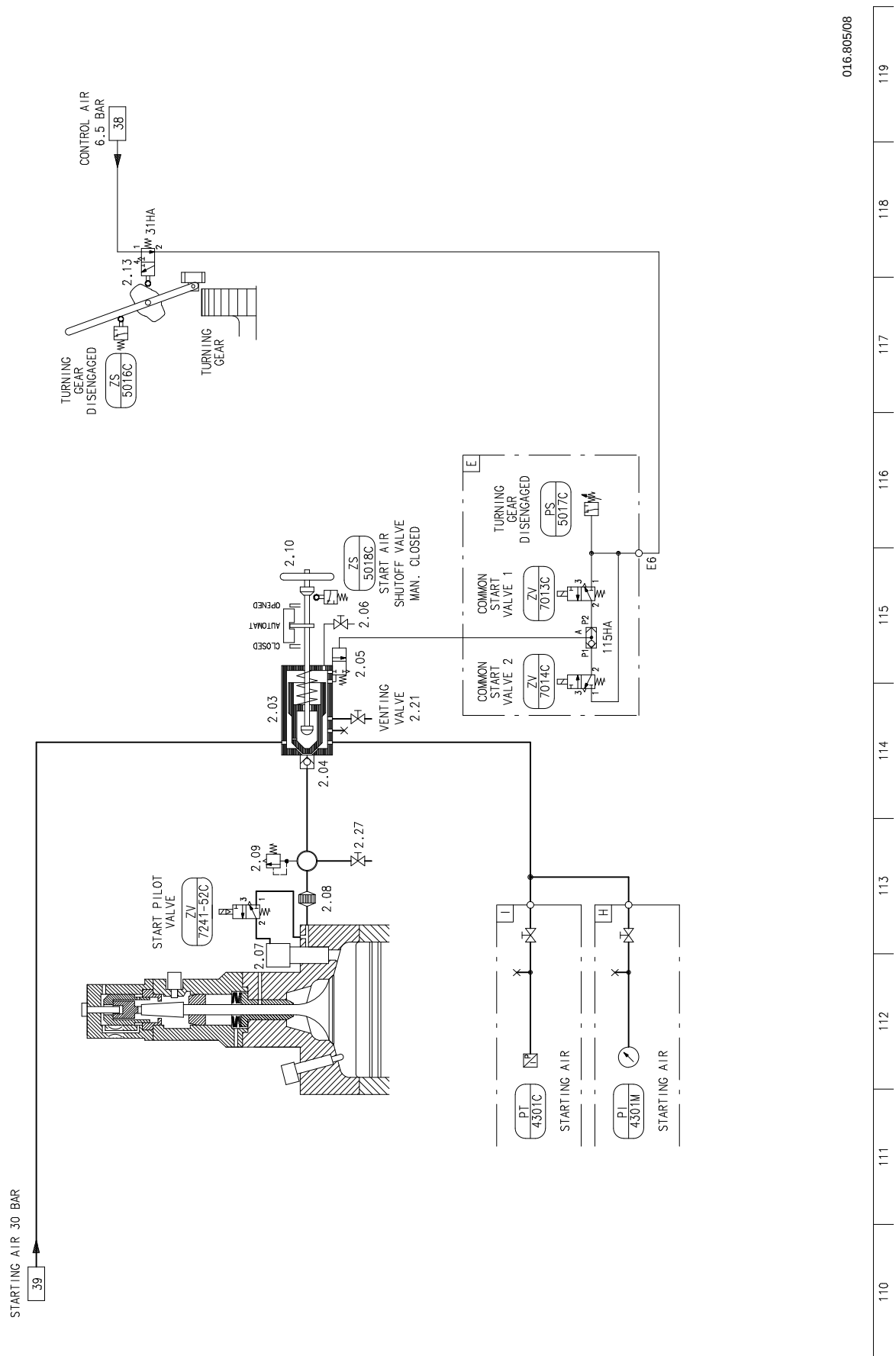
60 61 62 63 64 65 66 67 68 69

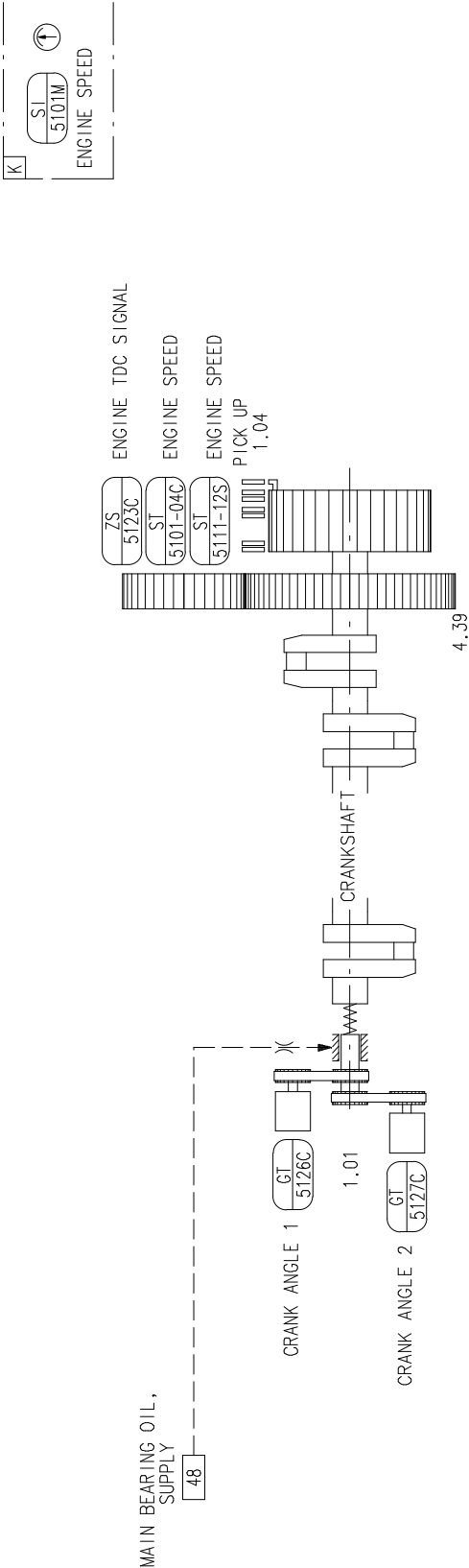
## Fuel Supply

(6 Pumps)



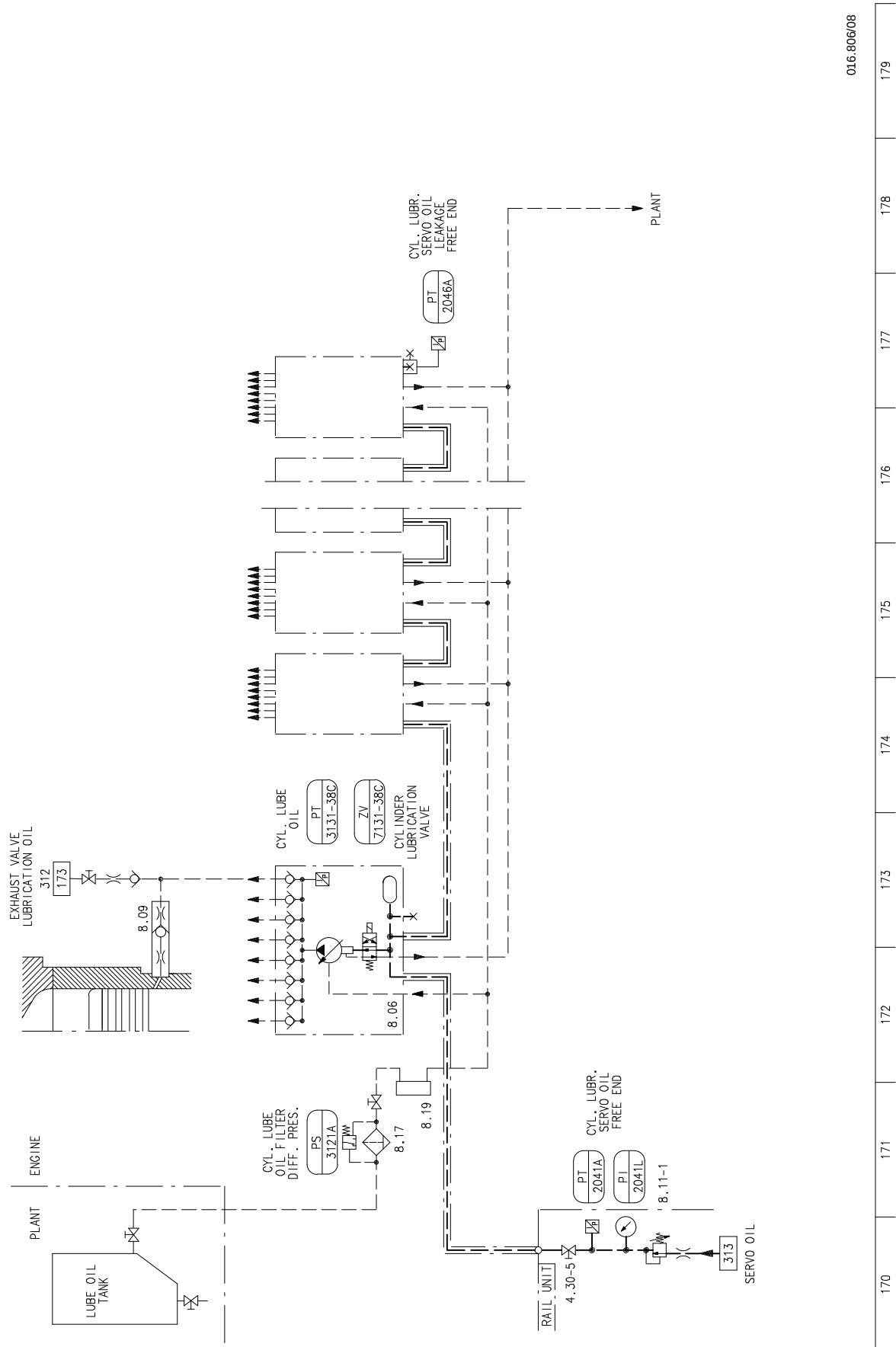
## Starting System





Cylinder Lubrication Pulse

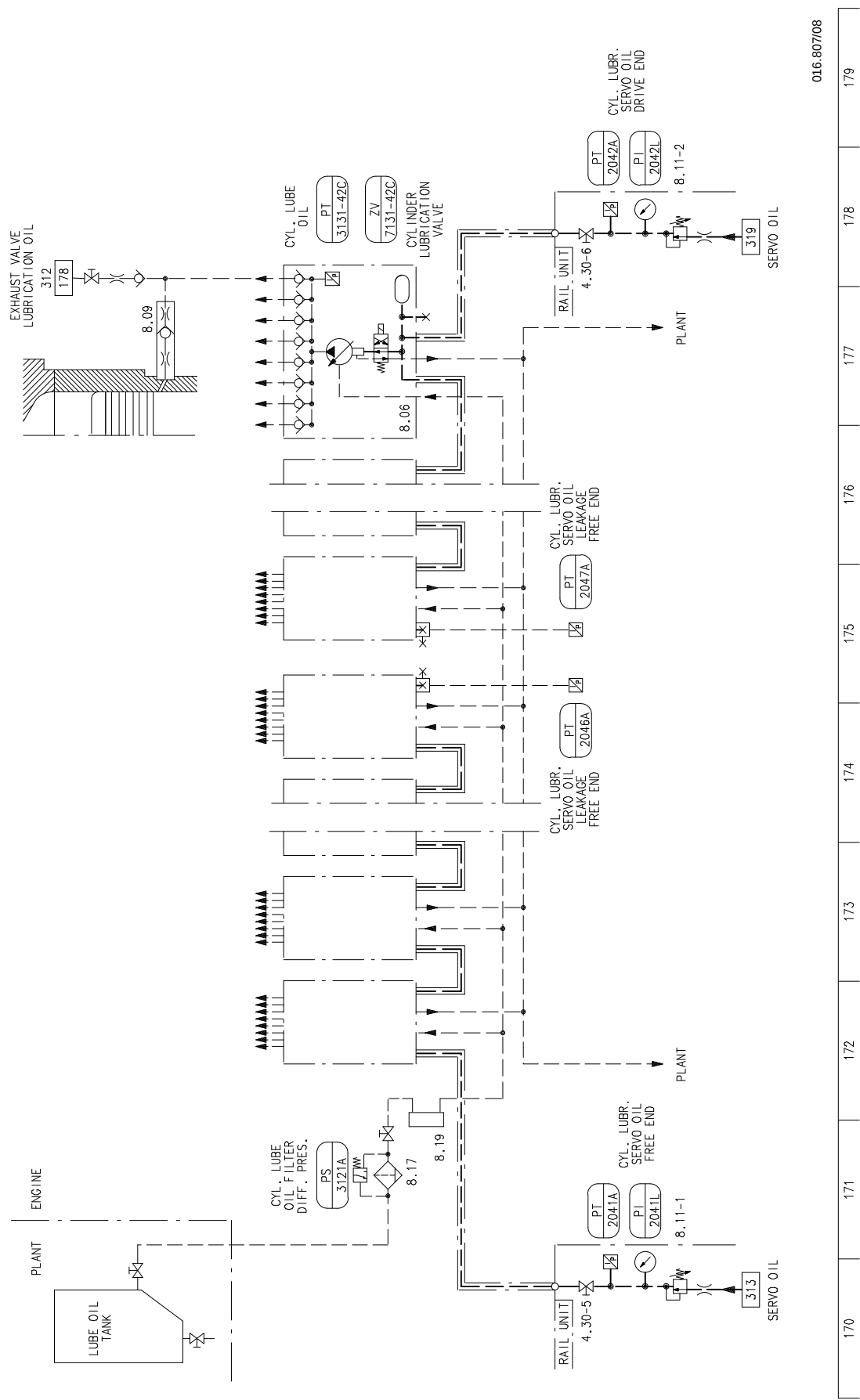
(6 to 8 Cylinders)



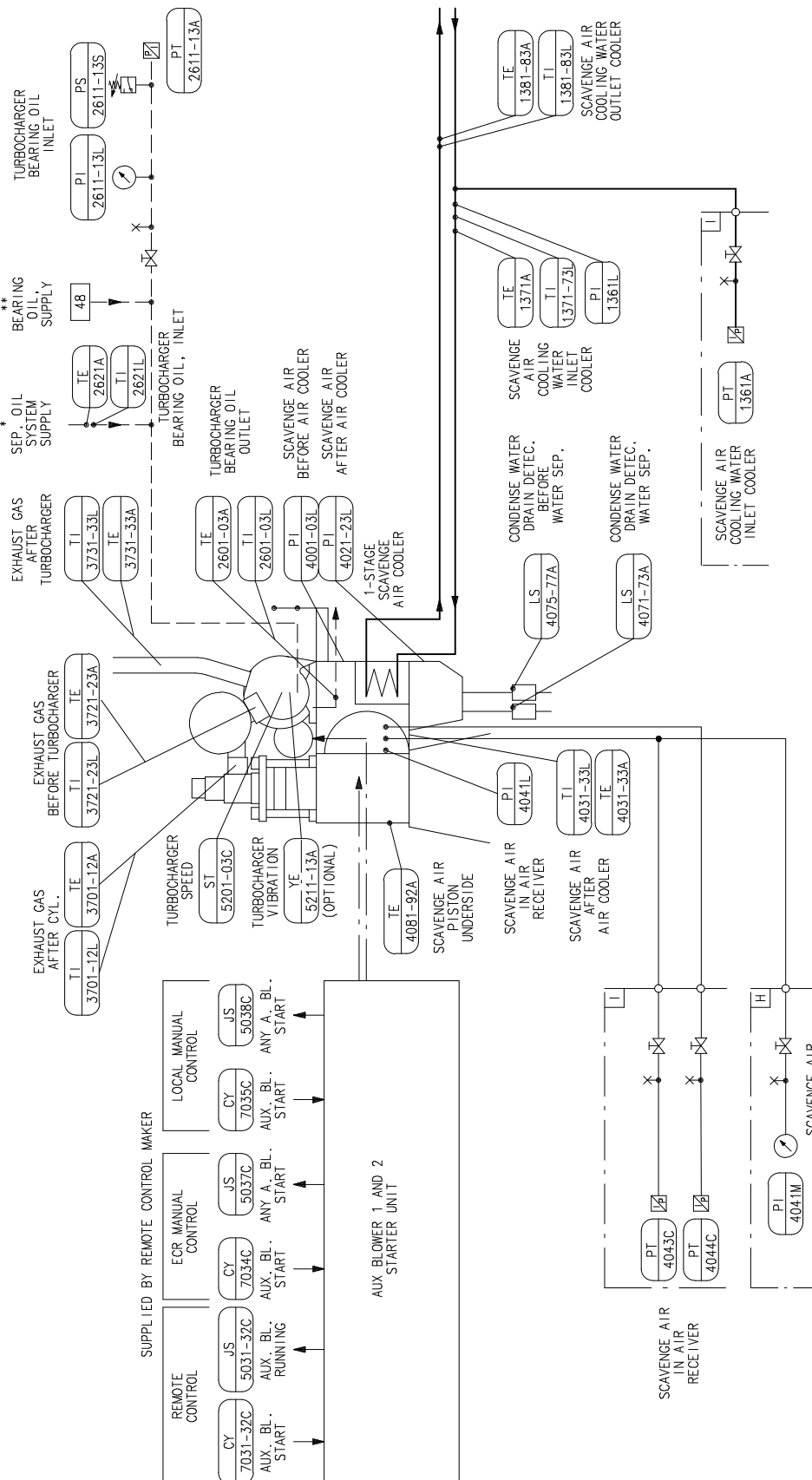
016.806/08

Cylinder Lubrication Pulse

(9 to 12 Cylinders)



# Exhaust Gas / Turbocharger Type TPL, MET and NA / Scavenge Air / Auxiliary Blower for 1-Stage Scavenge Air Cooler



\* IN CASE OF MAIN BEARING OIL SUPPLY THIS INLET IS OMITTED

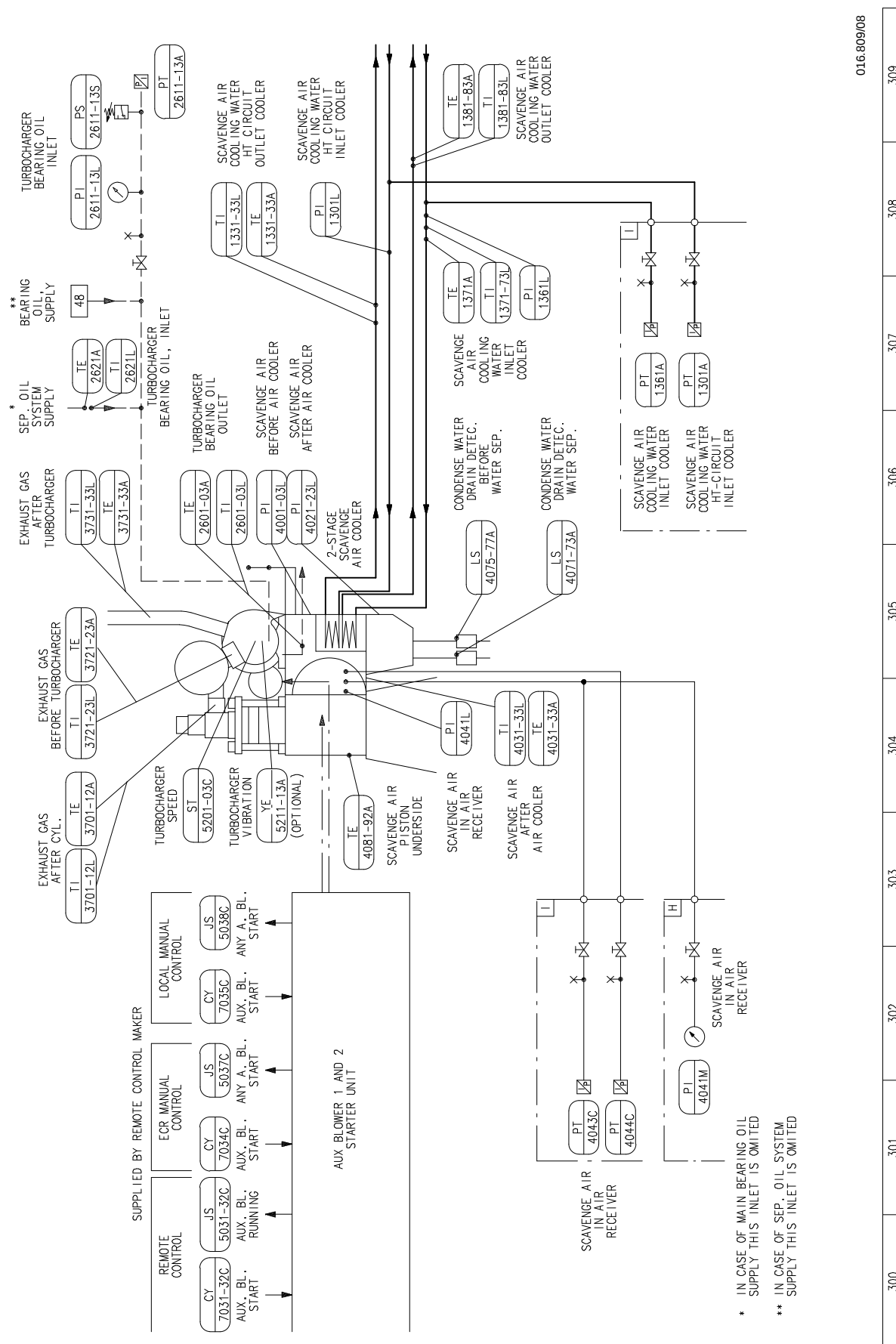
\*\* IN CASE OF SEP. OIL SYSTEM SUPPLY THIS INLET IS OMITTED

016.808/08

300 | 301 | 302 | 303 | 304 | 305 | 306 | 307 | 308 | 309

## Exhaust Gas / Turbocharger Type TPL, MET and NA / Scavenge Air / Auxiliary Blower

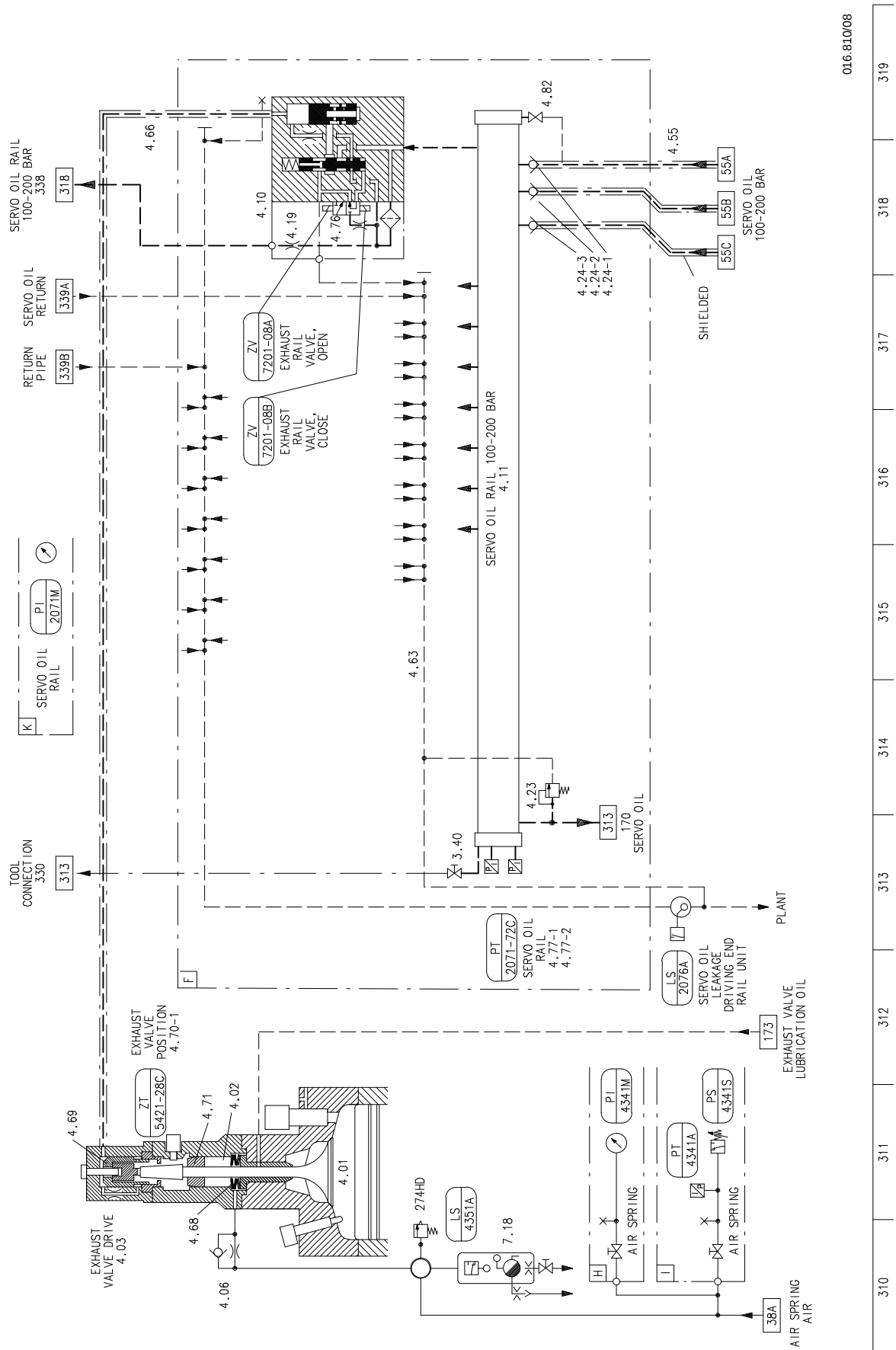
for 2-Stage Scavenge Air Cooler



016.809/08

Exhaust Valve Drive / Air Spring

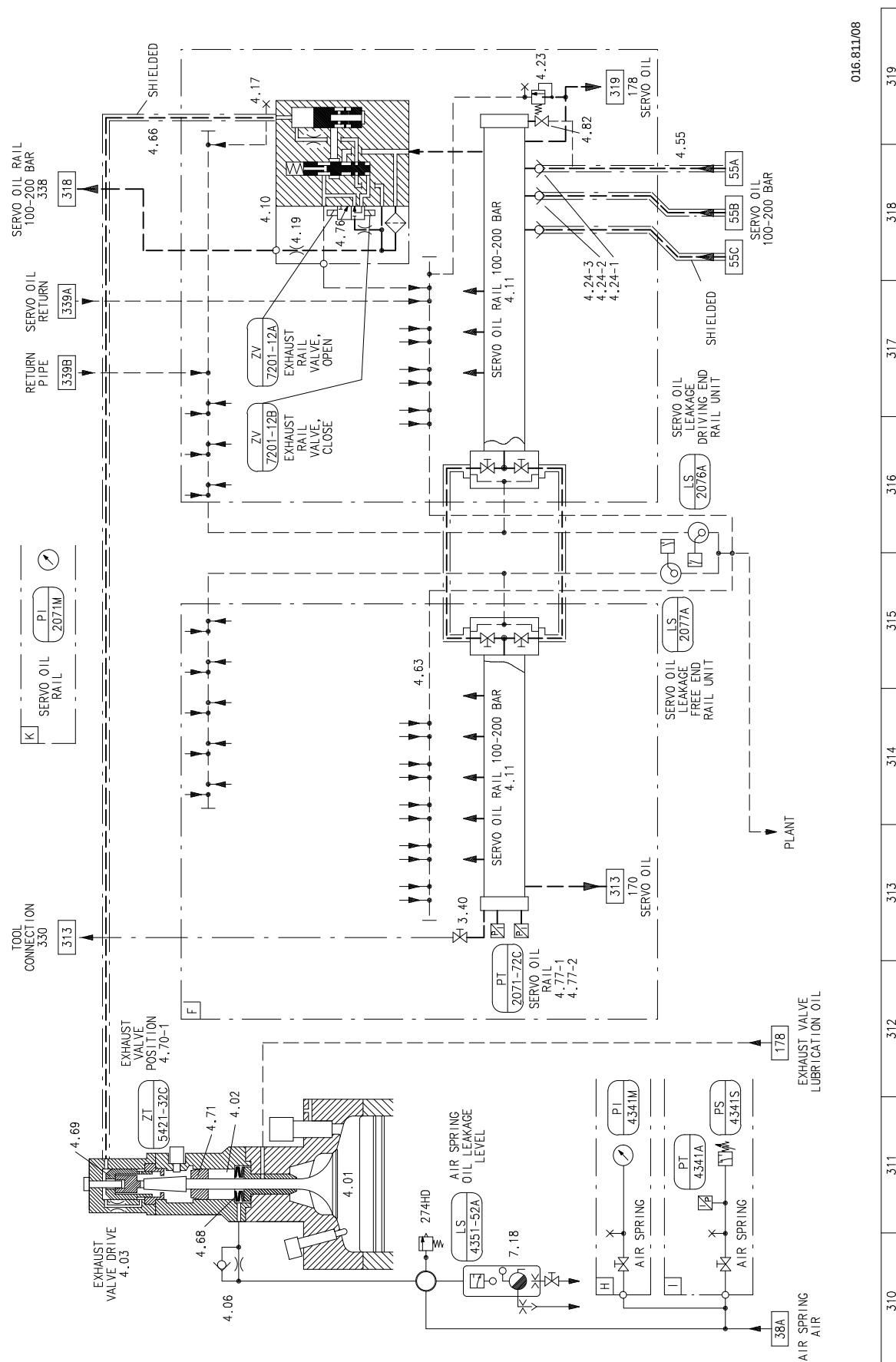
(6 to 8 Cylinders)



016.810/08

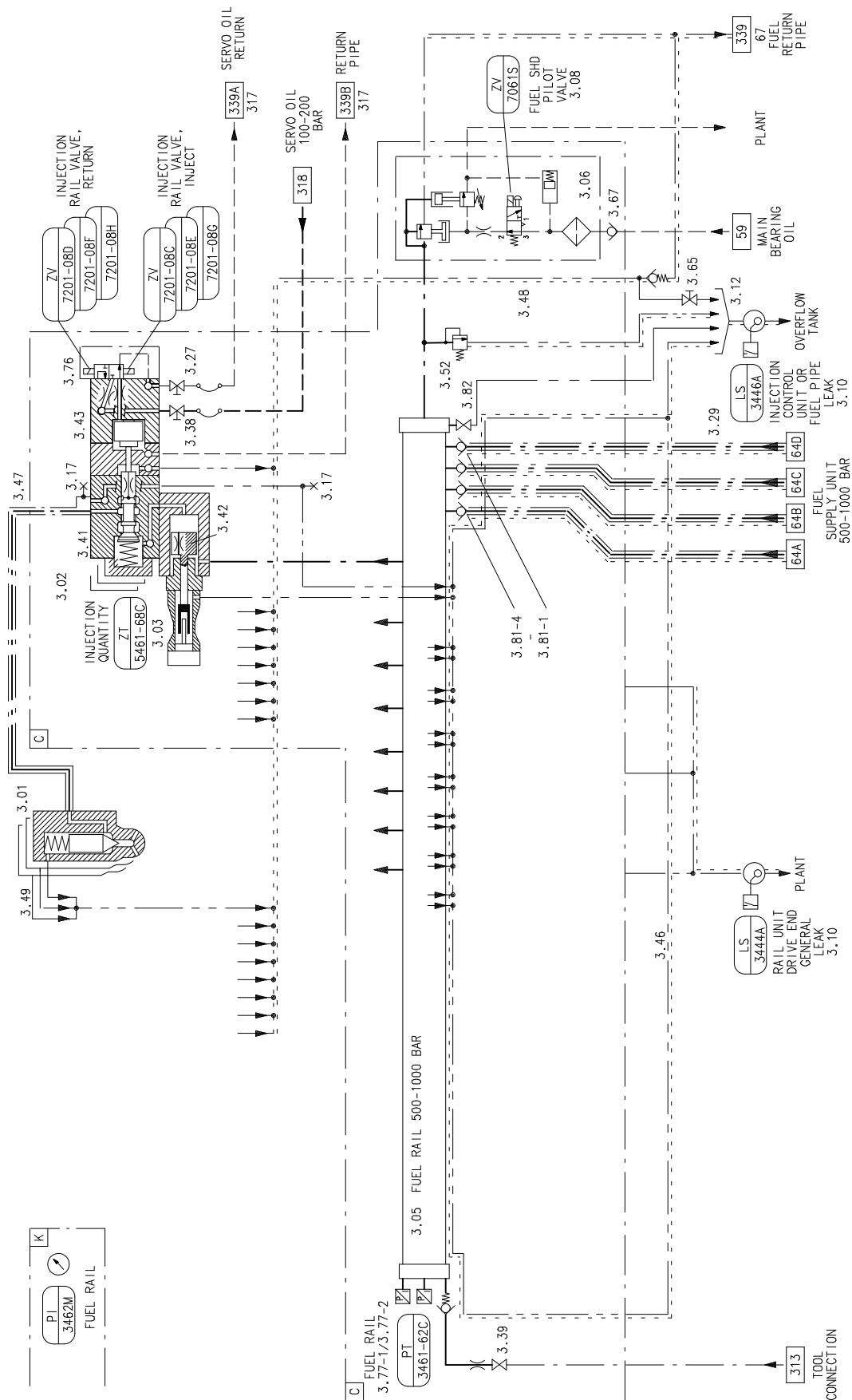
## Exhaust Valve Drive / Air Spring

(9 to 12 Cylinders)



# Fuel Injection

(6 to 8 Cylinders)

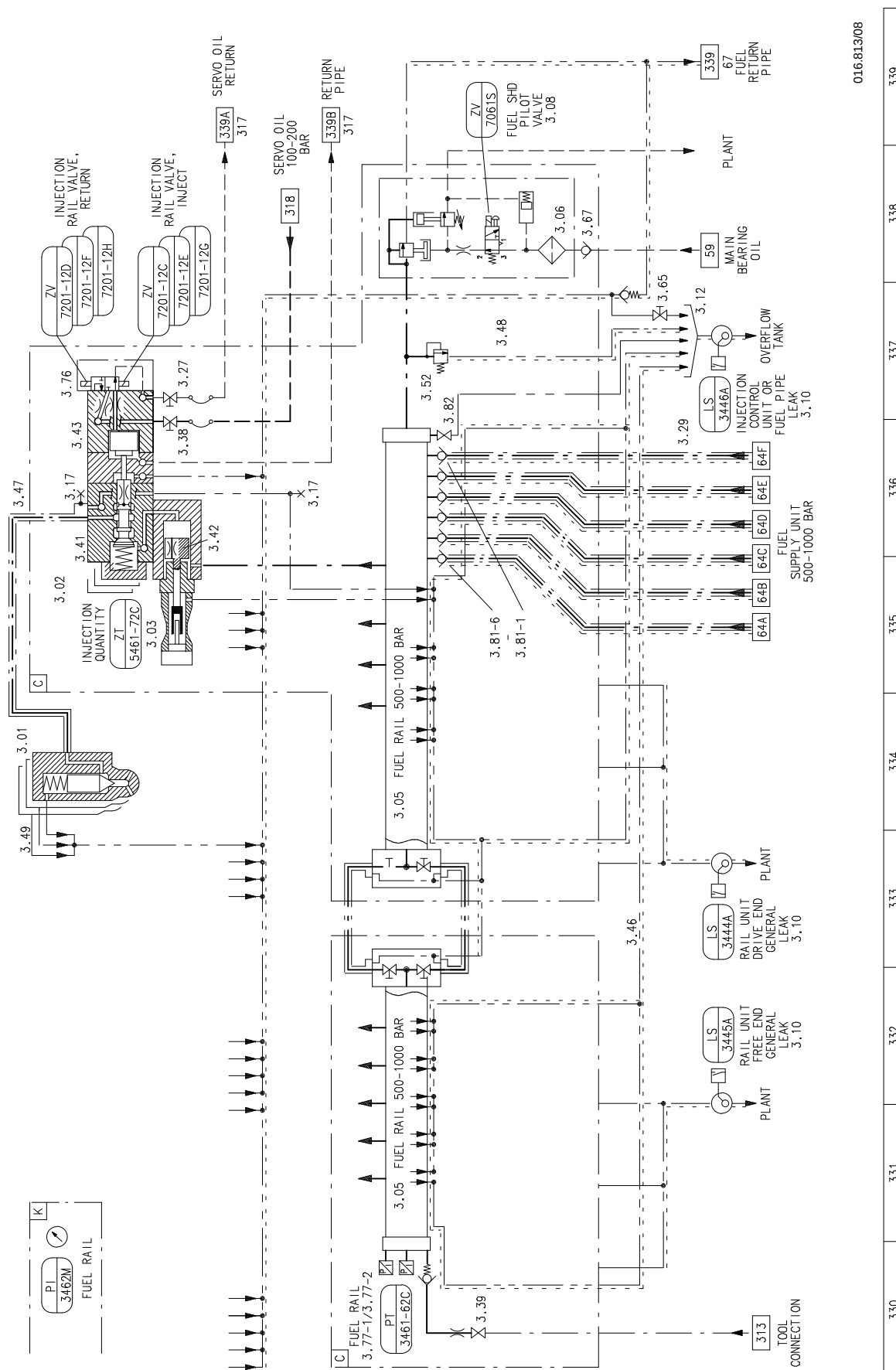


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|     |     |     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 330 | 331 | 332 | 333 | 334 | 335 | 336 | 337 | 338 | 339 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|

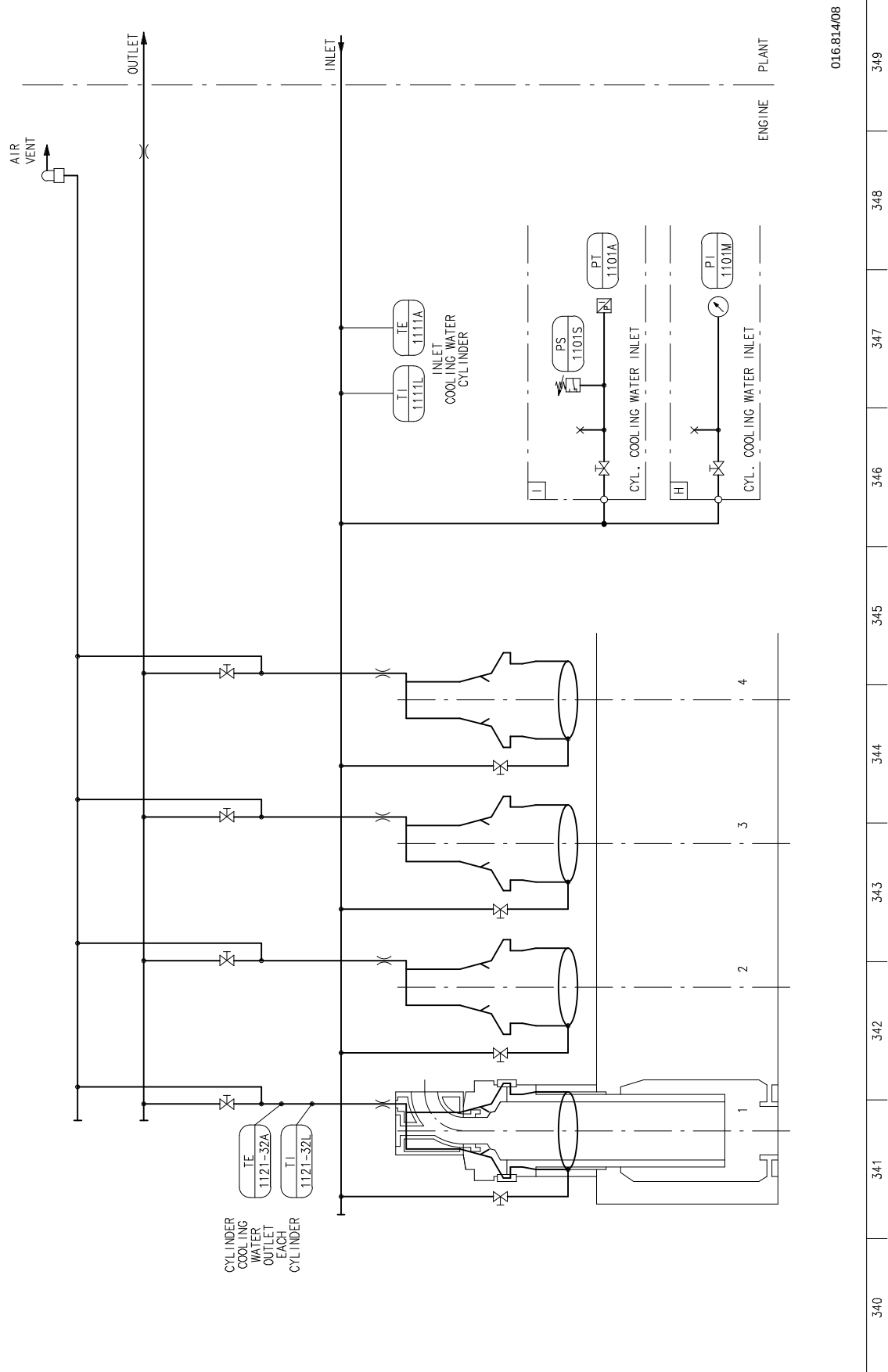
## Fuel Injection

(9 to 12 Cylinders)

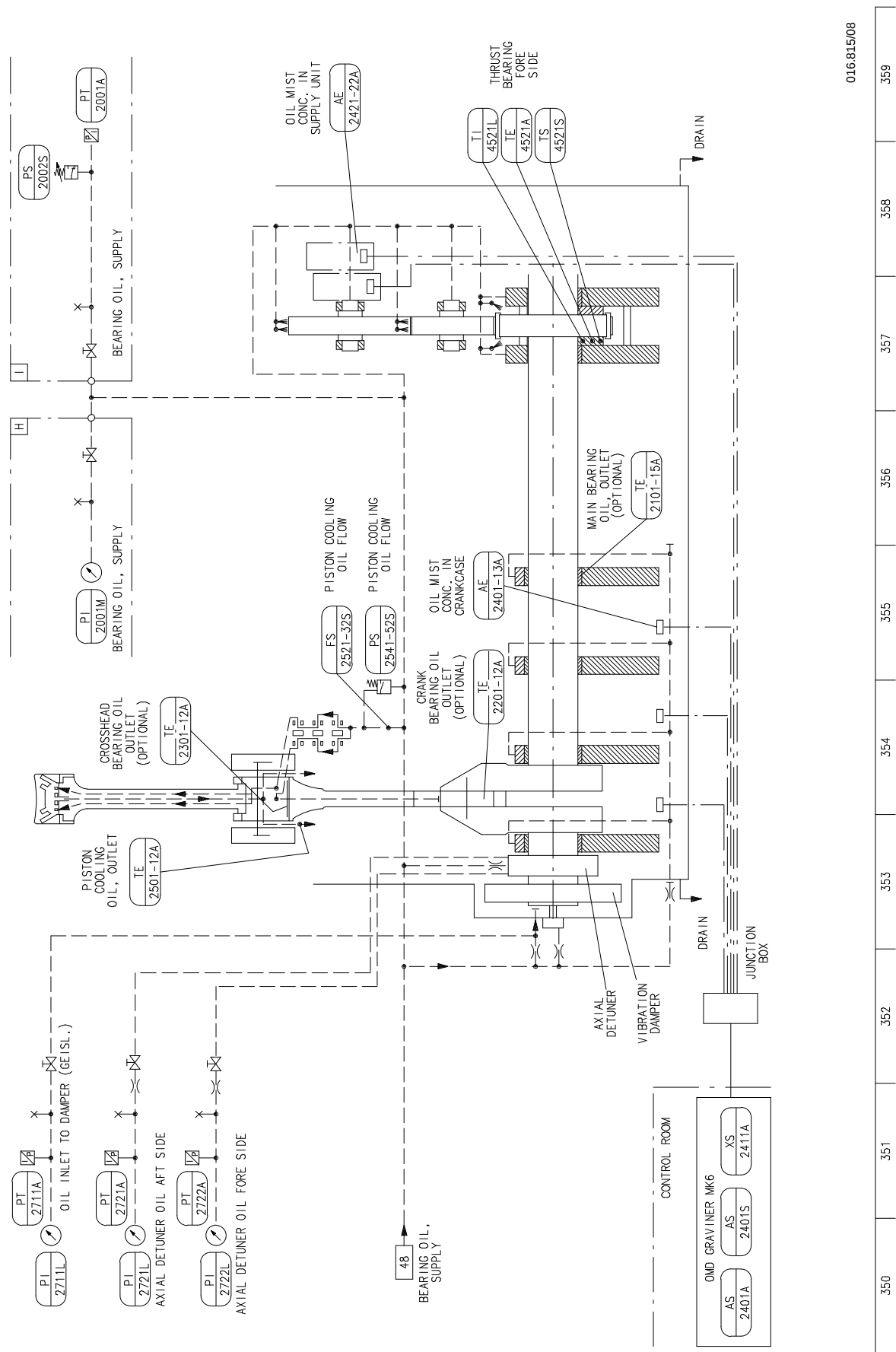


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# Cooling Water



Main Bearing Lubrication / Piston Cooling / OMD



016.815/08

## Drive Supply Unit

### 1. General

The drive of the supply unit is arranged at the driving end of the engine.

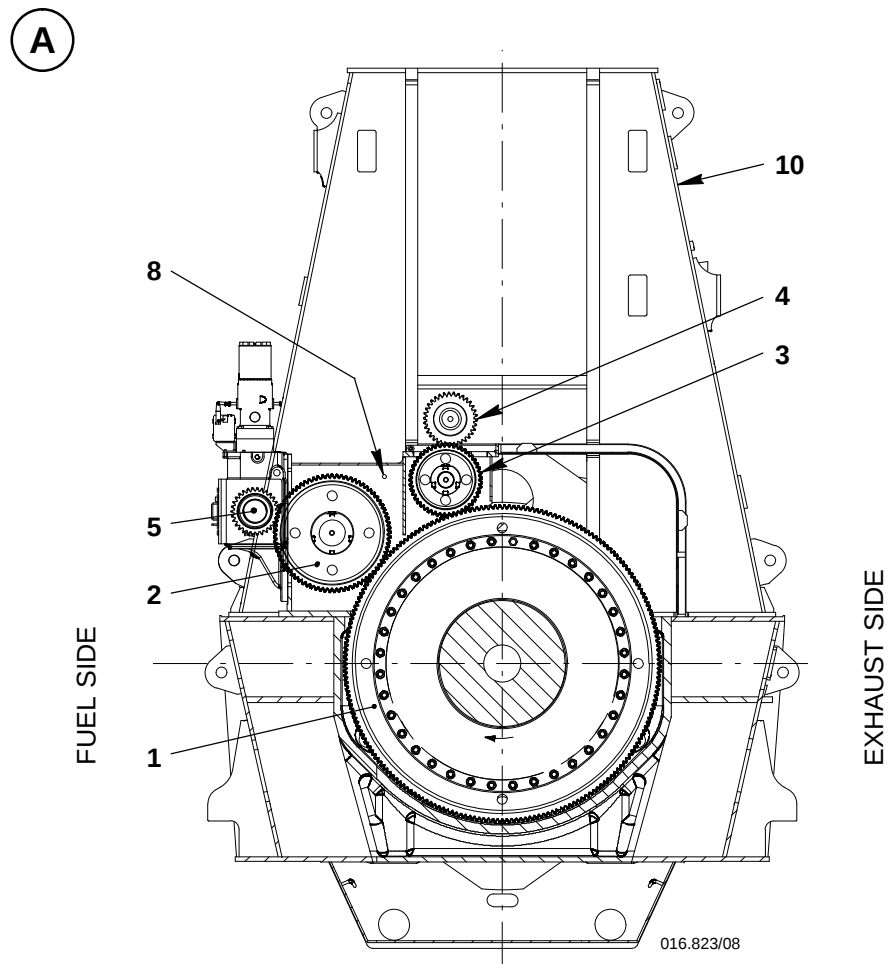
Driving wheel 5 of the fuel pump unit and driving wheel 4 of the servo pump unit are driven by gear wheel 1 on crankshaft 7 via intermediate wheels 2 and 3.

The condition of the tooth profile must be checked periodically. In particular new gear wheels must be checked frequently after a short running-in period (see Maintenance Manual [4104-1](#)).

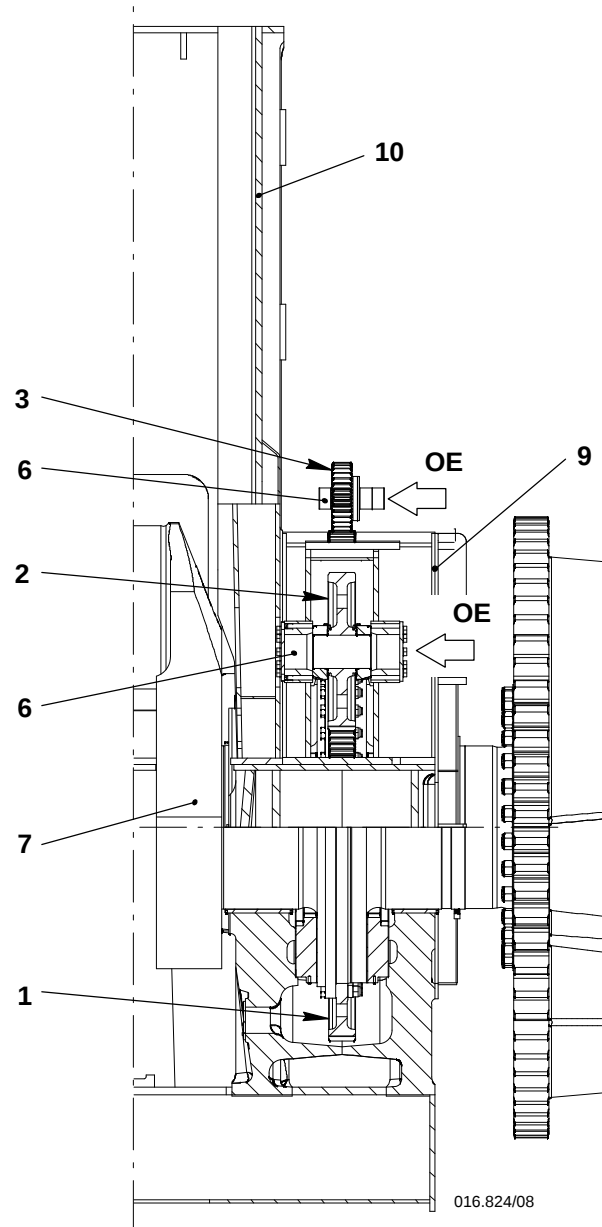
Should abnormal noises be heard from the area of the gear train, their cause must be established immediately.

### 2. Lubrication

The bearings 6 of intermediate wheels 2 and 3 are lubricated via connections 'OE'. The gear teeth are supplied with bearing oil through the spray nozzles 8 (see Lubricating Oil Diagram [8016-1](#)).



## Drive Supply Unit

**B**

**Key to Illustrations:** 'A' Cross section (6 to 8 cylinders)  
 'B' Longitudinal section (6 to 8 cylinders)

- |                                     |                                   |
|-------------------------------------|-----------------------------------|
| 1 Gear wheel on crankshaft          | 7 Crankshaft                      |
| 2 Intermediate wheel                | 8 Spray nozzle                    |
| 3 Intermediate wheel                | 9 Bearing housing for supply unit |
| 4 Driving wheel for servo pump unit | 10 Column                         |
| 5 Driving wheel for fuel pump unit  | OE Oil inlet                      |
| 6 Bearing for intermediate wheels   |                                   |

## Shut-off Valve for Starting Air

### 1. General

(see figure and Control Diagram [4003-2](#)).

The shut-off valve for starting air blocks off or releases the starting air into the engine. It can be put in the following positions by means of the handwheel:

- CLOSED (closed by hand)
- AUTOMAT
- OPENED (opened by hand)

When the engine is on stand-by or in operation the shut-off valve is positioned at AUTOMAT where it is held by the locking lever 6.

#### CHECK

The test valve 2.06 can be actuated to check whether the valve opens. When the shut-off valve is ready for operation then valve 1 opens which is clearly audible, however, the engine will not be started.



**Remark:** When the engine is not in service, the following measures must be taken:

- ⇒ Close the shut-off valves of starting air bottles 9.01.
- ⇒ Close the shut-off valve by means of handwheel 5 (locking lever 6 in position CLOSED).
- ⇒ Open venting valve 2.21 (by that the shut-off valve and the air feed pipes are vented).
- ⇒ Open venting valve 2.27 (by that the starting air distribution piping is vented).
- ⇒ Engage turning gear.

After each manoeuvring period the starting air distributor piping must be drained of condensate water. To this end venting valve 2.27 has been provided in the distributor piping (see also Starting Air Diagram [8018-1](#)).

### 2. Function

#### Ready for starting:

Space 'ER' is filled with starting air from inlet pipe 'LE'. Space 'VR' is filled through balancing bore 'EB'. Valve 1 is held shut by spring 3 and by the pressure in space 'VR'.

#### Starting:

Common start valve 8 or 11 is activated by the corresponding FCM-20 module (see also [4002-1](#) 'Engine-related control functions').

Control valve 7 is actuated by control air 'SL' via common start valve 11 and vents space 'VR'. Valve 1 opens and starting air from space 'ER' enters to the starting air distribution piping 'LV' via non-return valve 2.

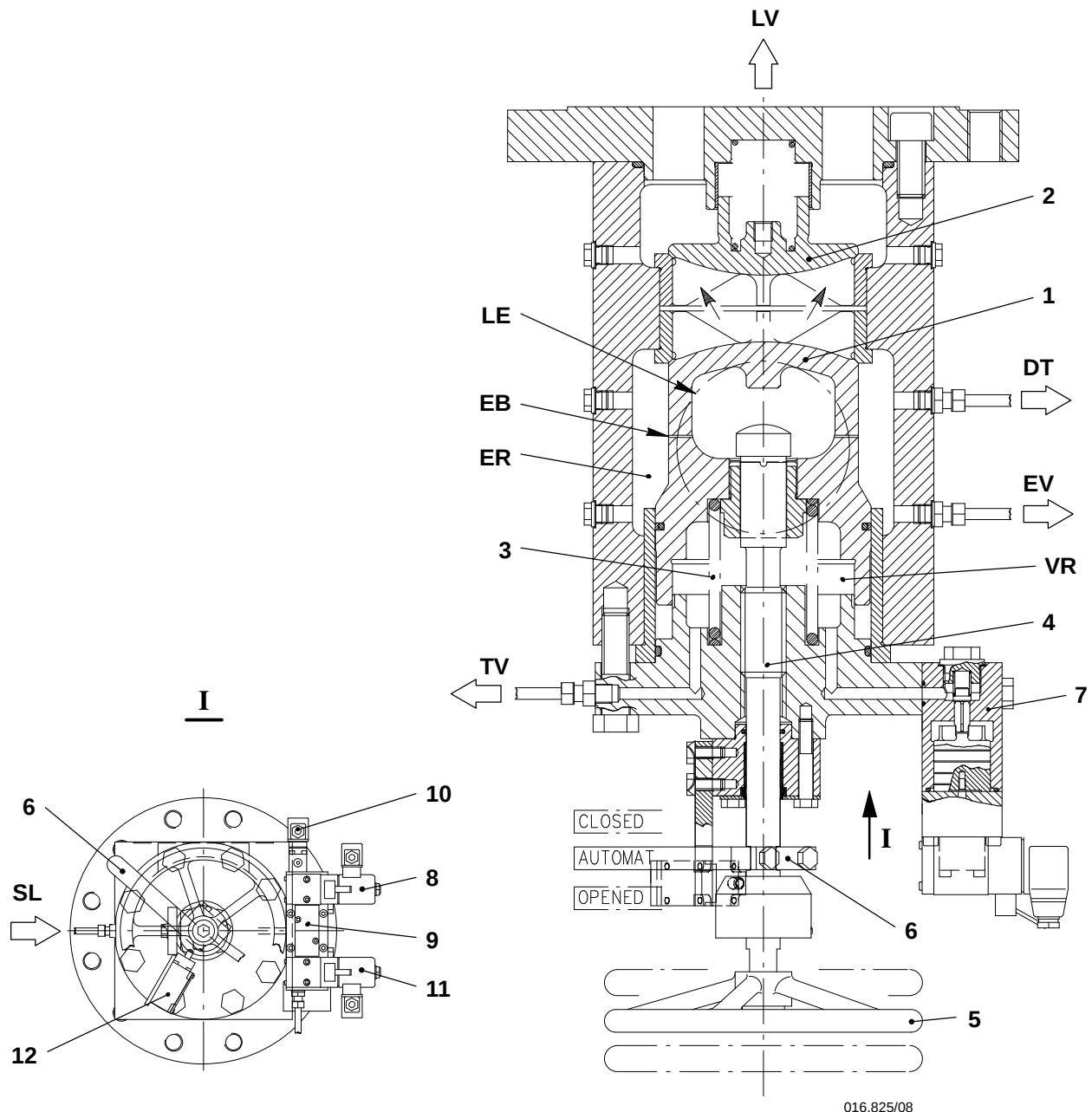
#### End of start:

Control valve 7 closes space 'VR' which again fills with starting air via the balancing bores 'EB'. Valve 1 shuts.

#### Function check:

When valve 2.06 is actuated on the ready-to-start engine, space 'VR' is vented and valve 1 opens audibly.

## Shut-off Valve for Starting Air

**Key:**

- 1 Valve
- 2 Non-return valve
- 3 Spring
- 4 Spindle
- 5 Handwheel
- 6 Locking lever
- 7 Control valve 2.05
- 8 Common start valve ZV7014C
- 9 Duplex non-return valve 115HA
- 10 Pressure switch PS5017C
- 11 Common start valve ZV7013C
- 12 Limit switch ZS5018C

- DT To instrument panel and pressure transmitter PT4301C
- EB Balancing bore
- ER Air inlet space
- EV To venting valve 2.21
- LE Air inlet piping (hidden drawn)
- LV To starting air distributor piping and starting valves 2.07
- SL Control air
- TV To test valve 2.06
- VR Valve space

## Control Air Supply

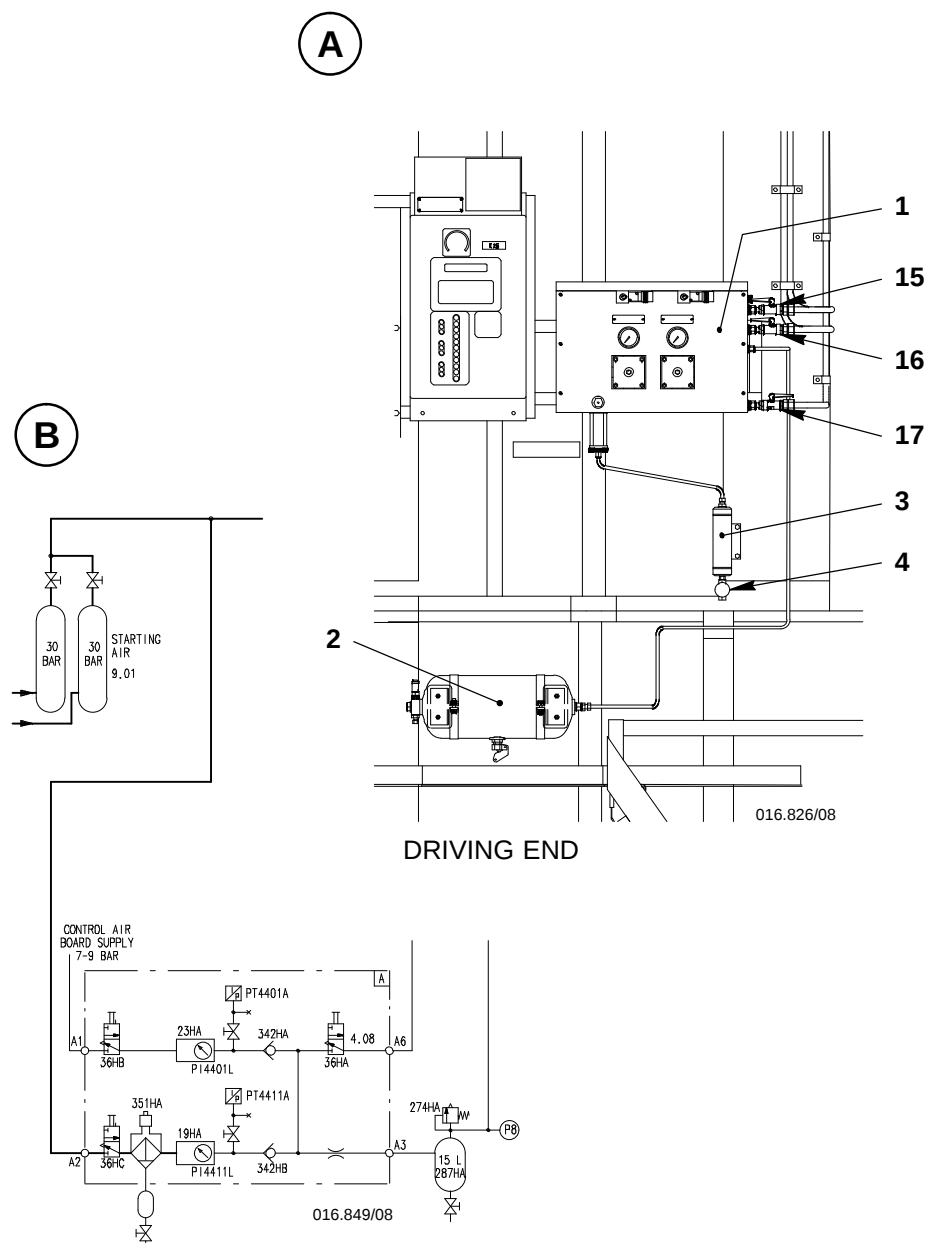
## 1. General

The compressed air required for the air spring of the exhaust valves and the turning gear interlock is primarily taken from the shipboard system. The air must be clean and dry in order to prevent blockages occurring in the control units.

The air piping system is arranged in such a way that, upon failure of the shipboard system supply, reduced compressed air will be taken from the starting air system.

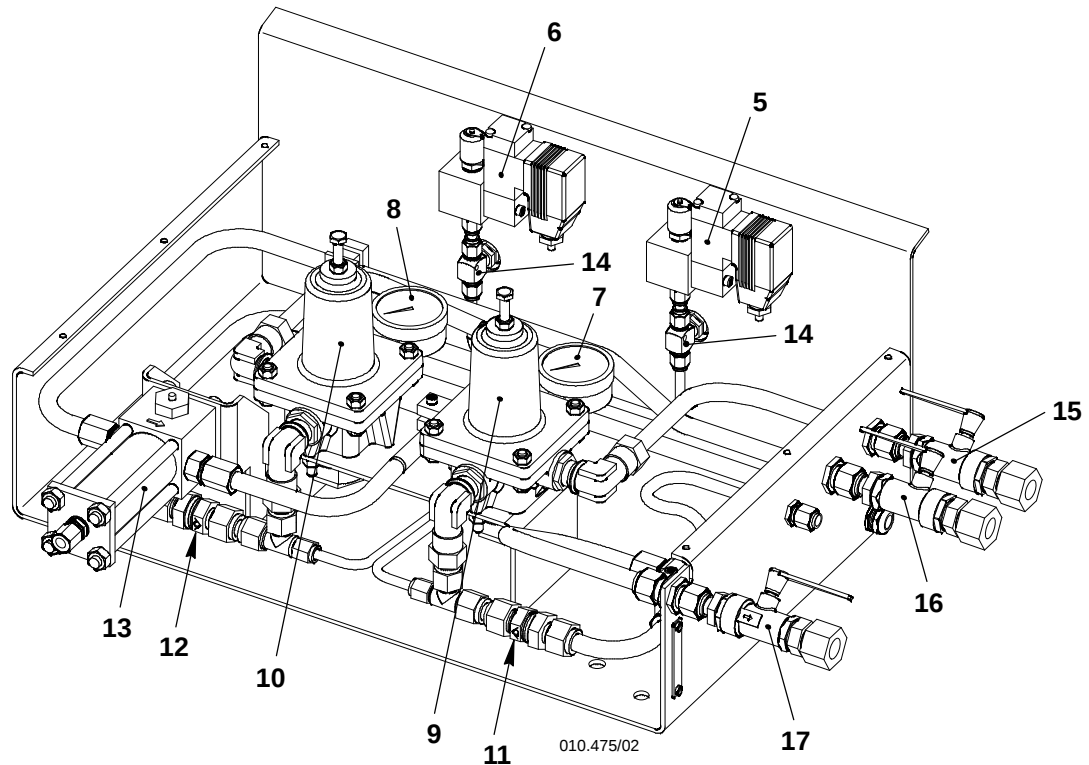
The shut-offs, pressure reducing valve, filters etc. necessary for feeding air to the various units are summarized in the control air supply unit **A** (Fig. 'C').

The designations used to identify the individual pieces of equipment on the illustrations are identical to the ones used on the Control Diagram 4003-2.



## Control Air Supply

C



**Key to Illustrations:** 'A' Arrangement of control air supply  
 'B' Diagram of control air supply unit **A**  
 'C' Control air supply unit **A**

- |                                    |                                                         |
|------------------------------------|---------------------------------------------------------|
| 1 Control air supply unit <b>A</b> | 14 Control valve                                        |
| 2 Air bottle 287HA                 | 15 Shut-off and venting cock 36HB for control air       |
| 3 Condensate water container       | 16 Shut-off and venting cock 36HC for starting air      |
| 4 Condensate water drain valve     | 17 Shut-off and venting cock 36HA (4.08) for air spring |
| 5 Pressure transmitter PT4401A     |                                                         |
| 6 Pressure transmitter PT4411A     |                                                         |
| 7 Pressure gauge PI4401L           |                                                         |
| 8 Pressure gauge PI4411L           |                                                         |
| 9 Pressure reducing valve 23HA     |                                                         |
| 10 Pressure reducing valve 19HA    |                                                         |
| 11 Non-return valve 342HA          | A1 Control air from board system                        |
| 12 Non-return valve 342HB          | A2 Starting air from starting air system                |
| 13 Filter 351HA                    | A3 Connection to air bottle 287HA                       |
|                                    | A6 Air spring air supply                                |

## Local Control Panel

## 1. General

Control components are provided in the local control panel required for operating the engine. As this panel is supplied by the remote control manufacturer, the relevant components may differ from the example in Fig. 'B'.

Brief instructions for manoeuvring from the local control panel are given on nameplate for LOCAL MANUAL CONTROL (Local Control) by operating elements (for detailed description see 4003-1 'Engine local control' and Manoeuvring 0260-1).

## 2. Fitted components

## 2.1 WECS-9520 MANUAL CONTROL panel

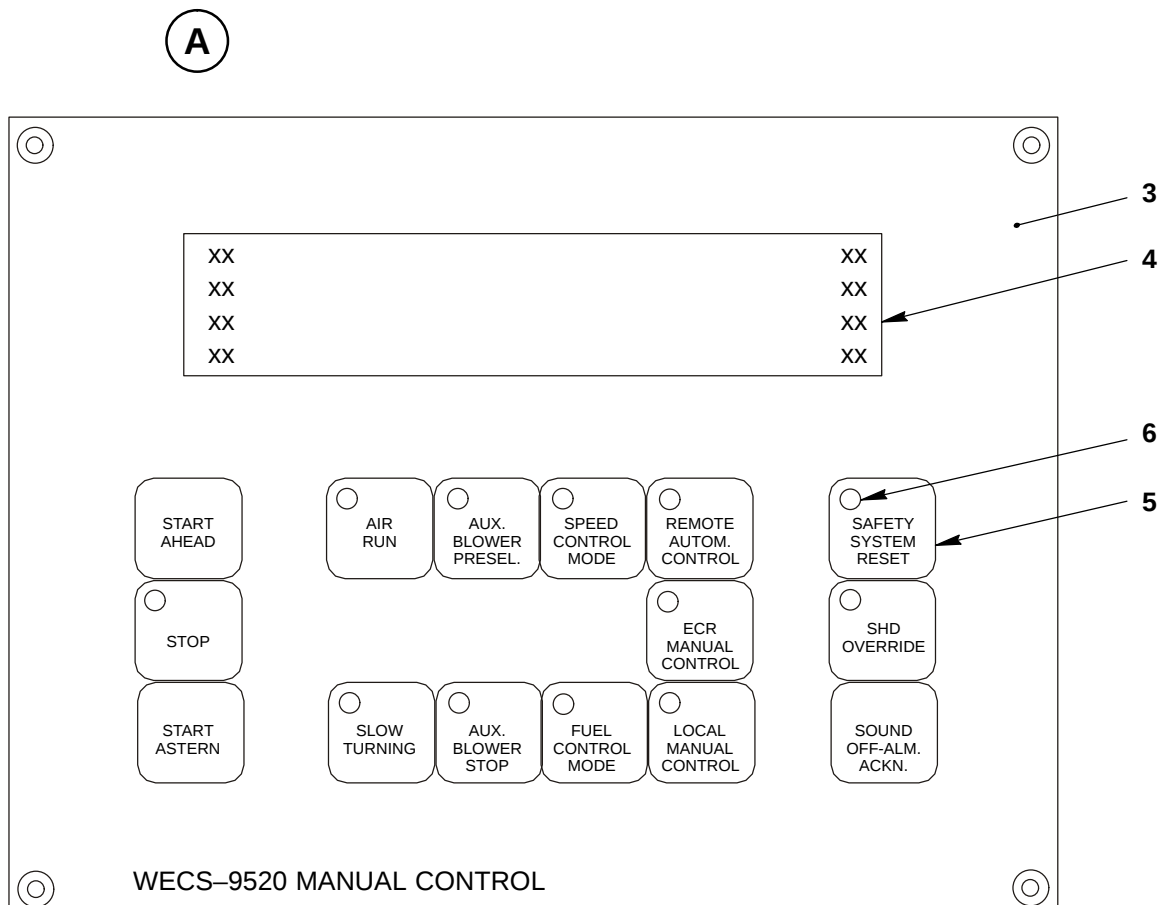
The WECS-9520 manual control panel, supplied by Wärtsilä Switzerland Ltd. to the remote control manufacturers, contains buttons and indications necessary for running the engine from the local manoeuvring stand (in backup mode).



**Remark:** The buttons function only in the corresponding mode of operation, i.e. with an active control stand. The functions described below may also be carried out on ECR manual control panel which is arranged in the control room console.

The two manual control panels are connected to WECS-9520 which will power them, and therefore these function independently of the remote control. However, they are always identically, and for any problems regarding the manual control panels, please contact Wärtsilä Switzerland Ltd.

**Operating buttons and their functions:**



## Local Control Panel

| Button                |        |       | Function                                                                                                                                                | Purpose and action                                                                                                                        |
|-----------------------|--------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Designation           | Colour | LED   |                                                                                                                                                         |                                                                                                                                           |
| START AHEAD           | GREEN  | none  | Engine START AHEAD<br>Interruption running ASTERN<br>(reversing from ASTERN - AHEAD)                                                                    | Auxiliary blower preselect signal is generated automatically                                                                              |
| STOP                  | GREY   | RED   | Engine STOP interrupts fuel injection                                                                                                                   | LED lights up as long as STOP order is on                                                                                                 |
| START ASTERN          | RED    | none  | Engine START ASTERN<br>Interruption running AHEAD<br>(reversing from AHEAD - ASTERN)                                                                    | Auxiliary blower preselect signal is generated automatically                                                                              |
| AIR RUN               | GREY   | GREEN | Engine start with starting air only<br>(fuel command adjusted to 'zero' )<br>After a longer shut-down or maintenance works with opened indicator valves | LED lights up as long as button is pressed<br>Operation functions at engine standstill only                                               |
| AUX. BLOWER PRESEL.   | GREY   | GREEN | Set auxiliary blower status from STOP to PRESELECT                                                                                                      | LED lights up, if auxiliary blowers are preselected<br>Effected by pressing the buttons AUX. BLOWER PRESEL. or START AHEAD / START ASTERN |
| SPEED CONTROL MODE    | GREY   | GREEN | Setting of speed nominal value to electronic speed control system, adjustable by rotary knob (speed / fuel)                                             | LED lights up, if SPEED CONTROL MODE is selected<br>LED FUEL CONTROL MODE extinguishes                                                    |
| REMOTE AUTOM. CONTROL | GREY   | GREEN | Transfer LOCAL MANUAL CONTROL (Local Control) to REMOTE AUTOM. CONTROL (Remote Control)                                                                 | During transfer of control both green LEDs blink and then light up constantly after takeover                                              |
| ECR MANUAL CONTROL    | GREY   | GREEN | Transfer LOCAL MANUAL CONTROL (Local Control) to ECR MANUAL CONTROL                                                                                     | During transfer of control both green LEDs blink and then light up constantly after takeover                                              |
| SLOW TURNING          | GREY   | GREEN | Releasing an automatic SLOW TURNING (AHEAD)<br>Slow turning sequence can be stopped at any time by pressing button once again                           | LED blinks during SLOW TURNING<br>Programme is stopped automatically, if engine finished a complete revolution or by malfunction          |
| AUX. BLOWER STOP      | GREY   | RED   | Switching auxiliary blowers off manually                                                                                                                | LED lights up, if auxiliary blowers are switched off (start impulse to auxiliary blowers cancelled)                                       |

## Local Control Panel

| Button                |        |       | Function                                                                                                                                                                     | Purpose and action                                                                                                                                                                                    |
|-----------------------|--------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Designation           | Colour | LED   |                                                                                                                                                                              |                                                                                                                                                                                                       |
| FUEL CONTROL MODE     | GREY   | RED   | Setting of fuel injection quantity to WECS-9520, adjustable by rotary knob (speed / fuel)                                                                                    | LED lights up, if FUEL CONTROL MODE is selected<br>Upon failure of electr. speed control system or if fuel injection quantity regulation is required                                                  |
| LOCAL MANUAL CONTROL  | GREY   | GREEN | Transfer from ECR MANUAL CONTROL to LOCAL MANUAL CONTROL (Local Control)<br><br>Transfer from REMOTE AUTOM. CONTROL (Remote Control) to LOCAL MANUAL CONTROL (Local Control) | After takeover of control both green LEDs light up constantly<br><br>Takeover to LOCAL MANUAL CONTROL must be acknowledged at control room console                                                    |
| SAFETY SYSTEM RESET   | GREY   | GREEN | Resetting of still blocked shut-down conditions in safety system                                                                                                             | LED lights up, if all shut-down conditions are established again and that all shut-downs can be reset                                                                                                 |
| SHD OVERRIDE          | GREY   | RED   | Overriding of shut-downs<br><br>Resetting override (by constantly lighting LED)                                                                                              | If a shut-down with possibility of overriding is present, LED blinks or lights up constantly if it is overridden<br>Reestablish previous condition (i.e. of a shut-down still indicated or not reset) |
| SOUND OFF – ALM ACKN. | GREY   | none  | Switch off acoustical alarms (bell / buzzer)<br><br>Information about version and check of software on display                                                               | (Shut-down) alarm indications change from blinking to constantly lighting up<br>Pressing button for approx. 5 seconds                                                                                 |

**Display:**

- Speed setting
- Fuel injection quantity (fuel command)
- Fuel rail pressure
- Servo oil rail pressure

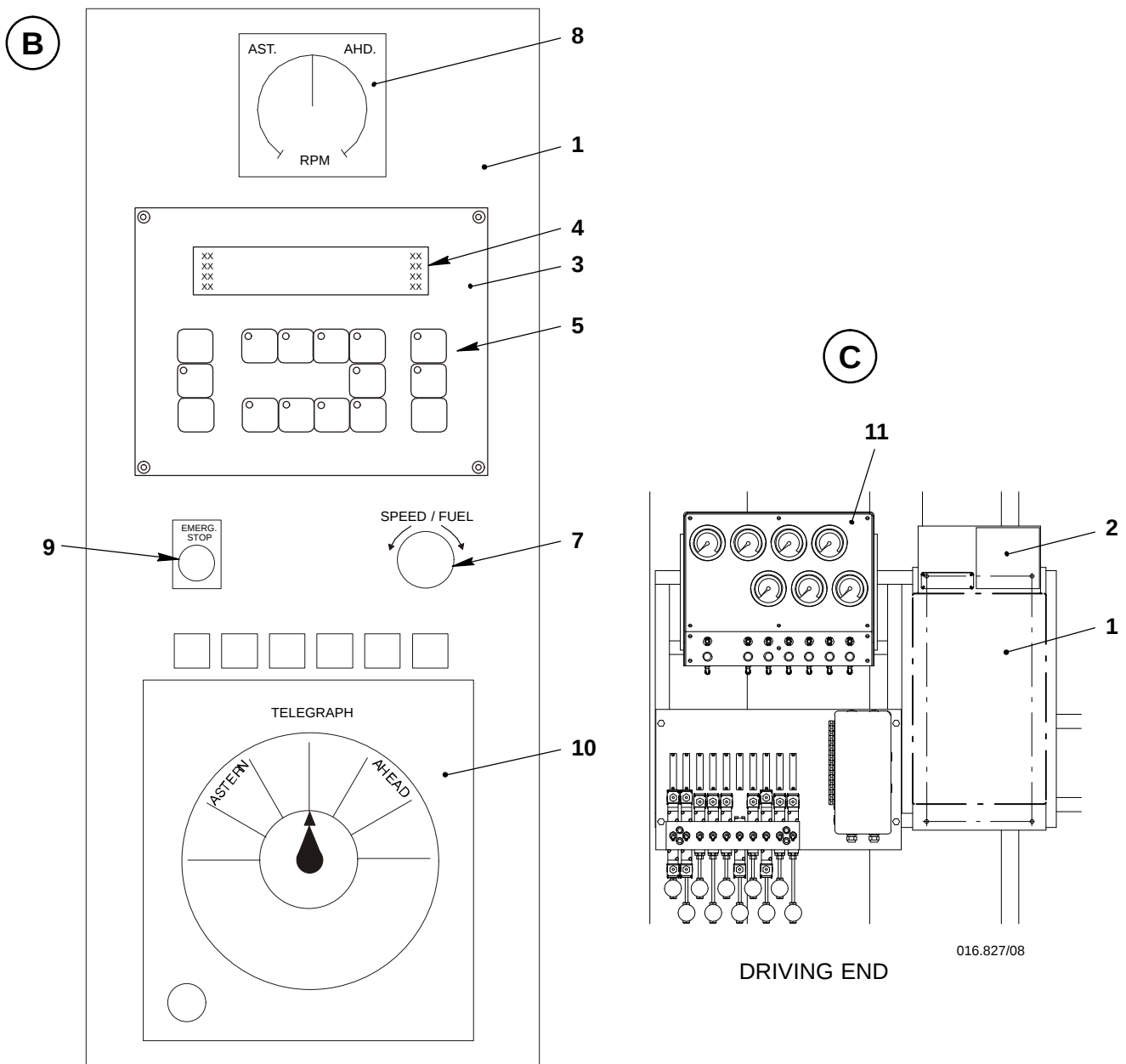
Furthermore, important conditions (statuses) are displayed in 3<sup>rd</sup> and 4<sup>th</sup> scanning line on the left as:

- Turning Gear Engaged and No Aux. Blower Running
- Emergency stop
- Overspeed
- Shut-down active
- Shut-down expected
- Slow-down request
- Start interlock (together with indication in 3<sup>rd</sup> scanning line)

**2.2 Remote control**

- Rotary knob for speed setting or fuel injection quantity adjustments
- Emergency stop
- Telegraph

## Local Control Panel



## Key to Illustrations:

- |                                    |                                                 |
|------------------------------------|-------------------------------------------------|
| 1 Control panel                    | 'A' WECS-9520 Manual control panel              |
| 2 Nameplate with brief instruction | 'B' Front view of local control panel (example) |
| 3 WECS-9520 manual control panel   | 'C' Arrangement of local control panel          |
| 4 Display                          |                                                 |
| 5 Attendance buttons               | 7 Rotary knob (speed / fuel)                    |
| 6 LEDs                             | 8 ME tachometer                                 |
|                                    | 9 Emergency stop button                         |
|                                    | 10 Telegraph                                    |
|                                    | 11 Instrument panel                             |

## Pick-up for Speed Measurement

### 1. General

To measure the engine speed (rpm) several proximity sensors have been combined to a speed pick-up unit, arranged on the front side of the column.

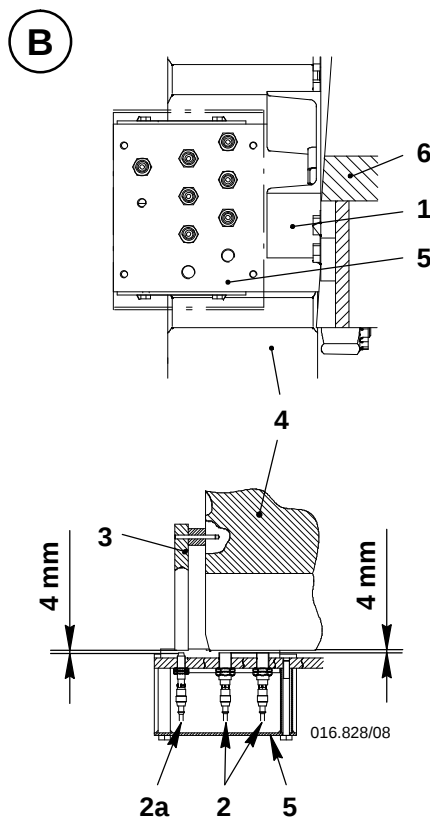
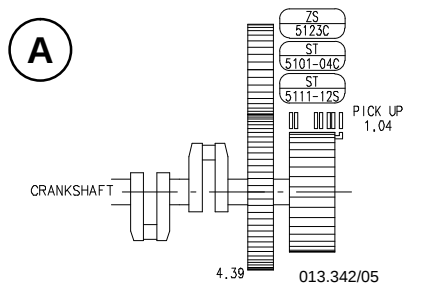
For safety reasons 3 electrically separated proximity sensor groups are provided:

- Speed detection in the RCS
- Overspeed safety system
- Speed control system

### 2. Function

The speed impulse measurement takes place with the proximity sensors 2 contact-less (inductive) at the toothing of the flywheel 4. The electric speed signals are transferred via DENIS-9520 to the remote control system for monitoring the load and speed-dependent functions, as well as to the speed indicating instruments.

The proximity sensor 2a has been provided to indicate the comparison measurement of the TDC position for the crank angle transmitters.



#### Key to Illustrations:

'A' Schematic diagram

'B' Arrangement of measuring points

- 1 Pick-up holder
- 2, 2a Proximity sensor
- 3 Crank angle mark
- 4 Flywheel
- 5 Casing
- 6 Column

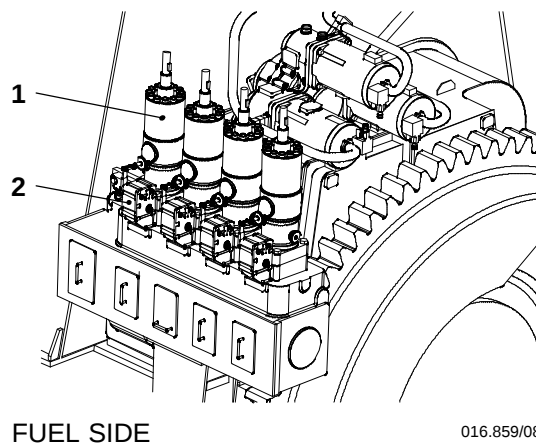
## Fuel Pump

### 1. General

Depending on the number of cylinders, three or four fuel pumps 1 are fitted on the fuel pump unit (see Fig. 'A' and Fuel Pump Unit 5581-1).

They deliver fuel under high pressure into the fuel rail via the rising pipes.

The fuel pumps are controlled to supply as much fuel as necessary to maintain the required pressure (load-dependent) in the fuel rail.



DRAWN FOR  
6 TO 8 CYLINDERS

### 2. Function

The compression spring 11 presses the guide piston 12 and roller 14 onto the cam 16 via lower spring carrier 13. The pump plunger 18 is brought into a stroke motion by the cam on the rotating camshaft. The required fuel quantity is controlled by the control grooves 'ST' of the pump plunger.

The regulation of the fuel quantity is carried out by the movement of the toothed rack 9 whose teeth mesh on the toothed regulating sleeve 8 causing it to turn. The latter is connected to the pump plunger by driver 'KM' turning the pump plunger when the toothed rack moves. When the pump plunger passes the BDC the plunger space 'PR' is filled through two inlet bores 'ZB' in the pump cylinder and two control grooves 'ST' in the pump plunger (see Fig. 'C') depending on the regulating position ('0' for zero delivery until '10' for maximum delivery).



**Remark:** No fuel is supplied when the inlet bores 'ZB' overlap the control grooves 'ST' in position '0'.

The toothed rack is connected to the fuel pump actuator (see 5583-1).

## Fuel Pump

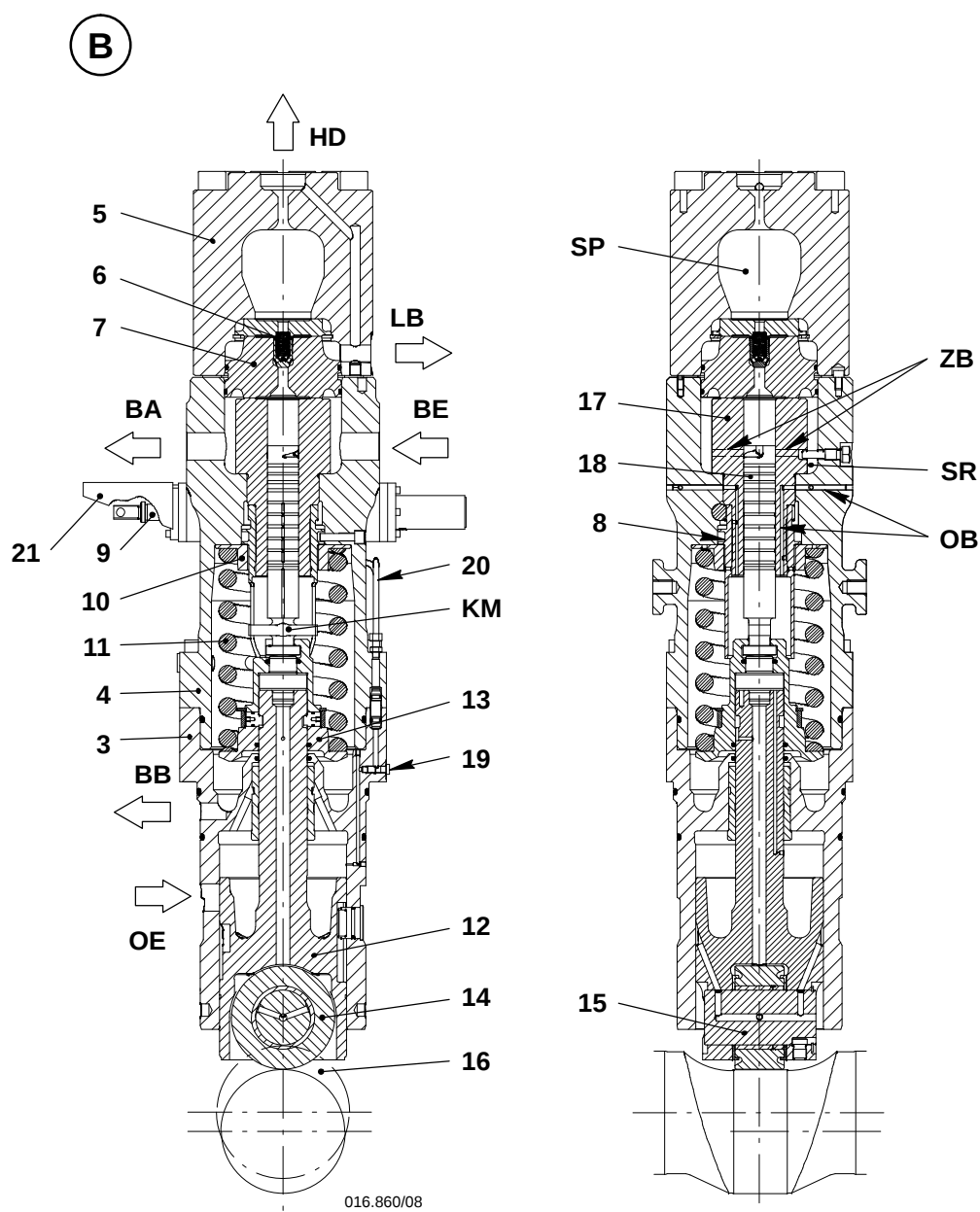
### 3. Lubrication

The fuel pump is lubricated with engine lube oil which enters the lower housing 3 through the inlet bore 'OE' in the housing of the fuel pump unit.

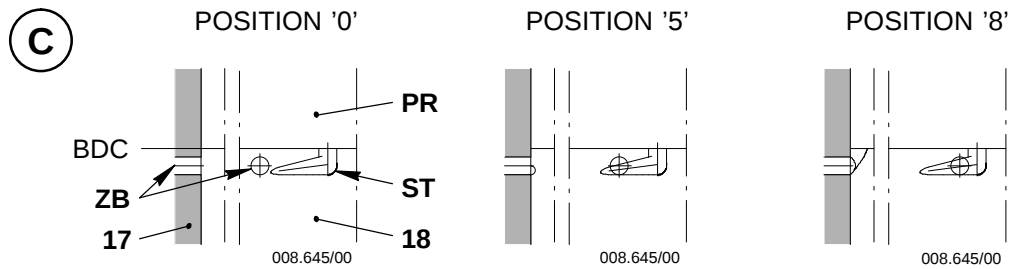
Part of lube oil ensures lubrication of the guide piston, the floating pin 15 and roller 14 via spot faces, annular groove and bores in the guide piston. The flowing down lube oil lubricates the cam running surface.

An other part of lube oil ensures lubrication of the regulating sleeve 8 via lubricating oil bores 'OB' in the upper housing 4 and the pump cylinder 17.

The pump plunger 18 is lubricated with leakage fuel. It is derived via drain bore 'BB', together with leakage oil from the regulating sleeve, through an internal bore in the housing of the fuel pump unit.



## Fuel Pump



**Key to Illustrations:**

- 'A' Arrangement of fuel pump
- 'B' Fuel pump
- 'C' Control groove of pump plunger

- |                                 |                            |
|---------------------------------|----------------------------|
| 1 Fuel pump                     | 19 Orifice                 |
| 2 Fuel pump actuator            | 20 Oil pipe                |
| 3 Lower housing                 | 21 Covering                |
| 4 Upper housing                 |                            |
| 5 Pump cover                    |                            |
| 6 Valve body } non-return valve | BA Fuel oil outlet         |
| 7 Valve block }                 | BB Leakage fuel drain bore |
| 8 Regulating sleeve             | BE Fuel inlet              |
| 9 Regulating (toothed) rack     | HD HP to fuel rail         |
| 10 Upper spring carrier         | KM Driver of pump plunger  |
| 11 Compression spring           | LB Leakage fuel outlet     |
| 12 Guide piston                 | OB Lubricating oil bore    |
| 13 Lower spring carrier         | OE Lubricating oil inlet   |
| 14 Roller                       | PR Plunger space           |
| 15 Pin                          | SP Accumulation space      |
| 16 Cam                          | SR Suction space           |
| 17 Pump cylinder                | ST Control groove          |
| 18 Pump plunger                 | ZB Inlet bore              |



## Cutting Out and Cutting In of the Fuel Pump

### 1. General

As a rule, in the event of a defect in a fuel pump (e.g. seizing of pump plunger) or a rising pipe break between fuel pump and fuel rail, the fault must be remedied immediately.

Should this not be possible because the engine has to be put back in service, the corresponding fuel pump can be cut out.



Cutting out and cutting in of defective fuel pumps may only be carried out at engine standstill!

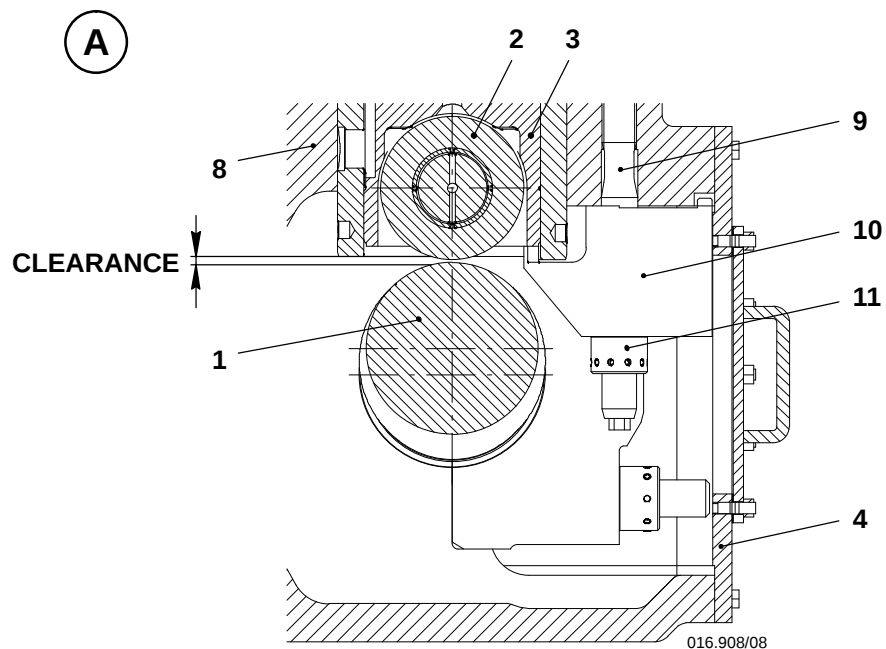


**Remark:** With one fuel pump cut out the engine may be maintained approximately in unrestricted operation.

With two fuel pumps cut out the engine can only be operated at reduced load.

### 2. Cutting Out and Cutting In of Fuel Pump

#### 2.1 Device (roller lifting tool) for cutting out and cutting in



Key to Illustrations: 'A' Roller lifting tool  
'B' Assembling  
'C' Arrangement for blank flange

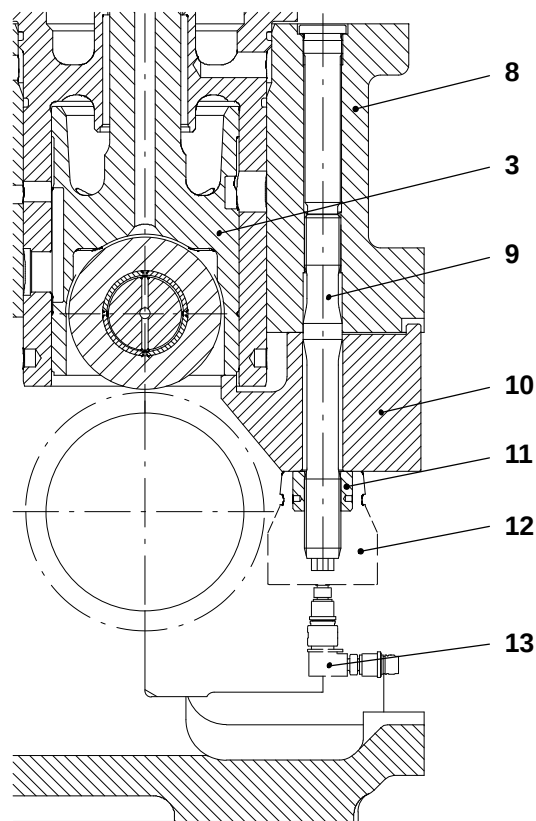
- |                         |                                      |              |
|-------------------------|--------------------------------------|--------------|
| 1 Cam                   | 9 Elastic bolt                       | } tool 94430 |
| 2 Roller                | 10 Pad                               |              |
| 3 Guide piston          | 11 Round nut                         |              |
| 4 Cover                 | 12 Pre-tensioning jack (tool 94430a) |              |
| 5 Fuel supply <b>B</b>  | 13 Coupling element (tool 94934g)    |              |
| 6 Fuel rising pipe 3.29 | 14 Blank flange (tool 94569)         |              |
| 7 Intermediate piece    | 15 Blank flange (tool 94569a)        |              |
| 8 Casing fuel pump unit |                                      |              |

## Cutting Out and Cutting In of the Fuel Pump

### 2.2 Cutting out procedure

- Engine at standstill.
- ⇒ Remove cover 4 and ascertain position of the corresponding cam. Turn the engine with turning gear till roller 2 of guide piston 3 reaches the highest position (cam peak).
- ⇒ Screw in elastic bolt 9 (together with pad 10) till the stop.
- ⇒ Screw on round nut 11 till touching pad 10 and paying attention that the latter is in contact with guide piston 3 and casing 8.
- ⇒ Thread pre-tensioning jack 12 with opened vent screw onto elastic bolt 9 till touching pad 10 as shown in Fig. 'B'.
- ⇒ Tension elastic bolt with 1500 bar following Maintenance Manual 9403-4. Check corresponding tightening angle of  $84^\circ$  (see Maintenance Manual 0352-1).
- ⇒ Check whether roller 3 is lifted off from cam 1 by approx. 3 mm.
- ⇒ Remove the pre-tensioning jack and refit cover 4.

**B**



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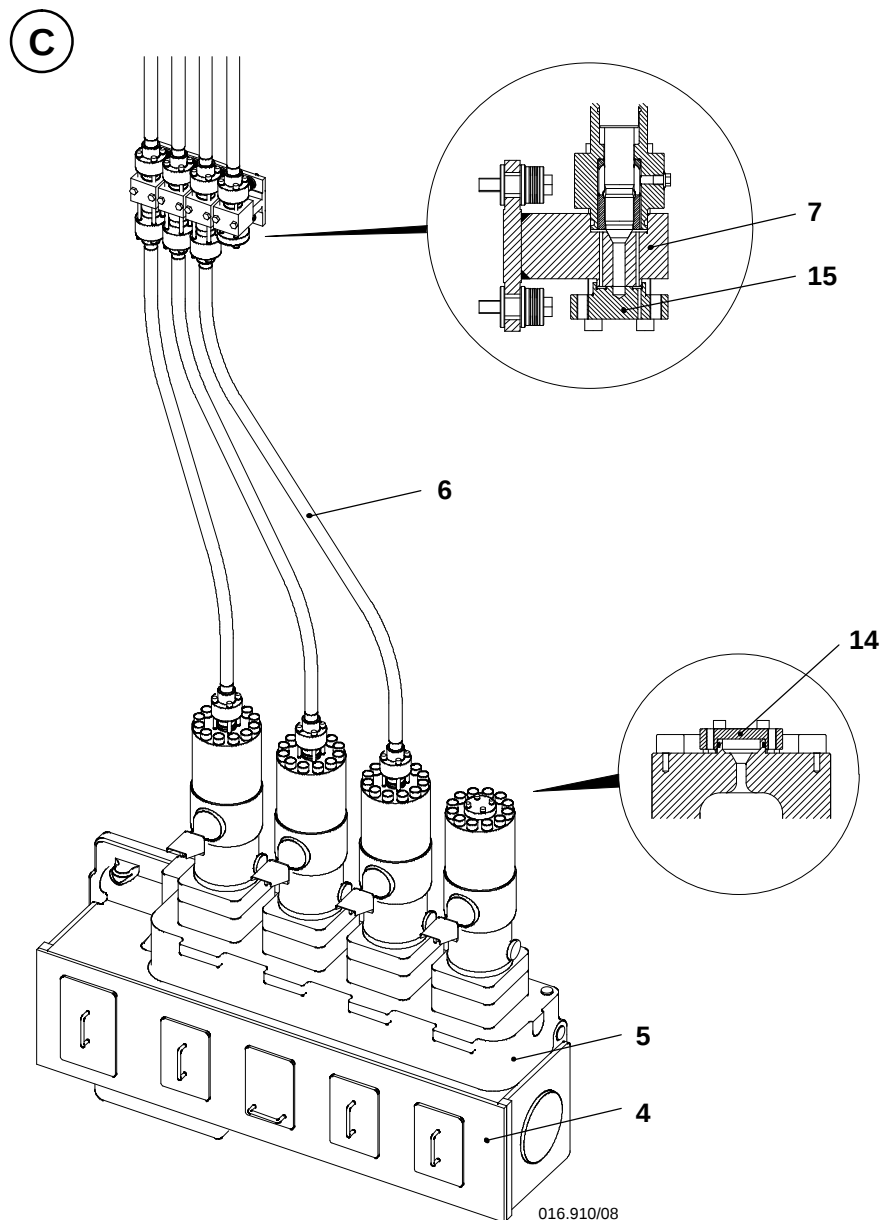
## Cutting Out and Cutting In of the Fuel Pump

### 2.3 Blanking off fuel pump and fuel rail



**Remark:** With leaky non-return valves, a pressure can built up itself in the plunger space of the fuel pumps leading to an increased load on the cut-out tool. This must be prevented by means of taking the following measures:

- ⇒ Remove fuel rising pipe 6 from the cut-out fuel pump (see Fig. 'C' and 8752-1 'Removal' in the Maintenance Manual).
- ⇒ Fit blank flange 14 with its proper screws (tool 94569) to fuel pump.
- ⇒ Fit blank flange 15 with its proper screws (tool 94569a) to intermediate piece 7 on fuel rail.
- For tightening values and lubricant of the relevant screws see 0352-1 in the Maintenance Manual.



## Cutting Out and Cutting In of the Fuel Pump

---

### 2.4 Cutting in procedure

- Engine at standstill.
- ⇒ Remove cover 4 and ascertain position of the corresponding cam. Turn the engine with turning gear till roller 2 of guide piston 3 reaches the highest position (cam peak).
- ⇒ Thread pre-tensioning jack 12 with opened vent screw onto elastic bolt 9 till touching pad 10 as shown in Fig. 'B'.
- ⇒ Tension elastic bolt with 1530 bar following Maintenance Manual 9403-4. Unscrew round nut 11 by ½ turn.
- ⇒ Remove the pre-tensioning jack and the round nut. Subsequently turn out the elastic bolt and remove it together with the pad.



**Attention!** After removing the round nut, the pad must be fixed by hand.

- ⇒ Remove blank flanges 14 and 15 (tools 94659 and 94569a) and refit fuel rising pipe 6 (see also 8752-1 'Fitting' in the Maintenance Manual).

## Fuel Pressure Control Valve 3.06

---

### 1. General

#### 1.1 Normal operation



**Attention!** In normal operation the knurled (adjusting) screw must be fully turned down!

WECS-9520 regulates the fuel pressure which remains below the opening pressure of the fuel pressure control valve 1. The latter is normally closed (see also [4002-1](#) 'Fuel pressure control').

The valve acts as a pressure relief valve and opens if the fuel pressure exceeds approx. 1050 bar. The opening pressure is properly adjusted by means of adapted adjusting disc 7 and tightened knurled screw 8.

#### 1.2 Emergency stop

The safety system activates fuel shut-down pilot valve 6 reducing the fuel pressure to less than 200 bar (in most cases to '0' bar). Therefore an injection is no longer possible.



**Remark:** The fuel shut-down pilot valve is only one out of three actuating devices to shut down the engine; the others are:

- immediate injection stop (WECS-9520)
- fuel pump delivery to '0'.

#### 1.3 Emergency operation



**Attention!** For emergency operation the knurled (adjusting) screw must be fully turned out!

The fuel pressure control valve takes over the fuel pressure regulating function in case of failures in the fuel pressure regulating system, as by:

- missing or wrong control signals
- fuel pump actuator(s) out of service
- blocked toothed rack.

The fuel pumps are fixed in maximum delivery position. This can be applied to all fuel pumps or only to a single one, depending on the failure (see [0515-1](#) 'Defective actuator').

If the fuel pressure exceeds the opening pressure, the fuel pressure control valve will open, gradually draining enough fuel to maintain the adjusted maximum pressure. In this case a longer operating time should be avoided!

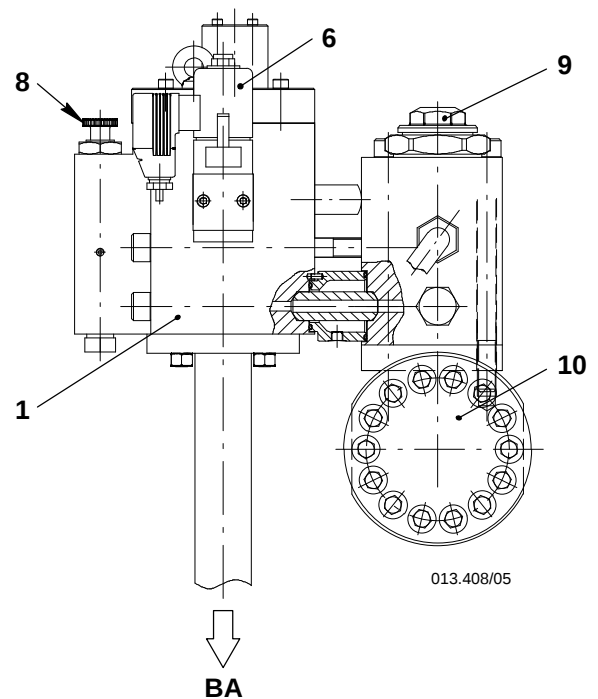
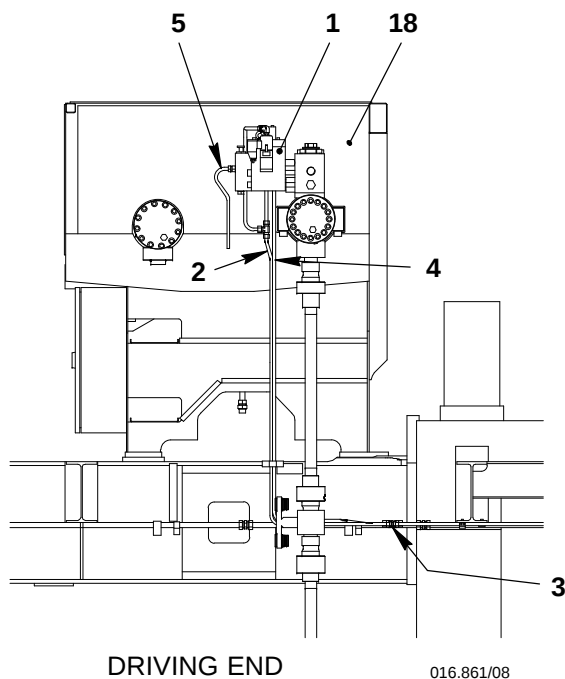
The knurled screw must therefore be fully turned out counter-clockwise till the stop. This reduces the opening pressure to approx. 600 bar, ensuring safe operation over the whole load range.



**Remark:** The opening of the fuel pressure control valve can be confirmed acoustically: a strong 'whistling' noise indicates that fuel is being drained.

## Fuel Pressure Control Valve 3.06

A



## 2. Function

### 2.1 Regulating function

Due to the oil pressure on top of piston 11 valve tip 12 is pressed onto valve seat 13. The fuel pressure also works against the internal oil pressure regulating valve 17. An increasing fuel pressure reduces the oil pressure. The valve tip is lifted off from the valve seat and fuel is drained if the oil pressure drops below a certain threshold value.

Compression springs 14 & 15 and knurled screw 8 define the regulating characteristic of the oil pressure regulating valve.

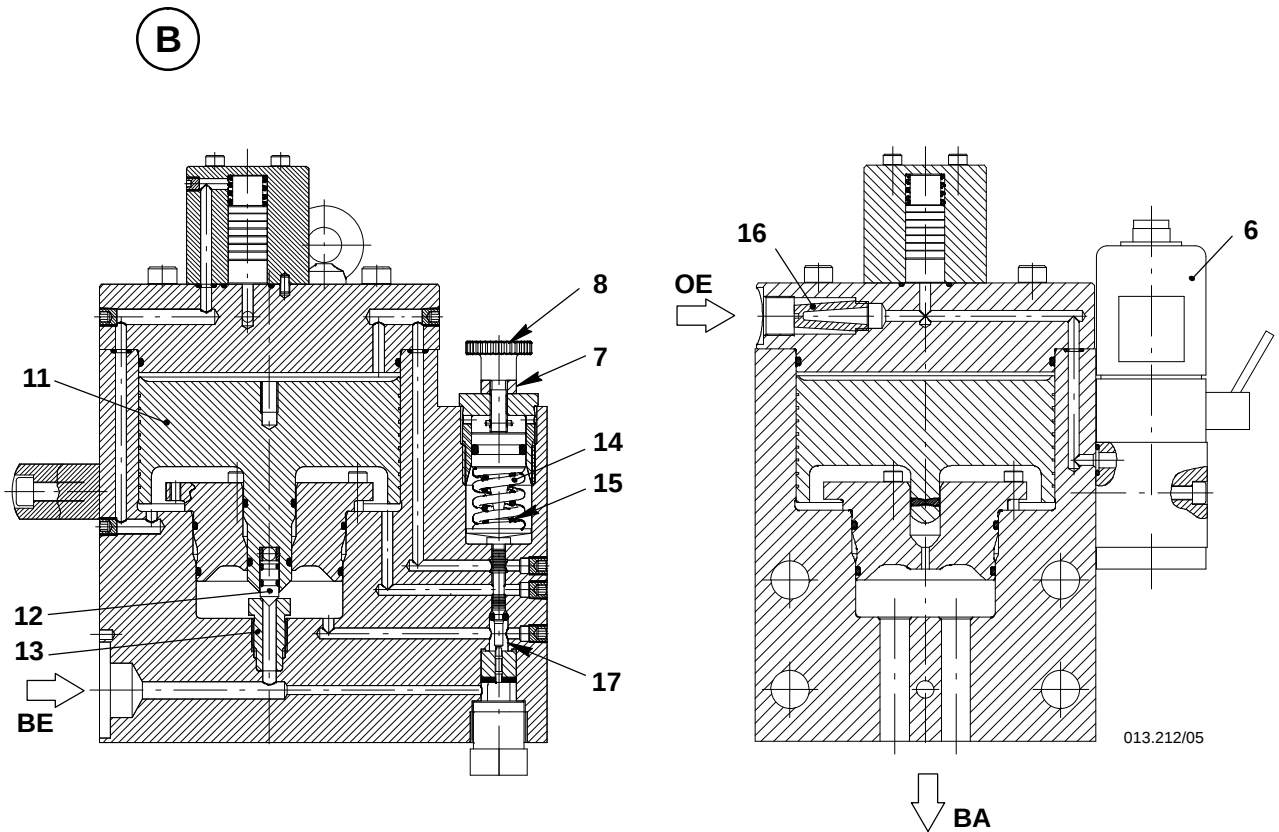
### 2.2 Function check

During normal operation the function can be confirmed by carefully turning the knurled screw counter-clockwise till the valve starts to open, relieving the fuel pressure.

### 2.3 Emergency stop function

If the fuel shut-down pilot valve 6 is energized the oil pressure on top of piston 11 is relieved, the valve tip is lifted off from the valve seat and fuel is drained.

## Fuel Pressure Control Valve 3.06

**Key to Illustrations: 'A' Arrangement of fuel pressure control valve 3.06****'B' Fuel pressure control valve 3.06**

- |                                       |                                  |
|---------------------------------------|----------------------------------|
| 1 Fuel pressure control valve 3.06    | 13 Valve seat                    |
| 2 Bearing oil supply pipe             | 14 Compression spring            |
| 3 Non-return valve 3.67               | 15 Compression spring            |
| 4 Bearing oil drain                   | 16 Filter                        |
| 5 Leakage control pipe                | 17 Oil pressure regulating valve |
| 6 Fuel shut-down pilot valve 3.08     | 18 Rail unit                     |
| 7 Adjusting disc                      |                                  |
| 8 Knurled screw                       |                                  |
| 9 Fuel overpressure safety valve 3.52 |                                  |
| 10 Fuel rail 3.05                     | BA Fuel outlet (drain)           |
| 11 Piston                             | BE Fuel inlet                    |
| 12 Valve tip                          | OE Oil inlet                     |



## Fuel Pump Unit

---

### 1. General

The fuel pump unit is located at driving end, however on fuel side for 6 to 8 cylinder engines, and one on exhaust side and on fuel side each for 9 to 12 cylinder engines.

The following components are integrated in or mounted on the housing of the fuel pump unit:

***Camshaft connection:***

It consists of camshaft 2 and gear wheel 3 fitted with head screws 4. The bedding is ensured by bearing halves 5 and thrust bearing ring halves 6.

The drive is effected via the gear wheel on crankshaft and an intermediate wheel (see Drive Supply Unit 4104-1).

***Fuel pumps:***

Depending on the number of cylinders, three or four fuel pumps 7 are mounted on the fuel pump unit.

- Description see Fuel Pump [5556-1](#).

***Fuel pump actuator:***

Each fuel pump is equipped with a fuel pump actuator 8. The actuators (electrical control elements) control all fuel pumps simultaneously.

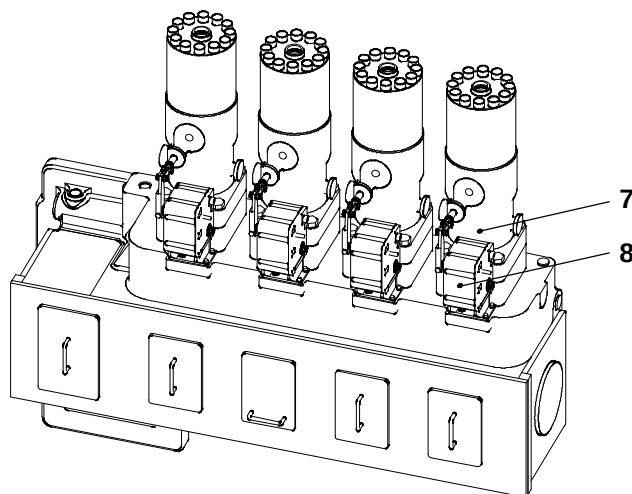
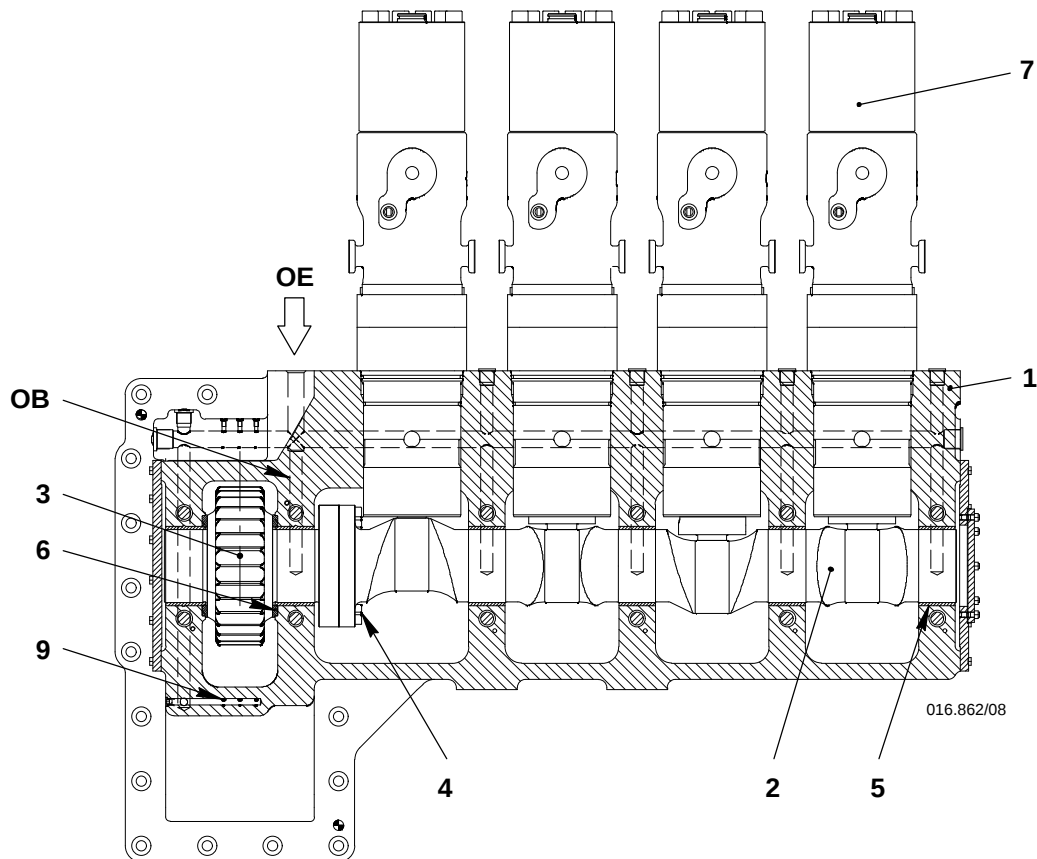
- Description see fuel pump actuator [5583-1](#).

### 2. Lubrication

Lubrication of the bearings and fuel pumps is ensured via oil inlet 'OE' and oil bores 'OB'.

The gear wheel 3 is lubricated by spray nozzles 9 which are integrated in the housing.

## Fuel Pump Unit

**Key:**

- 1 Housing
- 2 Camshaft 3.55
- 3 Gear wheel 4.42
- 4 Head screw
- 5 Bearing half
- 6 Thrust bearing ring half
- 7 Fuel pump 3.14
- 8 Fuel pump actuator 3.21
- 9 Spray nozzle

OB Oil bore  
OE Oil inlet

## Fuel Pump Actuator

---

### 1. General

The actuator 2 is connected with fuel pump 1. Connecting element 4 permits the regulating rack 5 to be positioned in the fuel pump by the movement of the actuator lever 3. An electrically-operated actuator is provided for each fuel pump.

### 2. Function

Controlled by the WECS-9520 system every actuator regulates the required fuel quantity, maintaining the necessary operating pressure in the fuel rail.

During normal operation the actuators work simultaneously, i.e. the regulating position and the fuel quantity of the fuel pumps are identical.

If a pump plunger seizes and therefore blocks the regulating rack, the corresponding actuator must not be made currentless (overload protection).

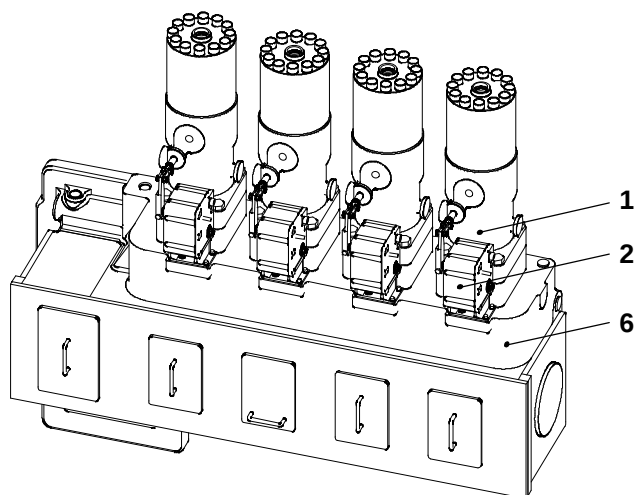
If an actuator fails, its regulating output remains in position. The other actuators take over the control of the fuel quantity regulation (see also [0515-1](#) 'Defective actuator').



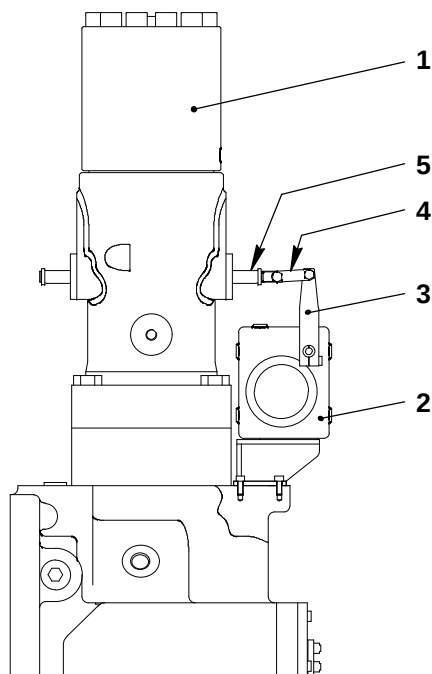
**Remark:** In the lower load range (at lower fuel consumption) fuel pressure control valve 3.06 takes over the fuel pressure regulating function as the fuel quantity supply can not further be reduced by the actuators (see also [5562-1](#) 'Fuel pressure control valve 3.06').

Fuel Pump Actuator

---



016.862/08



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**Key to Illustrations:**

- |                  |                      |
|------------------|----------------------|
| 1 Fuel pump 3.14 | 4 Connecting element |
| 2 Actuator 3.21  | 5 Toothed rack       |
| 3 Actuator lever | 6 Fuel pump unit     |

## Servo Pump Unit

### 1. General

Integrated in the servo pump unit 1, there are two or three servo oil pumps 2 (pump for short) depending on numbers of cylinders.

These pumps ('wobble-plate pumps') ensure the supply of servo oil for the movements of the exhaust valves and the injection. They are operated with additionally filtered bearing oil. The servo oil is fed to the pumps via the automatic filter 8 (see Fig. 'A').

The drive is effected via the gear wheel on crankshaft, intermediate gear 7, gear wheels 3 & 4, pinion 5 and shaft 6 (see Fig. 'B' and Drive Supply Unit 4104-1).

### 2. Function

In normal operation the pumps are controlled in such a manner that the load of the total load range is equally distributed to them.

The electrically controlled pressure regulating system (nominal pressure value depending on engine load) adjusts the servo oil system pressure over the entire load range, i.e. high pressure (approx. 200 bar) at high engine load, and reduced pressures at low engine load.

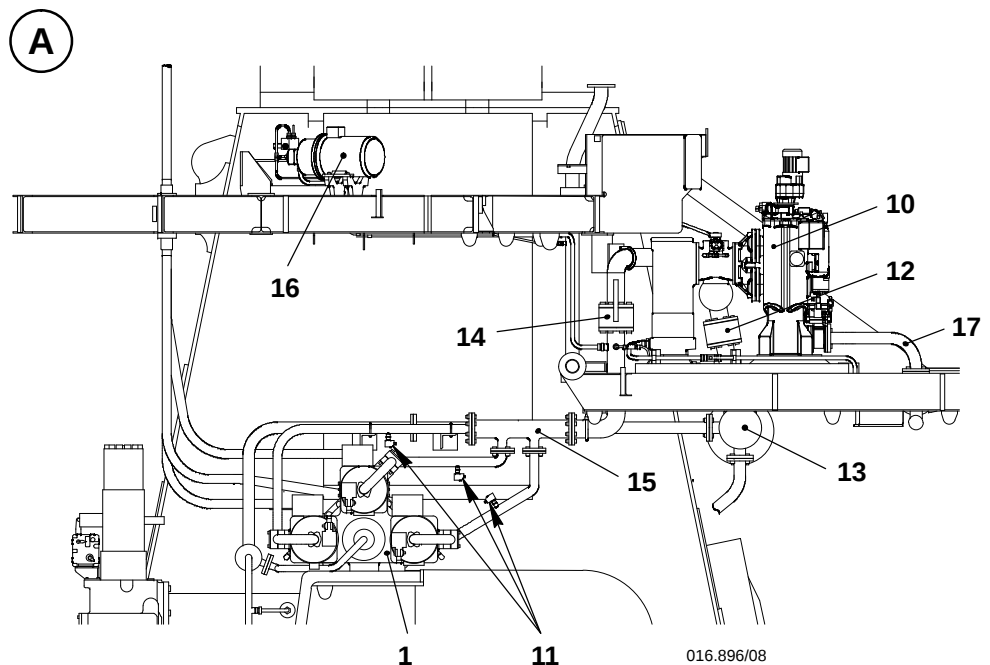
Sharable overload protections 'SB' on each shaft 6 prevents total loss of the gear wheel 4 if a pump is seized completely (see Fig. 'B').

In case of a single pump failure, engine operation can be maintained over the entire load range.

Flow sensors 11, which are fitted into every inlet pipe of the pumps monitor the oil supply. A possible failure of a pump is indicated in the alarm and monitoring system.



**Attention!** The operating mode with a pump out of order must not be considered as permanent. If another pump fails the engine will no longer be operative! The defective pump has to be exchanged as quickly as possible (see Maintenance Manual 5591-1).

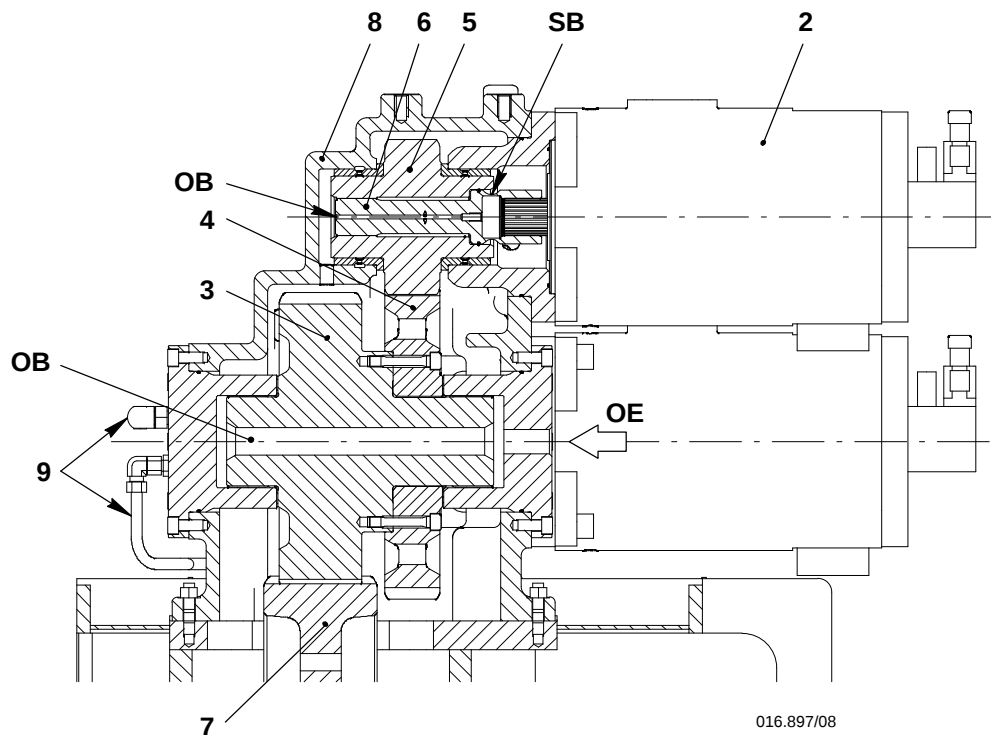


016.896/08

## Servo Pump Unit

**3. Lubrication**

Lubrication of the bearings is provided from oil inlet 'OE' via gear wheel 3, distributing pipes 9, internal bores in casing 8 and shaft 6. Integrated spray holes arranged in the mentioned bores serve for lubrication of the tooth flanks.

**B**

**Key to Illustrations: 'A' Arrangement of automatic filter and Servo pump unit**  
**'B' Arrangement of servo oil pump**

- |                             |                                   |
|-----------------------------|-----------------------------------|
| 1 Servo pump unit           | 12 Stop valve 4.37                |
| 2 Servo oil pump 4.15       | 13 Oil inlet pipe on exhaust side |
| 3 (Driving) gear wheel 4.42 | 14 Stop valve 4.80                |
| 4 Gear wheel 4.44           | 15 Supply pipe 4.51               |
| 5 Pinion 4.45               | 16 Servo oil service pump 4.88    |
| 6 Shaft 4.50                | 17 Flushing oil drain pipe        |
| 7 Intermediate wheel 4.41   |                                   |
| 8 Casing                    | OB Oil bore                       |
| 9 Distributing pipe         | OE Oil inlet                      |
| 10 Automatic filter 4.20    | SB Shearable overload protection  |
| 11 Flow sensor 4.54         | (predetermined breaking point)    |

## Scavenge Air Receiver

### 1. General

The scavenge air receiver 1 is fitted to the cylinder jacket 9 on the exhaust side. It is designed as a complete weldment consisting of receiver, turbocharger support, air duct, scavenge air cooler casing and underslung 4. The receiver is divided into two spaces 'VR' and 'RC' by a longitudinal wall 13. Air flaps 2 are fitted on the separating wall.

### 2. Function

When operating the turbocharger blows scavenge air via the air duct and cooler through the water separator in the underslung into pre-space 'VR' of the receiver. The scavenge air flows into the receiver space 'RC' through air flaps 2 and via openings in the cylinder jacket 9 to piston underside 'KU' and through scavenge ports into the cylinder, when the respective piston is near BDC. Air flaps 2 prevent back-flow into the pre-space 'VR' of the receiver.

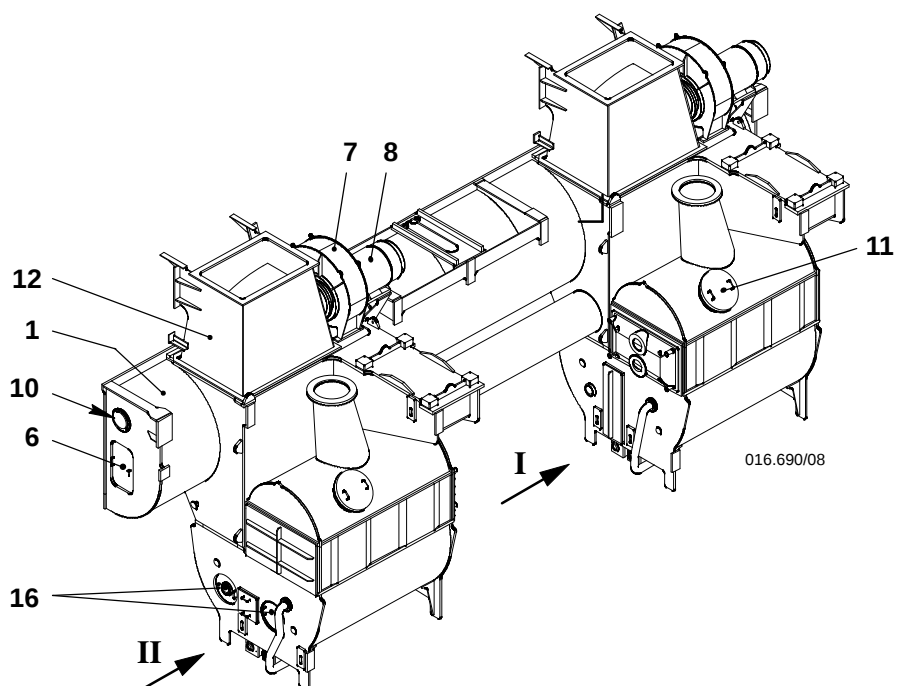
Two auxiliary blowers 7 are mounted on the upper receiver side. At the start of the engine or at low engine load the auxiliary blowers are switched on. They suck scavenge air from pre-space 'VR' via suction box 12 and deliver it into receiver space 'RC'. Air flaps 3 placed underneath the suction box prevent back-flow of the air when the auxiliary blowers are switched off.

Depending on number of cylinders a relief valve 10 is mounted at one or both end(s) of the scavenge air receiver. It opens when the air pressure rises above the admissible value in the receiver space 'RC'.

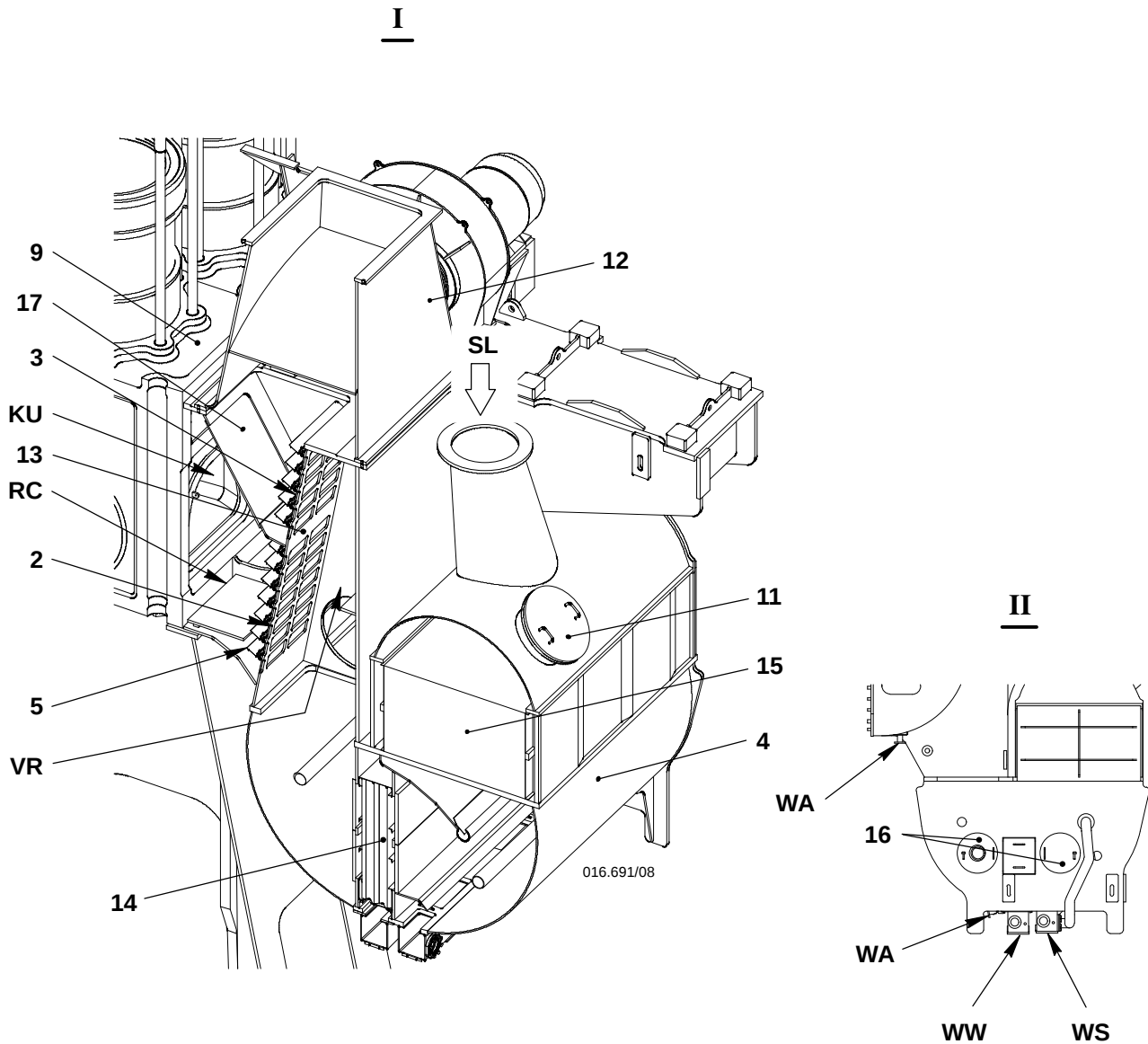
Access into the space 'RC' is possible through the hinged covers 6 **at engine standstill**. Part of the cylinder liner running surface, of the piston, and piston rings, and of the piston rod gland as well as of the air flaps 2 can be inspected from the receiver space 'RC'. The hinged covers 17 can be opened to examine air flaps 3.



**Remark:** Should the exhaust gas turbochargers be defective, covers 11 and 16 at the air duct and underslung must be opened for emergency operation (see Turbocharger Out of Service [0590-1](#)).



## Scavenge Air Receiver

**Key to Illustrations:**

- |                                                         |                                                                                           |
|---------------------------------------------------------|-------------------------------------------------------------------------------------------|
| 1 Scavenge air receiver                                 | 14 Water separator                                                                        |
| 2 Air flaps                                             | 15 Scavenge air cooler                                                                    |
| 3 Air flaps to auxiliary blower                         | 16 Cover                                                                                  |
| 4 Underslung                                            | 17 Hinged cover                                                                           |
| 5 Stop plate                                            |                                                                                           |
| 6 Hinged cover                                          |                                                                                           |
| 7 Auxiliary blower                                      | KU Piston underside                                                                       |
| 8 Electric motor                                        | RC Receiver space                                                                         |
| 9 Cylinder jacket                                       | SL Scavenge air from the exhaust gas turbocharger                                         |
| 10 Relief valve                                         | VR Pre-space                                                                              |
| 11 Cover                                                | WA Water drain from receiver (oleiferous)                                                 |
| 12 Suction box (fixed support for exhaust gas manifold) | WS Condensate after scavenge air cooler and dirty water from scavenge air cooler cleaning |
| 13 Longitudinal wall                                    | WW Water drain from water separator                                                       |

## Turbocharging

---

### 1. General

Turbochargers are exactly tuned to the engine depending on the number of cylinders, service output, mode of operation etc.

Indications on operation, maintenance and servicing are described in the respective documentation of the manufacturer (which is part of the Operating Manual). The cleaning of turbochargers in operation is described in [6510–1](#).

### 2. Function

Exhaust gas 'AG' from the cylinders is accumulated in the exhaust gas manifold 10, led to the turbine 12 of the TC and thereafter comes out to the environment through the ship-side exhaust system 'AP'. The exhaust gas rotates the turbine 12 which drives the compressor 11 mounted on the same shaft.

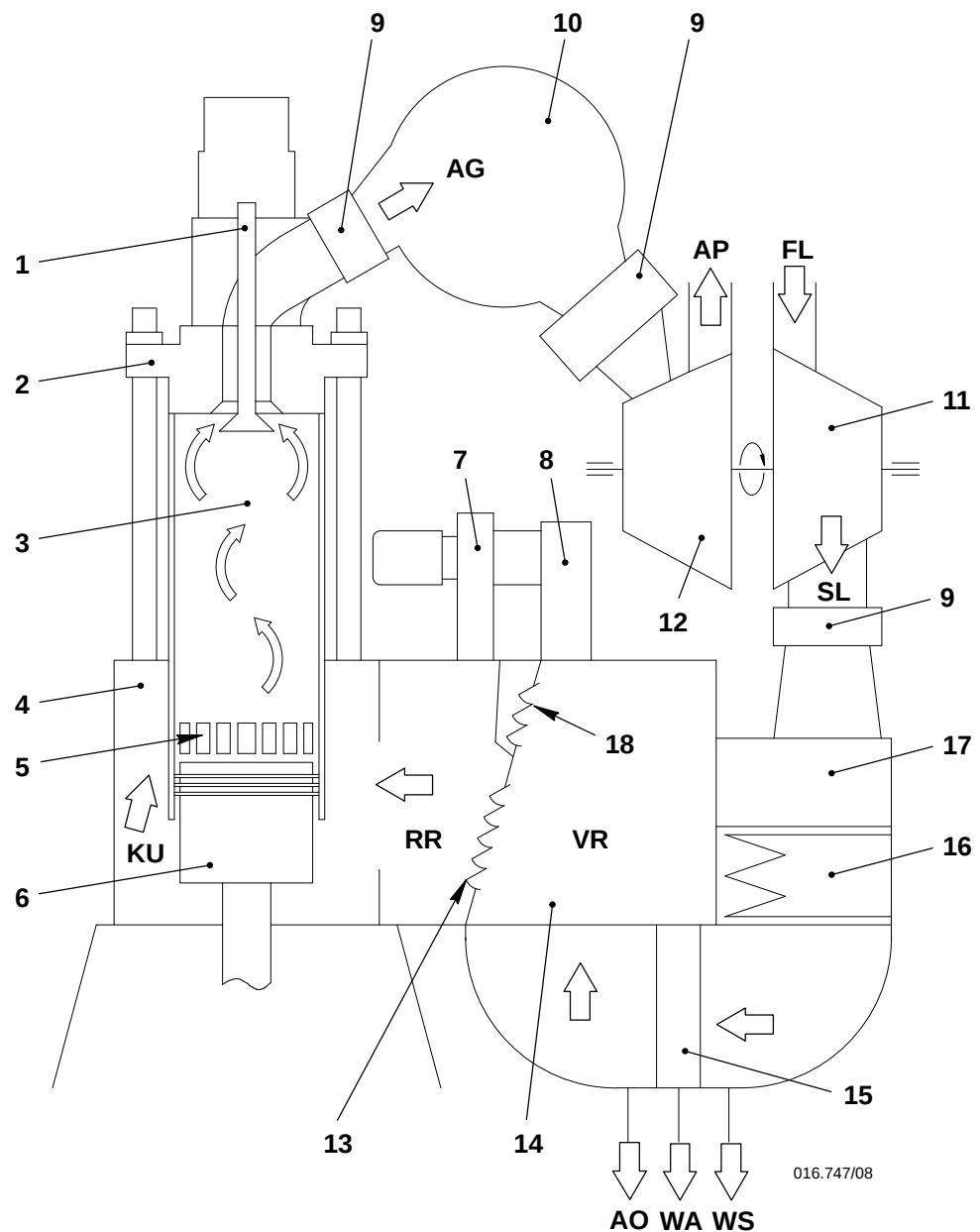
The compressor draws fresh air 'FL' from the engine room via a silencer and compresses it to a higher pressure (scavenge air pressure 'SL'). The scavenge air heated by the compression process is led via air duct 17 to the scavenge air cooler 16 which cools the air to a lower temperature range. Depending on the humidity in the air, the cooling action produces a considerable amount of condensate water which is separated in water separator 15 and drained off via several drains 'WA'.

The scavenge air passes from the receiver pre-space 'VR' to receiver space 'RR' through the air flaps 13 and then into the space 'KU' of the piston underside. When the piston 6 is near to BDC (inlet ports open) scavenge air flows into cylinder 3 through inlet ports 5.

After the compression, combustion, and expansion process, the exhaust valve 1 opens and exhaust gas 'AG' flows into the exhaust gas manifold 10, completing the cycle.

When starting the engine or in the case of low load operation, the auxiliary blower 7 supplies air into the receiver space 'RR'. Air flaps 13 and 18 prevent a back-flow of air (see also Scavenge Air Receiver [6420–1](#)).

## Turbocharging

**Key:**

- 1 Exhaust valve
- 2 Cylinder cover
- 3 Cylinder liner
- 4 Cylinder jacket
- 5 Inlet ports
- 6 Piston
- 7 Auxiliary blower
- 8 Air inlet casing
- 9 Expansion piece
- 10 Exhaust gas manifold
- 11 Compressor
- 12 Turbine
- 13 Air flaps
- 14 Receiver
- 15 Water separator

- 16 Scavenge air cooler
- 17 Charging module
- 18 Air flaps before auxiliary blower

- AG Exhaust gas after cylinder
- AO Oily-water drain
- AP Exhaust gas, outlet
- FL Fresh air
- KU Piston underside space
- RR Receiver space
- SL Scavenge air after blower (compressor)
- VR Receiver pre-space
- WA Water drain from water separator
- WS Condensate after scavenge air cooler

## Cleaning the Turbocharger in Operation

Turbocharger TPL Type

## Overview

|    |                                   |     |
|----|-----------------------------------|-----|
| 1. | General .....                     | 1/8 |
| 2. | Wash-cleaning of compressor ..... | 1/8 |
| 3. | Wash-cleaning of turbine .....    | 3/8 |
| 4. | Dry cleaning .....                | 6/8 |

## 1. General

The exhaust gas turbochargers are equipped with a washing arrangement. It is possible to clean the compressor and the turbine while the turbocharger is running. Periodic cleaning prevents or reduces contamination. This allows the intervals between overhauls to be considerably prolonged. If the dirt accumulation becomes excessive (scavenge air pressure drops and higher exhaust gas temperatures) the turbocharger must be dismantled for cleaning, whereby the instructions in the turbocharger manual must be followed (see Operating Data Sheet [0250–1](#) for admissible pressure drop).

The cleaning of the silencer must take place following visual judgement. This should, however, only be carried out with the engine at shut-down (see also turbocharger manufacturer's instructions).



**Remark:** The fouling on the air side can be limited to a minimum with an additional felt mattress installed on the top of the silencer (coarse filter).

Based on an increasing pressure difference  $\Delta p$  (of 50% compared to shop test value at same engine load) or discolouration of the filter mat, the felt must be changed and the dirt can be washed out.

The following devices i.e. methods are available for periodical cleaning:

- Wash-cleaning of compressor (wet cleaning)
- Wash-cleaning of turbine (wet cleaning at reduced engine load)
- Dry cleaning of turbine (at full service load)

2. Wash-cleaning of compressor (see [Fig. 'A'](#))**Cleaning intervals:**

Every 24 operating hours

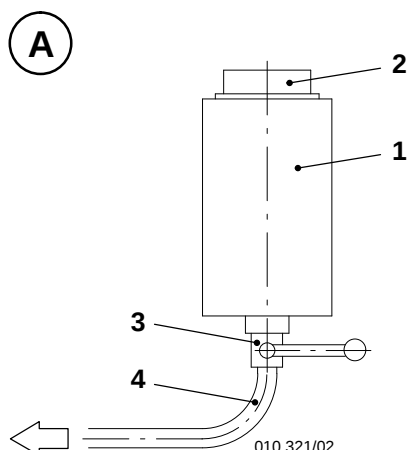
**Operating condition:**

The cleaning must take place when the engine is at working temperature and the load is as high as possible (full service load), i.e. at high turbocharger speed.

## Cleaning the Turbocharger in Operation

## Turbocharger TPL Type

## 2.1 Cleaning procedure



⇒ Open filling cap 2. Fill water container 1 with clean fresh water **(without cleaning agents)**.

- The water quantity is specified in the following table.

⇒ Close filling cap and open shut-off valve 3 for approx. three minutes.

⇒ Close shut-off valve and check, that all water has been sucked out.

⇒ Repeat the above procedure once.



**Remark:** With turbcharger TPL 85 repeat the above procedure once.

- The success of the cleaning operation can be evaluated by increased scavenge air pressure or by the lowering of the exhaust gas temperature.

**Key to Illustration: 'A'**

- 1 Water container
- 2 Filling cap
- 3 Shut-off valve
- 4 Water hose to compressor inlet

- When the compressor has been cleaned successfully in this manner, the engine should be kept operating under load for at least five minutes.



**Remark:** In dirty operating conditions the cleaning procedure can be repeated according to the following table.

Should the cleaning remain unsuccessful, we recommend to check and overhaul the turbocharger by an authorized ABB service company.

| Turbocharger<br>Type | Water quantity<br>[l] | Number of<br>cleaning cycles<br>max. |
|----------------------|-----------------------|--------------------------------------|
| TPL 80               | 3                     | 2                                    |
| TPL 85               | 3                     | 3                                    |

**3. Wash-cleaning of turbine (see Fig. 'B' to 'E')*****Cleaning intervals:***

Every 50 to 500 operating hours

**Guidance values**

- The cleaning interval depends upon environmental influences on the intake air and the extent of contamination of the turbocharger.
- The cleaning in service is best carried out on a routine basis. Regular wet cleaning is recommended, at first every 100 running hours (e.g. once a week). Depending on the contamination observed during turbocharger overhaul, the cleaning interval should be adapted accordingly.

***Operating condition:***

Engine power output must be reduced so that the exhaust gas temperature before the turbine is not higher or the scavenge air pressure is not lower than the limiting values mentioned below.

***Limiting values:***

- The temperature before the turbine should be **below 430 °C**.
- The scavenge air pressure should be **between 0.3–0.6 bar** prior to the turbine cleaning.
- The water pressure should be 1 bar **after shut-off valve 5** during water injection.

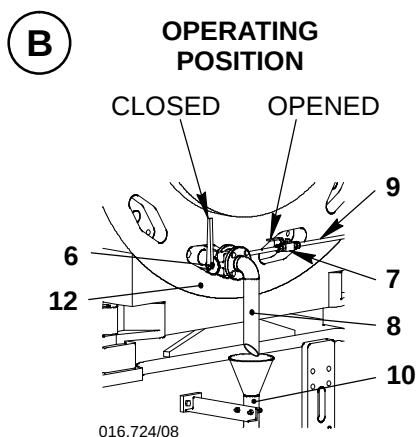
We recommend to wash the turbine at a scavenge air pressure of 0.4 bar (auxiliary blower in operation).

- Only clean fresh water **without** detergents or solvents is to be used for wet cleaning.
- Water supply must be min. 2 bar.
- If an SCR (Selective Catalytic Reduction) installation is fitted, the ammonia or urea injection must be stopped before the turbine is washed.
- After cleaning, the injection should only be restarted once the exhaust temperature before cleaning has been reached again.

## Cleaning the Turbocharger in Operation

## Turbocharger TPL Type

## 3.1 Cleaning procedure

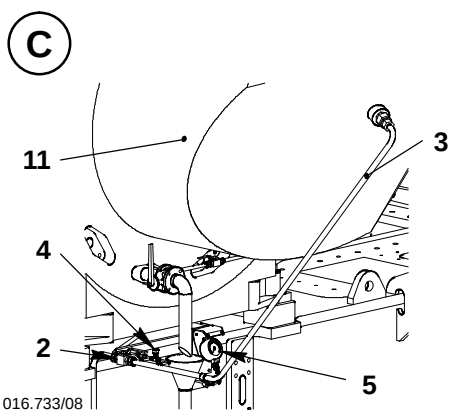
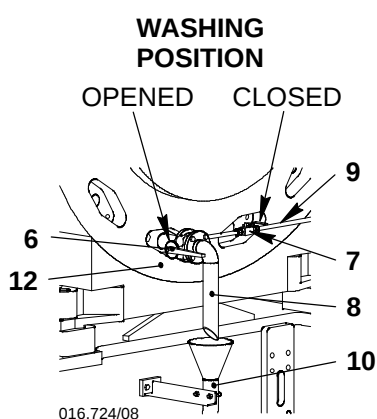


⇒ Open ball cock 6 in drain pipe 8 of gas outlet casing 12 and close ball cock 7 in tube for scavenge air 9 (WASHING POSITION). When the outlet is free, exhaust gas now flows from drain pipe 8. Should this not be the case, then the outlet must be freed. **Only then may the washing process be started!**

⇒ Reduce engine power till the required scavenge air pressure.

⇒ Before wet cleaning operate the engine at constant load for at least five minutes.

• Fresh water supply must be at hand till ball cock 2.



⇒ Open ball cock 2 slowly till pressure gauge 5 indicates 1.0 bar. Inject water for five minutes.



**Remark:** Discharge of water appears after about 2 to 3 minutes, but it may not necessarily appear.

**CHECK**

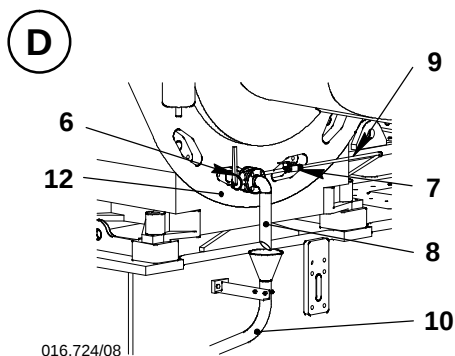
The lower turbocharger speed and lower exhaust gas temperature after turbocharger are signs whether enough water is being injected.



**Attention!** In cases of emergency (e.g. ship's safety), the engine load can be increased immediately during the washing procedure. However, the water supply is to be shut off immediately by means of ball cock 2.

⇒ Close ball cock 2.

⇒ When no more water flows out of drain pipe 8, close ball cock 6 again and reopen ball cock 7 (OPERATING POSITION).



## Cleaning the Turbocharger in Operation

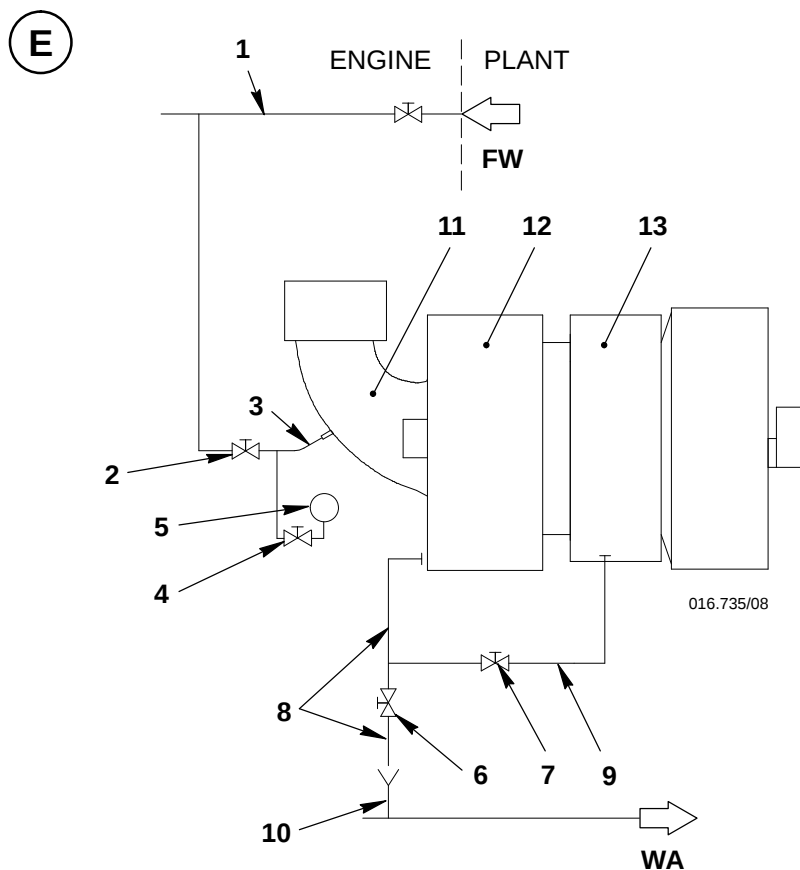
## Turbocharger TPL Type



**Remark:** On no account must the engine be shut down **immediately** after turbine washing. It should be operated for at least 10 minutes above 25% load in order to dry out the complete exhaust gas installation.

The cleaning should be repeated when the exhaust gas temperature after turbine is still too high at higher loads.

When no improvement in temperature behaviour is seen after three cleaning procedures, the turbocharger must be dismantled for cleaning, whereby the instructions in the Turbocharger Manual must be followed .



## Key to Illustrations:

- 'B' Ball cock positions (turbocharger wash-water outlet)  
 'C' Arrangement of wash-water inlet to turbocharger  
 'D' Arrangement of wash-water outlet from turbocharger  
 'E' Schematic diagram of turbocharger cleaning

- 1 Fresh water distributing pipe  
 2 Ball cock  
 3 Tube for water connection  
 4 Shut-off valve  
 5 Pressure gauge  
 6 Ball cock  
 7 Ball cock  
 8 Drain pipe

- 9 Tube for scavenge air  
 10 Drain pipe with funnel  
 11 Gas inlet casing  
 12 Gas outlet casing  
 13 Air outlet casing

FW Fresh water  
 WA Wash-water drain

## 4. Dry cleaning

Instead of water, dry solid particles in the form of granules are used for cleaning. A certain quantity of them, depending on the turbocharger size, is blown by compressed air into the exhaust pipe before the turbocharger.

The solid particles have a mechanical cleaning effect, possible deposits on nozzle ring and turbine blades being removed. However, since it is not possible to remove fairly thick deposits with the comparatively small quantity of solid particles required for each cleaning, this method has to be used more frequently.

This cleaning method has confirmed the excellent cleaning effect at exhaust gas temperatures over 500 °C before turbocharger.

### 4.1 Dry cleaning of turbine (see Fig. 'F' and 'G')

#### *Cleaning intervals:*

Every 24–48 operating hours

#### **Guidance values**

- The cleaning interval depends upon environmental influences on the intake air and the extent of contamination of the turbocharger.

#### *Operating conditions:*

The cleaning must take place when the engine is at working temperature and the load is as high as possible (full service load), i.e. at high turbocharger speed.

#### *Limiting values:*

- The scavenge air pressure should be above 0.5 bar.
- The required quantity of solid particles is shown in the following table.

| Turbocharger Type | Quantity [l] |
|-------------------|--------------|
| TPL 80            | 2.0          |
| TPL 85            | 3.0          |

### 4.2 Granulate specification

**Materials:** Hard, granulated materials, such as natural core granulates, softblast media or active charcoal particles.

**Mean grain size:** 1.2 to 2.0 mm

**Density:** max. 2.0 kg/dm<sup>3</sup>

**Storage:** Clean and dry area

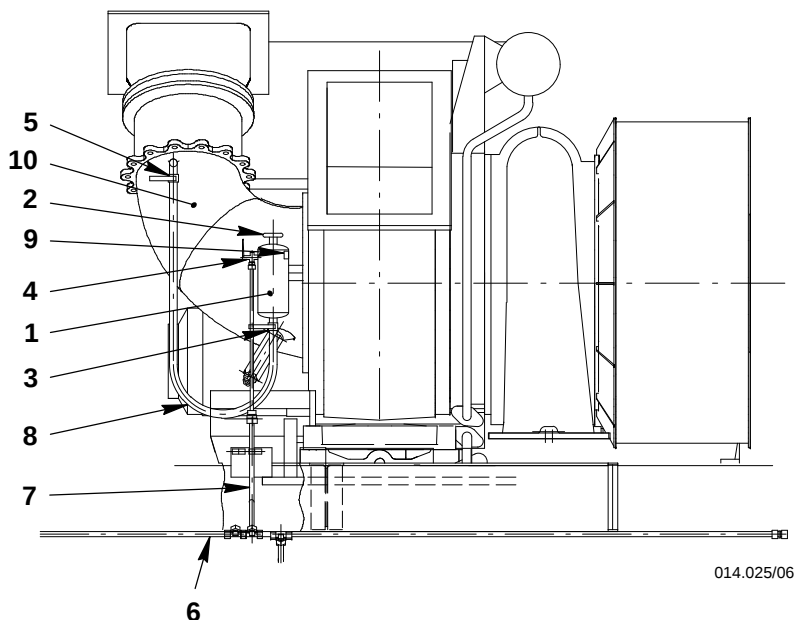
**Suppliers:** See documents of the turbocharger manufacturer



**Remark:** The dry cleaning plant must be blown through with compressed air prior to the proper cleaning (preparation). Therewith, possible collected deposits or condensate are being removed from the pipes.

### 4.3 Cleaning procedure

F



DRAWN FOR  
RT-flex84T-D

**Key to Illustrations:** 'F' Arrangement of dry cleaning plant  
'G' Schematic diagram

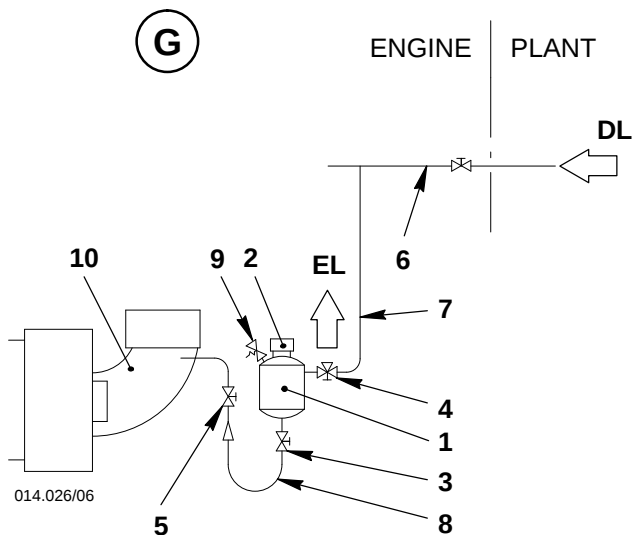
- |                                         |                     |
|-----------------------------------------|---------------------|
| 1 Pressure vessel                       | 8 Hose line         |
| 2 Closing cover                         | 9 Relief valve      |
| 3 Shut-off valve                        | 10 Gas inlet casing |
| 4 3-way valve for compressed air & vent |                     |
| 5 Shut-off valve                        |                     |
| 6 Compressed air distribution           | DL Compressed air   |
| 7 Compressed air supply pipe            | EL Vent             |

#### **Escaping residue:**

The granulate is burnt by the high exhaust temperatures and expelled together with finely removed dirt.



**Attention!** It may occur that during dry cleaning part of the blown-in solid particles escape through the chimney in singed condition.



**Initial position**, engine in normal operation (no cleaning procedure):

- 3-way valve 4 in position VESSEL VENTING.
- Shut-off valves 3 and 5 closed.
- Pressure vessel 1 empty and closed by means of closing cover 2.
- Compressed air must be at hand till 3-way valve 4.

**Cleaning procedure:**

## CHECK

Check whether shut-off valve 3 is closed and pressure vessel 1 is vented by means of 3-way valve 4.

- ⇒ Carefully loosen (a possible pressure is relieved) and remove closing cover 2 from pressure vessel 1.
- ⇒ Fill pressure vessel with the required quantity of granulates and close it again by means of the closing cover.
- ⇒ Open 3-way valve 4 (position vent 'EL' closed and passage to pressure vessel 1 open).
- ⇒ Open shut-off valves 5 and 3.
- The granulates are blown now into gas inlet casing 10 with compressed air.
- ⇒ Close shut-off valves 3 and 5 after about one minute (cleaning procedure is finished).
- ⇒ Close 3-way valve 4 (position vent 'EL' open and passage to pressure vessel 1 closed).



**Remark:** The cleaning should be repeated when the mean exhaust gas temperature after turbine is still too high at higher loads.

When no improvement in temperature behaviour is seen after three cleaning procedures, the turbocharger must be dismantled for cleaning, whereby the instructions in the Turbocharger Manual must be followed.

## Cleaning the Turbocharger in Operation

Turbocharger MET Type

## Overview

1. General ..... 1/5
2. Wash-cleaning of compressor ..... 1/5
3. Dry cleaning ..... 3/5

## 1. General

The exhaust gas turbochargers are equipped with a washing arrangement. It is possible to clean the compressor and the turbine while the turbocharger is running. Periodic cleaning prevents or reduces contamination. This allows the intervals between overhauls to be considerably prolonged. If the dirt accumulation becomes excessive (scavenge air pressure drops and higher exhaust gas temperatures) the turbocharger must be dismantled for cleaning, whereby the instructions in the turbocharger manual must be followed (see Operating Data Sheet 0250–1 for admissible pressure drop).

The cleaning of the silencer must take place following visual judgement. This should, however, only be carried out with the engine at shut-down (see also turbocharger manufacturer's instructions).



**Remark:** The fouling on the air side can be limited to a minimum with an additional felt mattress installed on the top of the silencer (coarse filter).

Based on the increase of the pressure difference ( $\Delta p$ ) to max. 10 mbar or discolouration of the filter mat, the felt must be changed and the dirt can be washed out.

The following devices i.e. methods are available for periodical cleaning:

- Wash-cleaning of compressor (wet cleaning)
- Dry cleaning of turbine (at full service load)

## 2. Wash-cleaning of compressor (see Fig. 'A')

**Cleaning intervals:**

Approx. 100 operating hours

**Guidance values**

- The cleaning interval depends upon environmental influences on the intake air and the extent of contamination of the turbocharger.

**Operating condition:**

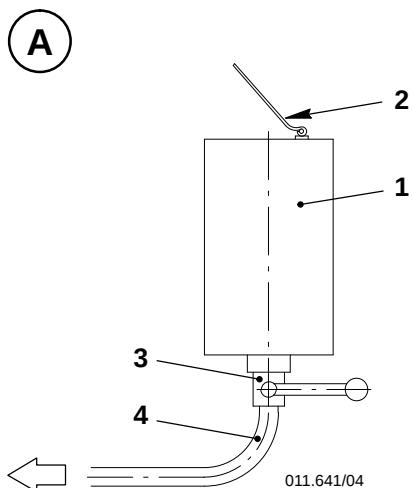
The cleaning must take place at reduced engine power (< 50% load), i.e. at lower turbocharger speed as shown in the following table:

| Turbocharger |                   | Water quantity<br>[l] | Injection time<br>[Sec.] |
|--------------|-------------------|-----------------------|--------------------------|
| Type         | Speed [rpm]       |                       |                          |
| MET 66MA     | approx. 5500–7500 | 2.5                   | approx. 50–100           |
| MET 71MA     | approx. 5000–7000 | 2.75                  | approx. 55–110           |
| MET 83MA     | approx. 4500–6000 | 3.0                   | approx. 60–120           |

## Cleaning the Turbocharger in Operation

## Turbocharger MET Type

## 2.1 Cleaning procedure

**CHECK**

- ⇒ Reduce engine power till the required turbocharger speed.
- Before wash-cleaning operate the engine at constant load for at least five minutes.
- CHECK** Check whether the screen is not clogged in the water container!
- ⇒ Open hinged cover 2. Fill water container 1 with clean fresh water (**without cleaning agents**).
- The water quantity is specified in the table.
- ⇒ Close hinged cover and open shut-off valve 3 for approx. 50–100 seconds.
- ⇒ Close shut-off valve 3 and check whether all water has been sucked of the container.
- The success of the cleaning operation can be evaluated by increased scavenge air pressure or by the lowering of the exhaust gas temperature.

**Key to Illustration: 'A'**

- 1 Water container
- 2 Hinged cover
- 3 Shut-off valve
- 4 Water hose to compressor inlet

- When the compressor has been cleaned successfully in this manner, the engine should be kept operating under load for at least 5 minutes.

### 3. Dry cleaning

Dry solid particles in form of granules are used for cleaning. A certain quantity of them, depending on turbocharger size, is blown by compressed air into the exhaust pipe before the turbocharger.

The solid particles have a mechanical cleaning effect, possible deposits on nozzle ring and turbine blades being removed. However, since it is not possible to remove fairly thick deposits with the comparatively small quantity of solid particles required for each cleaning, this method has to be used more frequently.

This cleaning method has confirmed the excellent cleaning effect at exhaust gas temperatures over 500 °C before turbocharger.

#### 3.1 Dry cleaning of turbine (see Fig. 'B' and 'C')

##### *Cleaning intervals:*

Every 100 operating hours

##### **Guidance values**

- The cleaning interval depends upon environmental influences on the intake air and the extent of contamination of the turbocharger.
- The cleaning in service is best carried out on a routine basis. Regular cleaning is recommended, at first every 100 running hours (e.g. once a week). Depending on the contamination observed during turbocharger overhaul, the cleaning interval should be adapted accordingly.

##### *Operating conditions:*

- The cleaning must take place when the engine is at working temperature and the load is as high as possible (full service load), i.e. at high turbocharger speed.

##### *Limiting values:*

- The scavenge air pressure must be above 0.5 bar.
- The maximum turbocharger speed and required quantity of solid particles for the corresponding turbocharger type is shown in the following table:

| Turbocharger |             | Quantity<br>[l] |
|--------------|-------------|-----------------|
| Type         | Speed [rpm] |                 |
| MET 66MA     | max. 11 900 | 2.6             |
| MET 71MA     | max. 11 000 | 3.0             |
| MET 83MA     | max. 9 400  | 3.5             |

#### 3.2 Granulate specification

|                        |                                                                                     |
|------------------------|-------------------------------------------------------------------------------------|
| <b>Materials:</b>      | Hard, granulated materials, such as milled walnut shell or grain (rice, wheat etc.) |
| <b>Mean corn size:</b> | 2.0 to 2.8 mm (grain diameter within 3 mm)                                          |
| <b>Storage:</b>        | Clean and dry area                                                                  |
| <b>Suppliers:</b>      | See documents of the turbocharger manufacturer                                      |

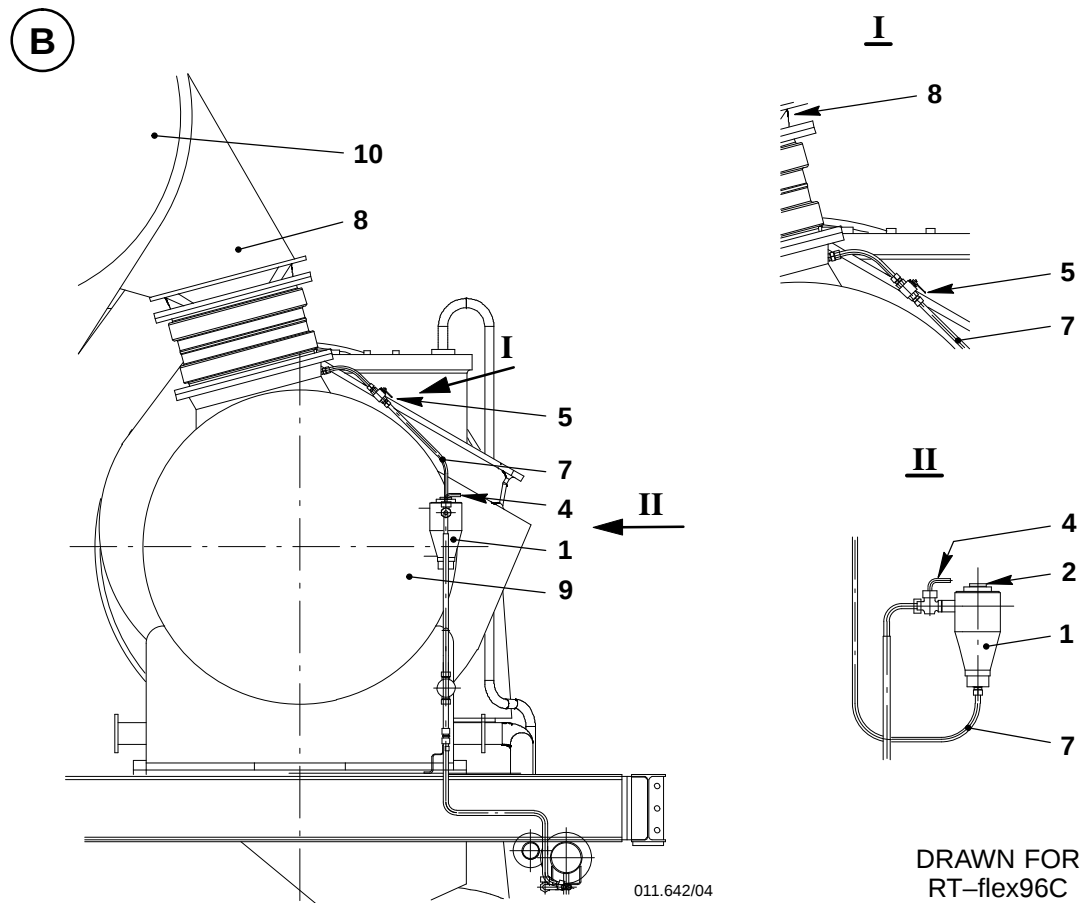


**Remark:** The dry cleaning device must be blown through with compressed air prior to the proper cleaning (preparation). Therewith, possible collected deposits or condensate are being removed from the pipes and the device cooled down.

## Cleaning the Turbocharger in Operation

## Turbocharger MET Type

## 3.3 Cleaning procedure



**Key to Illustrations:** 'B' Arrangement of dry cleaning device  
'C' Schematic presentation

- |                               |                                    |
|-------------------------------|------------------------------------|
| 1 Pressure vessel             | 7 Cleaning pipe                    |
| 2 Closing nut                 | 8 Exhaust pipe before turbocharger |
| 3 Shut-off valve              | 9 Gas inlet casing                 |
| 4 Shut-off valve              | 10 Exhaust gas manifold            |
| 5 Shut-off valve              |                                    |
| 6 Compressed air distribution | DL Compressed air                  |

**Escaping residue:**

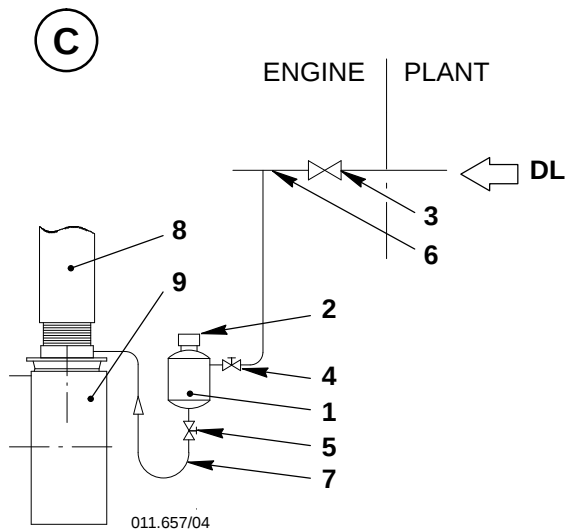
The granulate is burnt by the high exhaust temperatures and expelled together with finely removed dirt.



**Attention!** It may occur that during dry cleaning part of the blown-in solid particles escape through the chimney in singed condition.

## Cleaning the Turbocharger in Operation

## Turbocharger MET Type



**Initial position, engine in normal operation (no cleaning procedure):**

- Shut-off valves 4 and 5 closed.
- Pressure vessel 1 empty and closed by means of closing nut 2.
- Compressed air must be at hand till shut-off valve 4.

**Blow through (preparation):**

- ⇒ Open shut-off valves 4 and 5.
- ⇒ Close shut-off valves 5 and 4 after about two minutes (blow-through is finished).

**Cleaning procedure:**

- ⇒ Carefully loosen (a possible pressure is relieved) and remove closing nut 2 from pressure vessel 1.
- ⇒ Fill pressure vessel with the required quantity of granulates and close it again by means of the closing nut.
- ⇒ Open shut-off valves 4 and 5.
- The granulates are blown now into the exhaust pipe 8 with compressed air.
- ⇒ Close shut-off valves 5 and 4 after about two minutes (cleaning procedure is finished).



**Remark:** The cleaning should be repeated when the mean exhaust gas temperature after turbine is still too high at higher loads.

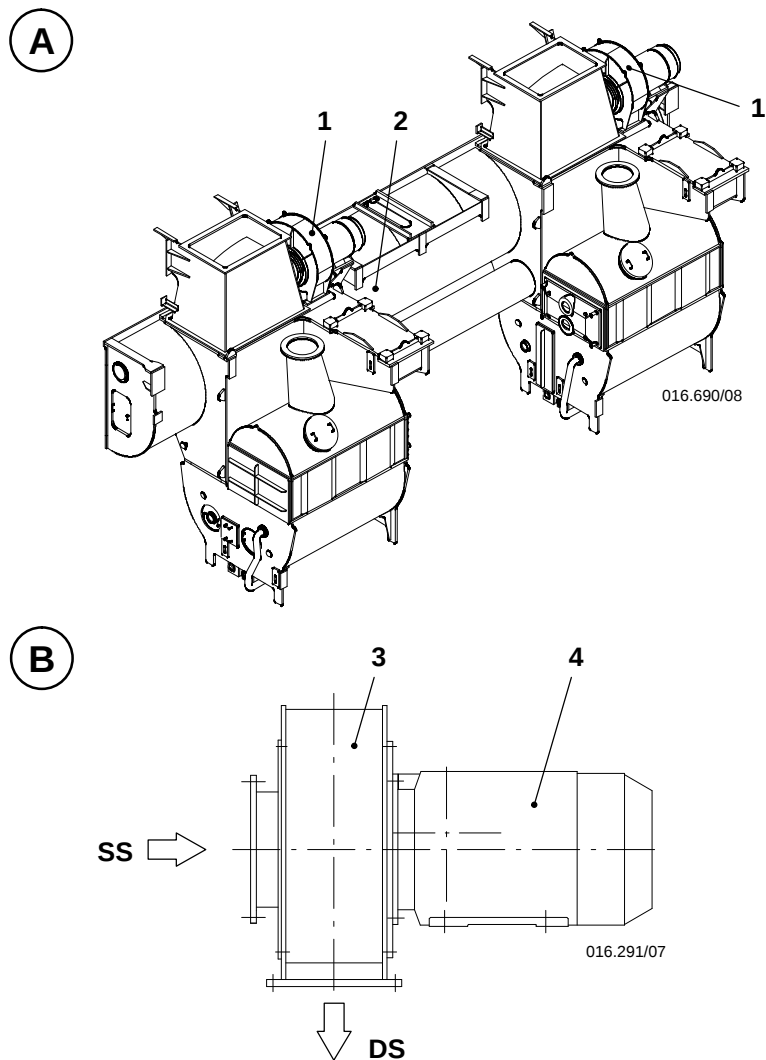
When no improvement in temperature behaviour is seen after three cleaning procedures, the turbocharger must be dismantled for cleaning, whereby the instructions in the Turbocharger Manual must be followed.



## Auxiliary Blower and Switch Box

### 1. Auxiliary blower

The auxiliary blowers 3 driven by electric motors 4 are mounted to the upper receiver side 2. They supply air from the receiver pre-space via suction casing into the receiver space during the start and operation at low load. Back-flow to the receiver, of the air blown in by the auxiliary blowers, is prevented by air flaps (see Scavenge Air Cooler [6420-1](#)).



**Key to Illustrations:** 'A' Arrangement of auxiliary blower  
'B' Auxiliary blower

- 1 Auxiliary blower right hand design
- 2 Receiver
- 3 Blower
- 4 Electric motor

DS Pressure side  
SS Suction side

## Auxiliary Blower and Switch Box

## 2. Switch box

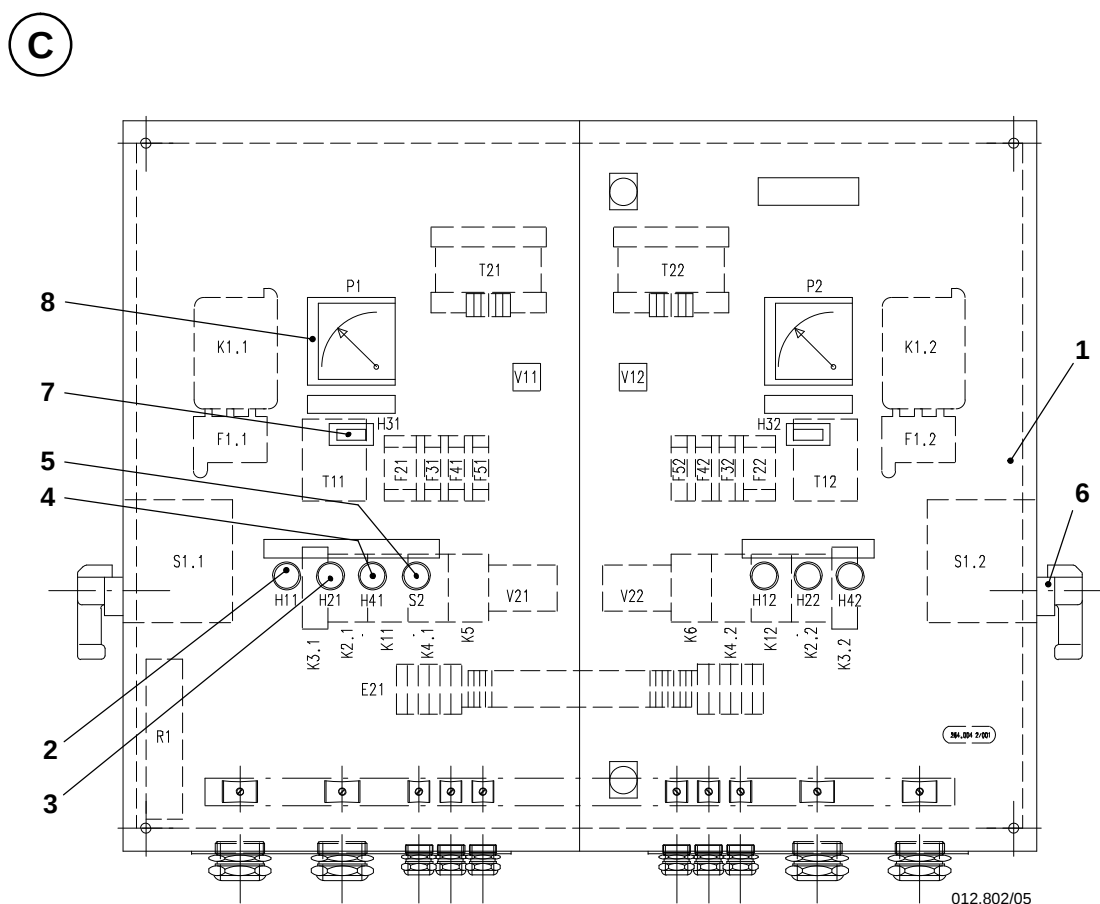
For each auxiliary blower an electrical switch box 1 is provided and supplied by the engine builder.

**Operating function:**

Pressing e.g. START AHEAD button, the 1<sup>st</sup> auxiliary blower starts immediately and all other auxiliary blowers start with approx. 4–6 seconds delay, provided that electric supply is switched by the main switch 6 (the voltage indication 2 is lit).

When the exhaust gas turbochargers produce a pressure of 0.45 bar in the receiver, the auxiliary blowers are cut off.

Should the scavenge air pressure sink below 0.35 bar, the auxiliary blowers are again switched on.

**Key to Illustration: 'C' Switch box (example)**

- |                      |                                  |
|----------------------|----------------------------------|
| 1 Switch box         | 5 Lamp test                      |
| 2 Voltage indicator  | 6 Main switch                    |
| 3 Service indicator  | 7 Hour counter                   |
| 4 Overload indicator | 8 Amperage indicating instrument |

## Scavenge Air Cooler

### Operating Instructions and Cleaning

---

#### 1. General

After each exhaust gas turbocharger a scavenge air cooler (SAC for short) is installed, whose purpose is cooling the compressed and thereby heated scavenge air before it gets to the cylinders via water separator and scavenge air receiver. The standard cooler is a single-stage multi-pass cooler. The cooling water flows through the cooler in various water passes in the opposite direction of the air flow. It enters the cooler at 'KE', flows through it in various directions, and leaves at 'KA'. The temperature difference water / scavenge air is thus distributed equally along the whole cooler.

#### 2. Operating instructions

As accumulated air in the cooling water system of the scavenge air cooler can lead to operating troubles on the engine and to damage of the SAC, proper functioning of the SAC venting must be ensured.

The scavenge air cooler temperature must be checked periodically in accordance with data in Operating Data Sheet [0250–1](#).

Should an alarm be triggered in operation by level switch 19 for the condensate collector 17, it must be investigated whether the water is condensate water or scavenge air cooling water. Should the latter be the case, then the cooler must be dismantled and repaired (see Maintenance Manual [6606–1](#)).

To prevent damage to the SAC, the correct cooling water flow must be maintained in operation. The flow of cooling water must not be throttled at partial load nor during manoeuvring.



**Remark:** The butterfly valves at the cooling water inlet and outlet pipes must not be used for controlling the flow rate, otherwise the water separators (plastic) could be damaged due to too high scavenge air temperatures at higher loads.

Concerning operation with a defective scavenge air cooler, recommendations can be found in [0550–1](#).

As a guide to proper functioning of the SAC, the temperature difference between scavenge air outlet and cooling water inlet at the SAC can be taken as a basis. The two temperature values have to be checked periodically. If the difference increases while engine load and cooling water flow remain unchanged, it is a sign of increasing fouling of the SAC.

If the **fouling is on the water side** of the SAC, the scavenge air temperature increases.

If the **fouling is on the air side**, the pressure difference ( $\Delta p$ ) of the scavenge air through the SAC increases. This does not show the full effect of the fouling because an increased resistance also causes a reduced air throughput from the turbocharger (pay attention to limiting values). More detailed indications for the monitoring of the SAC in operation are given in Operating Data Sheet [0250–1](#).

Higher scavenge air temperature and reduced air flows both lead to increased thermal loading of the engine and to higher exhaust gas temperatures.

Air side cleaning of the SAC can be carried out on the running engine. The water side can only be cleaned at standstill. The procedure on engine at standstill is described in [6606–1](#) of the Maintenance Manual.

## Operating Instructions and Cleaning

### 3. Air side cleaning of the SAC in service

The equipment necessary for air side cleaning of the SAC is installed on the engine (see Fig. 'A').

#### 3.1 Cleaning intervals

At the beginning we recommend to clean the SAC weekly. If there is no change in the pressure difference ( $\Delta p$ ) through the SAC, the cleaning interval can be increased (e.g. monthly).

Furthermore, take into account that the pressure difference may not exceed the maximum limit ( $\Delta p$  increase of 50% compared to shop test value at same engine load) (see also Maintenance Manual [0380-1](#)).

The degree of SAC contamination depends to a major extent on the condition of the intake air and the maintenance of the air suction filter on the turbocharger.

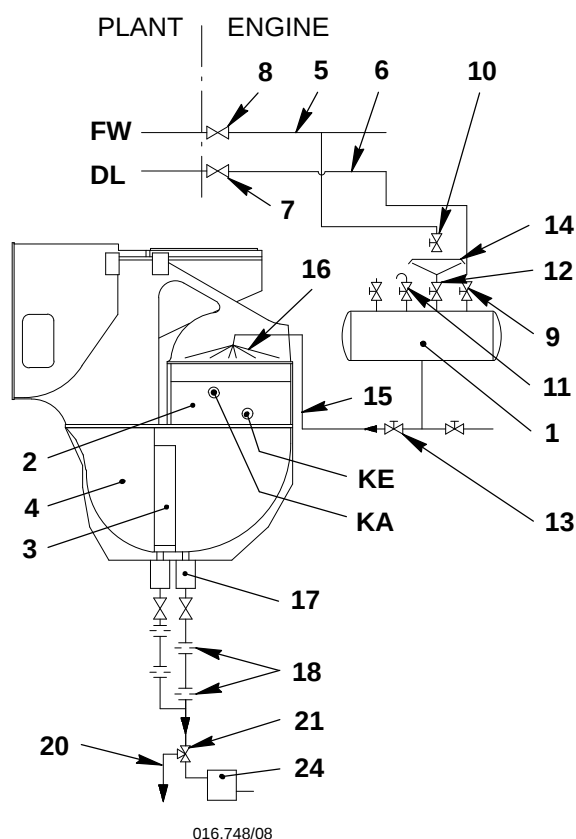


**Remark:** If possible no cooler cleaning should be carried out under tropical condition (increased condensate).

#### 3.2 Cleaning procedure

The cleaning should be carried out with the engine operating at partial load, i.e. below 50% load (see also instruction panel on the engine). The air temperature after compressor (turbocharger) must not be much above 100 °C as otherwise too much of the cleaning agent will vaporize.

A



⇒ Reduce engine power to mentioned values.

- Compressed air and fresh water must be available at shut-off valves 9 and 10.

⇒ Open shut-off valves 11 (vent) and 12.

⇒ Open slowly shut-off valve 10, fill fresh water and add the **specified quantity of cleaning fluid** (see paragraph 'Cleaning agent') into the container 1 (max. 20 litres) through filling funnel 14.



**Remark:** Cleaning fluid diluted with fresh water can also be filled into the funnel using a can. In this case shut-off valve 10 remains **closed**.

- Open shut-off valve 10 as much as to avoid a reflux of fresh water into the filling funnel.

⇒ Close shut-off valves 12 and 11.

⇒ Open shut-off valve 9 and ball valve 13 on the container, by which the content is sprayed through the spray nozzles 16 within about one minute.

⇒ Change over 3-way ball valve 21 and drain wash-water (see also [8345-1](#) 'Condensate drain').

⇒ Close shut-off valve 9 and ball valve 13.

⇒ Open shut-off valve 11 till container is vented.

⇒ Change over 3-way ball valve 21 to NORMAL OPERATION (see also [8345-1](#) 'Condensate drain').

⇒ Repeat the same procedure after about 10 minutes, **but add no cleaning fluid**.

- With this the cleaning process is terminated.

## Operating Instructions and Cleaning

---



**Remark:** As dirt loosened from the cooling fins might collect in the water separator elements or in the scavenge air receiver 4, they must occasionally be checked and cleaned out (see [Maintenance Manual](#)).

### 3.3 Cleaning agent

In principle only products from reputable firms should be utilized, their instructions concerning mixing ratio etc. have to be followed in detail.

For in-service cleaning, only such cleaning agents which have a sufficiently high flash point may be used. The cleaning fluid must be diluted with fresh water in accordance with the supplier's instructions.

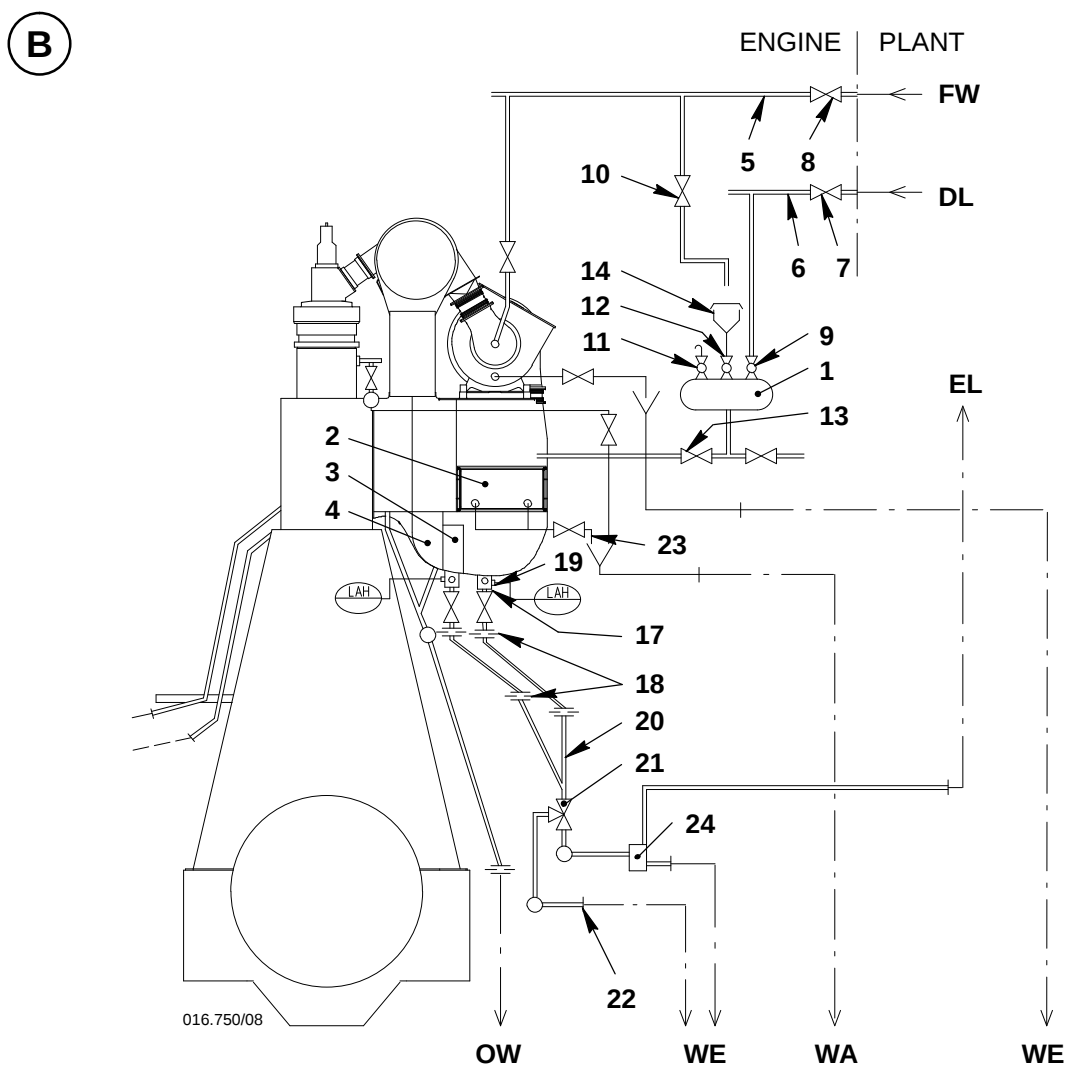


**Remark:** Detailed instructions on operation, maintenance and repair of scavenge air coolers are given in the Instruction Leaflet issued separately by the cooler manufacturer.

It is practical to obtain these Instruction Leaflets directly from the makers. It is also possible to order such Instruction Leaflets from the engine manufacturer or supplier. The following information must be given on request:

- Engine type and No.
- Engine supplier
- Cooler manufacturer and type
- Required language

## Operating Instructions and Cleaning



## Key to Illustrations:

'A' Schematic arrangement of washing plant

'B' Arrangement of washing water system on engine

- |                                    |                                             |
|------------------------------------|---------------------------------------------|
| 1 Container                        | 18 Throttling disc                          |
| 2 Scavenge air cooler              | 19 Level switch                             |
| 3 Water separator                  | 20 Condensate and wash-water drain          |
| 4 Receiver                         | 21 3-way ball valve                         |
| 5 Fresh water distributing pipe    | 22 Cleaning fluid and wash-water drain      |
| 6 Compressed air distributing pipe | 23 SAC drain                                |
| 7 Ball valve                       | 24 Venting unit                             |
| 8 Ball valve                       |                                             |
| 9 Shut-off valve                   |                                             |
| 10 Shut-off valve                  | DL Compressed air from board system 7–8 bar |
| 11 Shut-off valve (vent)           | EL Vent                                     |
| 12 Shut-off valve                  | FW Fresh water 2.5 bar                      |
| 13 Ball valve                      | KA Cooling water outlet                     |
| 14 Filling funnel                  | KE Cooling water inlet                      |
| 15 Distributing tube               | OW Drain to sludge water tank (oleiferous)  |
| 16 Spray nozzle                    | WA Drain to water drain tank                |
| 17 Condensate collector            | WE Drain to bilge water tank                |

## Cylinder Lubrication

---

### Overview

|    |                                                       |       |
|----|-------------------------------------------------------|-------|
| 1. | General .....                                         | 1/14  |
| 2. | Description of cylinder lubricating system .....      | 1/14  |
| 3. | Lubricating oil filter and measurement tube .....     | 3/14  |
| 4. | Lubricating pump .....                                | 6/14  |
| 5. | ALM-20 module (control unit) .....                    | 10/14 |
| 6. | Lubricating quill .....                               | 11/14 |
| 7. | Additional lubrication of exhaust valve spindle ..... | 12/14 |
| 8. | Control of cylinder lubricating system .....          | 13/14 |

### 1. General

The lubrication of the cylinder liners and pistons as well as of the exhaust valve spindle is performed by a separate lubricating system. The feed rate of cylinder lubricating oil to each lubricating point can be adjusted and is load-dependent controlled via the engine control system WECS-9520.

#### 1.1 Cylinder lubricating oil

Under normal operating conditions, a high-additive, alkaline cylinder lubricating oil is required. The alkalinity of the lubricating oil must be chosen with regard to the sulphur content of the fuel (see Lubricating Oils 0750-1).

#### 1.2 Cylinder lubricating oil for running-in

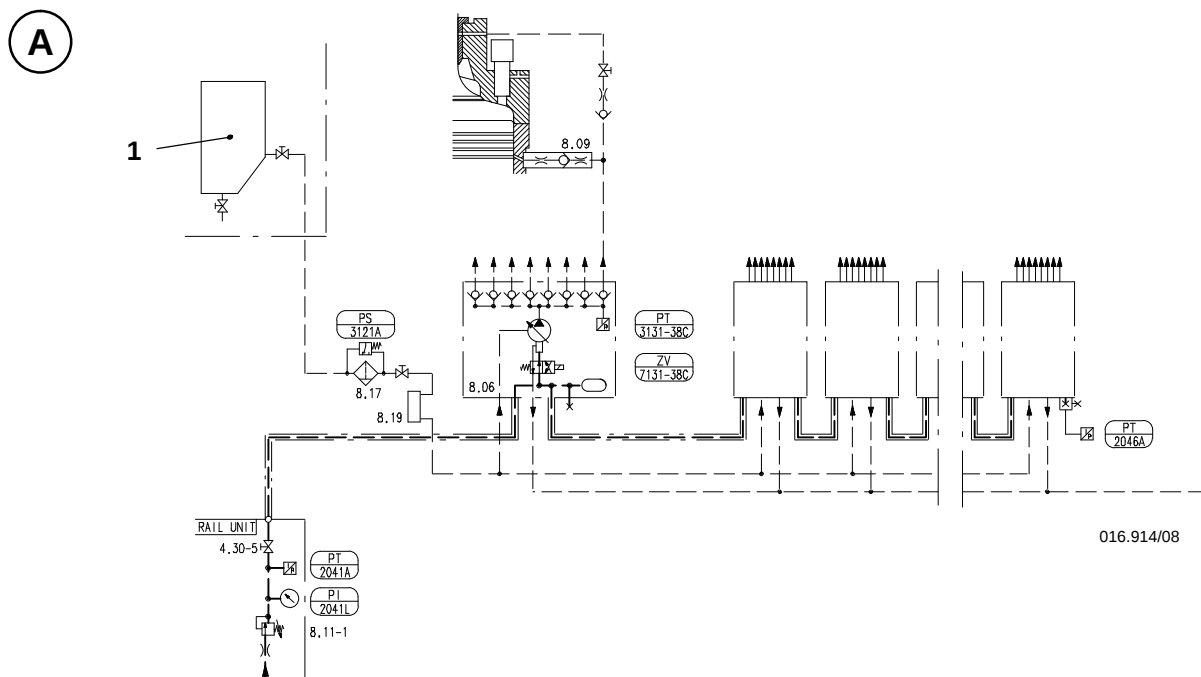
**For running-in we recommend the use of approved normal cylinder lubricating oil** (see Running-in of New Cylinder Liners and Piston Rings 0410-1).

### 2. Description of cylinder lubricating system

The diagram Fig. 'A' illustrates the complete system which consists of the following components:

- Daily service tank 1 for cylinder lubricating oil ... (plant side)
- Lubricating oil filter 8.17 ..... (one per engine)
- Lubricating pump 8.06 ..... (one per cylinder)
  - Control unit ALM-20
  - 4/2-way solenoid valve
  - Pressure transmitter
- Lubricating quill 8.09 with non-return valve ..... (eight per cylinder)
- Controlling of the system via the engine control system WECS-9520 (see 4002-1 'Cylinder lubricating system control')

## Cylinder Lubrication



### 2.1 Daily service tank (plant side)

The daily service tank 1 for the cylinder lubricating oil must be placed at a certain height above the engine, allowing the oil to flow down by static pressure via supply pipe and lubricating oil filter 8.17 to lubricating pumps 8.06.

### 2.2 Arrangement of lubricating pumps (Fig. 'B')

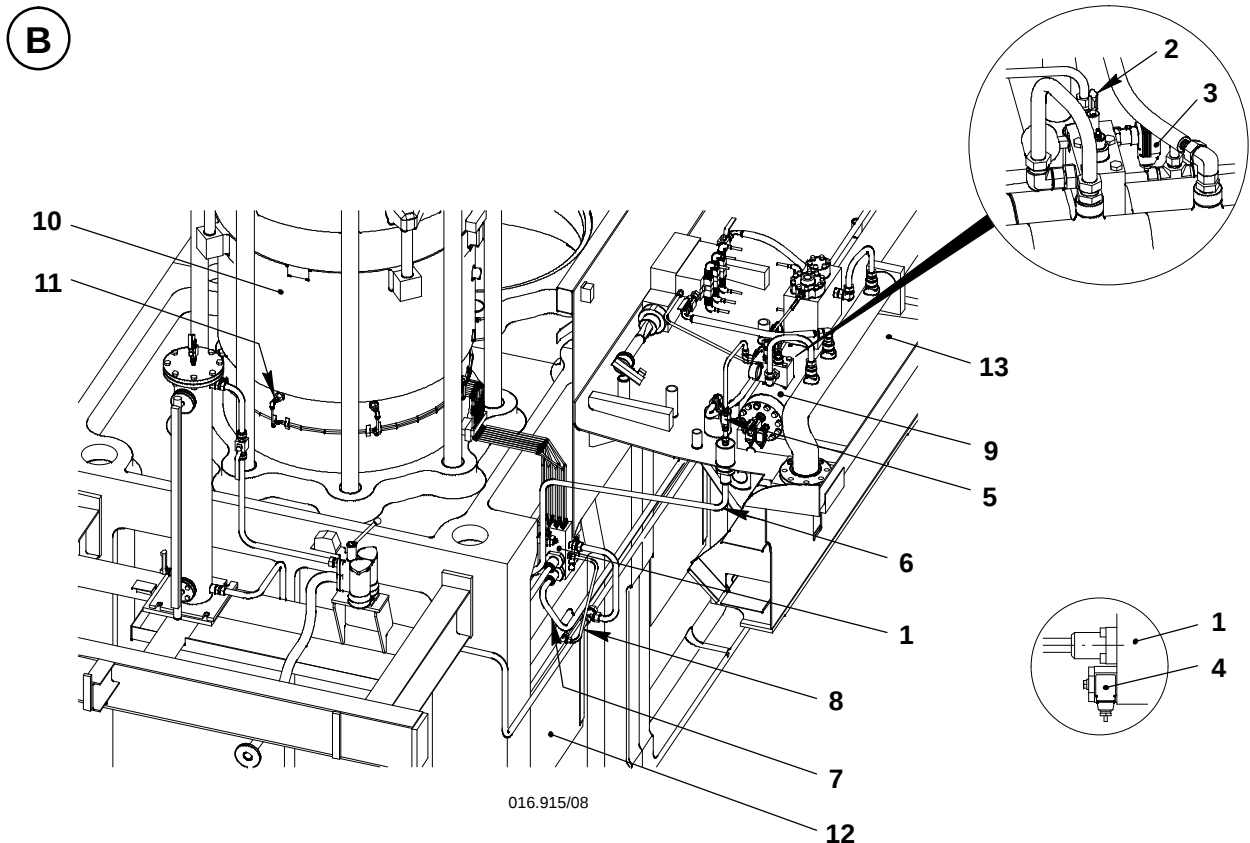
For each cylinder there is one lubricating pump 1 designed as a compact self-supporting unit and fastened to cylinder jacket 12 on fuel side by means of a support.

The lubricating pumps are driven by servo oil when the corresponding control signal is released via the engine control system WECS-9520. All lubricating pumps are connected to servo oil connecting pipes 7 (loop piping).

The pressure of the branched off servo oil (from servo oil rail at free end) is reduced to 60 bar by means of pressure reducing valve 2. For safety reasons, servo oil pipes 6 and 7 to the lubricating pumps are designed double-walled. Leakages (e.g. breakage of the inner HP piping) are monitored by pressure transmitter 4 and then an alarm is triggered in the alarm and monitoring system (see Fig. 'B'). Such problems can also be recognized visually by opening screw plug 10 (max. two turns) on the last lubricating pump(s) (see Fig. 'E').

For 9 to 12 cylinder engines a further oil supply from the servo oil rail at the driving end ensures the servo oil supply to the lubricating pumps (see also Control Diagram 4003-2).

## Cylinder Lubrication

**Key to Illustration: 'B' Arrangement of lubricating pumps**

- |                                  |                         |
|----------------------------------|-------------------------|
| 1 Lubricating pump 8.06          | 8 Servo oil return pipe |
| 2 Pressure reducing valve 8.11-1 | 9 Servo oil rail 4.11   |
| 3 Pressure transmitter PT2041A   | 10 Water guide jacket   |
| 4 Pressure transmitter PT2046A   | 11 Lubricating quill    |
| 5 Stop valve 4.30-5              | 12 Cylinder jacket      |
| 6 Servo oil pipe                 | 13 Rail unit            |
| 7 Servo oil connecting pipe      |                         |

**3. Lubricating oil filter and measurement tube (Fig. 'C')**

The lubricating oil filter (filter for short) 1 and measurement tube 4 are installed before the lubricating oil distribution to the lubricating pumps. The fouling factor is monitored by differential-pressure sensor 5 built-on the filter system. When exceeding the limited value an alarm is triggered in the alarm and monitoring system. In this case the fouled filter element must be exchanged (see [paragraph 3.2](#)).

**3.1 Venting the filter**

The filter is to be vented:

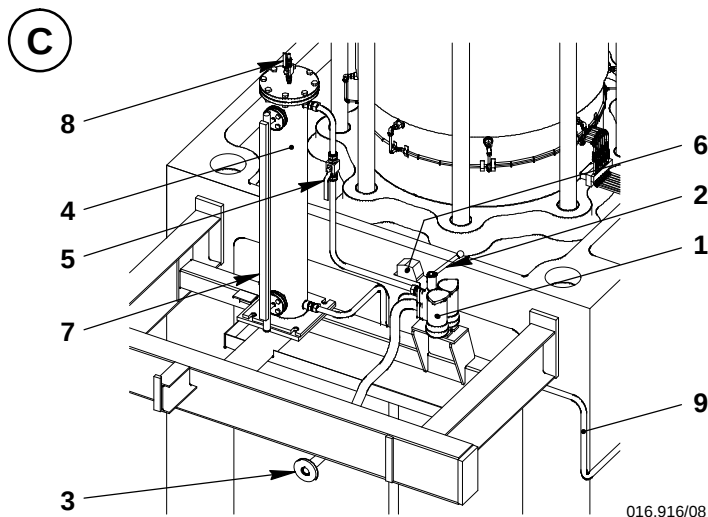
- by the first commissioning
- after changing filter elements

## Cylinder Lubrication

## 3.2 Exchange of filter element

Exchanging of fouled filter elements can be carried out during operation, without interruption of the oil flow to the lubricating pumps.

⇒ Change over lever 2 on lubricating (double) oil filter 1 and replace fouled filter element.



## Key to Illustration: 'C'

## Filter and measurement tube

- 1 Lubricating oil filter 8.17
- 2 Lever
- 3 Supply pipe
- 4 Measurement tube 8.19
- 5 Ball valve
- 6 Differential-pressure sensor PS3121A
- 7 Measurement tube with scale
- 8 Venting cock
- 9 Distributing pipe

## 3.3 Measurement of consumption at measurement tube

Thanks to an integrated magnetic level indicator and scale 7 it is possible to measure the lubricating oil consumption.

Using the operator interface, the (theoretical) specific feed rate is set with determined parameters in the engine control system WECS-9520.

To verify the settings and the proper functions of the components in the cylinder lubricating system, a measurement of the consumption can be carried out using the measurement tube 4.



**Remark:** The lubricating oil level should never drop below the mark (1) on scale as otherwise air can get into the system and cause malfunctions.

**Procedure:**

- ⇒ Close ball valve 5.
- ⇒ Open venting cock 8.
- ⇒ Start time measurement as soon as the oil level appears on scale 7 and mark this position.
- ⇒ After a determined measuring time (15 to 20 minutes) stop measuring and mark again the oil level.
- ⇒ Reopen ball valve 5.
- ⇒ Keep venting cock 8 open till oil flows bubble-free, then close it.
- ⇒ Determine the consumed oil quantity in litres by reading the distance between the two marks by applying the relevant conversion factor (1 cm = 0.196 l).



**Remark:** The conversion factor depends on the size of the measurement tube and furthermore pay attention to the marking (lettering) on the latter.

The actual feed rate can be subsequently determined (see Instructions Concerning Measurement of Cylinder Lubricating oil Consumption [7218-2](#)).

## Cylinder Lubrication

**4. Lubricating pump****4.1 General**

The modular design of the lubricating pump refers to the possibility of quickly replacing main components while the engine is running. The unit consists basically of: Pump body 1, baseplate 2, 4/2-way solenoid valve 3 and accumulator 4.

ALM-20 module (control unit) is located nearby the lubricating pump.



**Remark:** If a lubricating pump fails and a slow-down is released by the safety system, the fuel injection of the relevant cylinder must be cut out (see [0510-1](#) 'Measures').

**Baseplate:**

Baseplate 2 carries the main components. The servo oil feed and further routing of the media are integrated in the baseplate. The servo oil is thus looped through the baseplate on its way to the downstream lubricating pump.

In order to replace main components while the engine is running, shut-off valves 6 (servo oil) and 7 (lubricating oil inlet) as well as relief valve 8 are integrated in the baseplate (see [Fig. 'D'](#) and documentation of the lubricating pump supplier).



**Remark:** The condition of fully screwed out valves corresponds to normal operation (work setting).

**Pump body:**

Pump body 1 is primarily provided as pressure intensifier and distributor. Servo oil flows to the drive side of the central piston actuating the latter which carries the positively driven metering piston along with it. A set screw limits the central piston stroke determining thus the metering rate, which is equal for all metering pistons. Venting screws 11 and 12 serve for venting the lubricating pump (see [paragraph 4.3](#)).

**4/2-way solenoid valve:**

Corresponding signals control 4/2-way solenoid valve 3, which then releases relevant oil bores in order to actuate the central piston in the pump body.

**Accumulator:**

The function of accumulator 4 is to cushion any pressure peaks in the servo oil pipings, keeping a largely constant servo oil pressure.

The pre-startup check and recurrent tests of the gas cushion (gas precharge pressure) have to be performed in compliance with the documentation of the lubricating pump supplier.

**ALM-20 module (control unit):**

To check that the lubricating pump is working correctly, an ALM-20 module is provided for each lubricating pump, communicating with the engine control system WECS-9520 and providing pulse delivery and pressure monitoring.

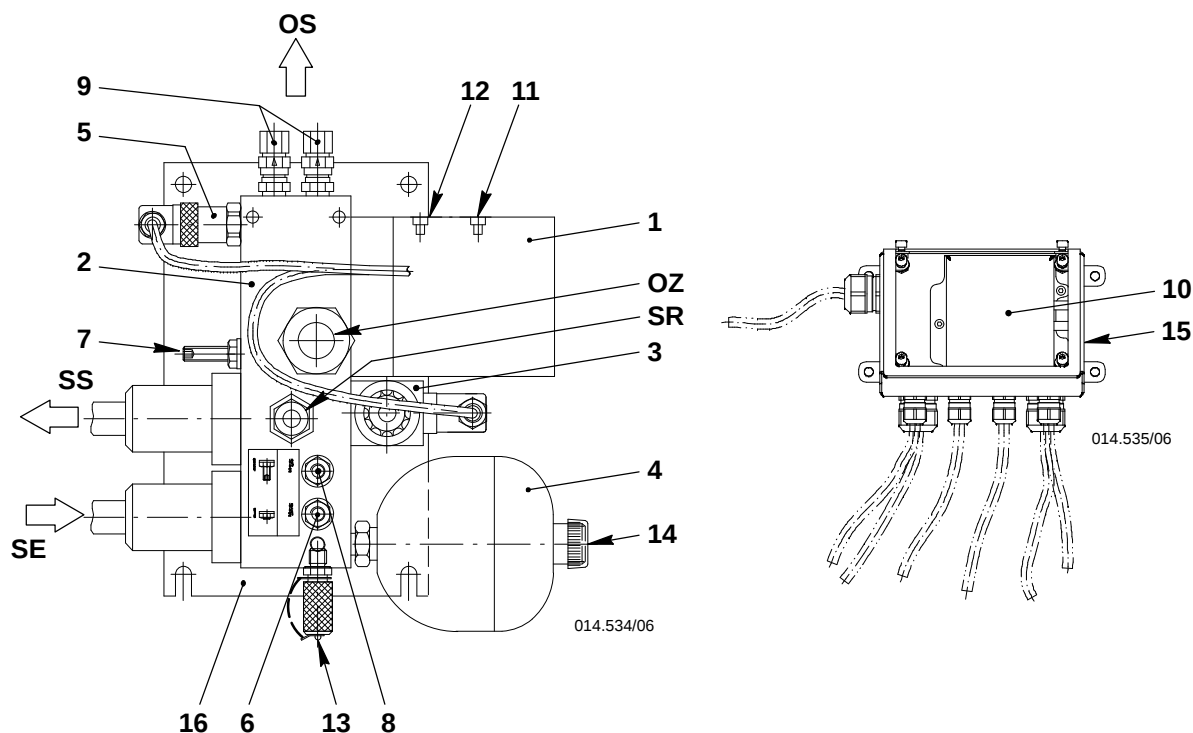
LEDs indicate the function status of the lubricating pump and the control (see [section 5](#)).



**Remark:** Exchanging of an ALM-20 module may be carried out during engine operation or at standstill (see [4002-4](#) 'Recommendations for replacing ALM-20 modules' and Location of flex Electronic Components [9362-1](#)).

## Cylinder Lubrication

D

**Key to Illustration: 'D' Lubricating pump**

- |                                                     |                                    |
|-----------------------------------------------------|------------------------------------|
| 1 Pump body                                         | 12 Venting screw (lubricating oil) |
| 2 Baseplate                                         | 13 Testing port                    |
| 3 4/2-way solenoid valve ZV7131-42C                 | 14 Filling connection              |
| 4 Accumulator                                       | 15 Control box E41.01-12           |
| 5 Pressure transmitter PT3131-42C                   | 16 Support                         |
| 6 Shut-off valve (servo oil)                        |                                    |
| 7 Shut-off valve (lubricating oil inlet)            |                                    |
| 8 Relief valve                                      | OS Oil to lubricating quill        |
| 9 Lubricating oil outlet port with non-return valve | OZ Oil supply                      |
| 10 ALM-20 module (control unit)                     | SE Servo oil inlet                 |
| 11 Venting screw (servo oil)                        | SR Servo oil return                |
|                                                     | SS Servo oil to next lubr. pump    |

**4.2 Function**

Servo oil flows via 4/2-way solenoid valve into the underside of the central piston, maintaining the latter in its upper limit position. The carried positively driven metering pistons have freed the lubricating oil inflow and the metering ducts are filled with lubricating oil.

When a lube pulse is triggered by the engine control system WECS-9520, ALM-20 module actuates the 4/2-way solenoid valve. Servo oil flows to the drive side of the central piston and the servo oil on the underside of the central piston flows back into the servo oil return pipe via the reversed 4/2-way solenoid valve. The central piston is pressed into its lower limit position. At the same time lubricating oil is conveyed at high pressure through the non-return valves in the lubricating oil outlet ports and finally injected in the cylinder liner via the lubricating quills.

## Cylinder Lubrication

---

After the central piston has reached its lower limit position, the engine control system WECS-9520 switches over the 4/2-way solenoid valve. Servo oil now flows via the latter to the underside of the central piston and presses the same into its upper limit position. The servo oil on the drive side of the central piston is directed through the 4/2-way solenoid valve back to the servo oil inlet. At the same time, the freed metering ducts are filled again with lubricating oil, to be ready for another lube pulse.

### 4.3 Venting the lubricating pump

Venting screws 11 (servo oil) and 12 (lubricating oil) in pump body 1 serve for venting the lubricating pump (see Fig. 'E').



**Remark:** For venting the cylinder lubricating system must be ready for operation (see Prepare the Cylinder Lubricating System 0140-1).

The lubricating pump is to be vented:

- by the first commissioning
- after a prolonged shut-down period
- after maintenance works
- in case of operating troubles (operating pressure, feed rate)

#### **Lubricating oil:**

- ⇒ Place an oil tray beneath the lubricating pump.
- ⇒ Open venting screw 12 by max. three turns.
- ⇒ Keep venting screw 12 open until oil flows bubble-free, then close and retighten it.

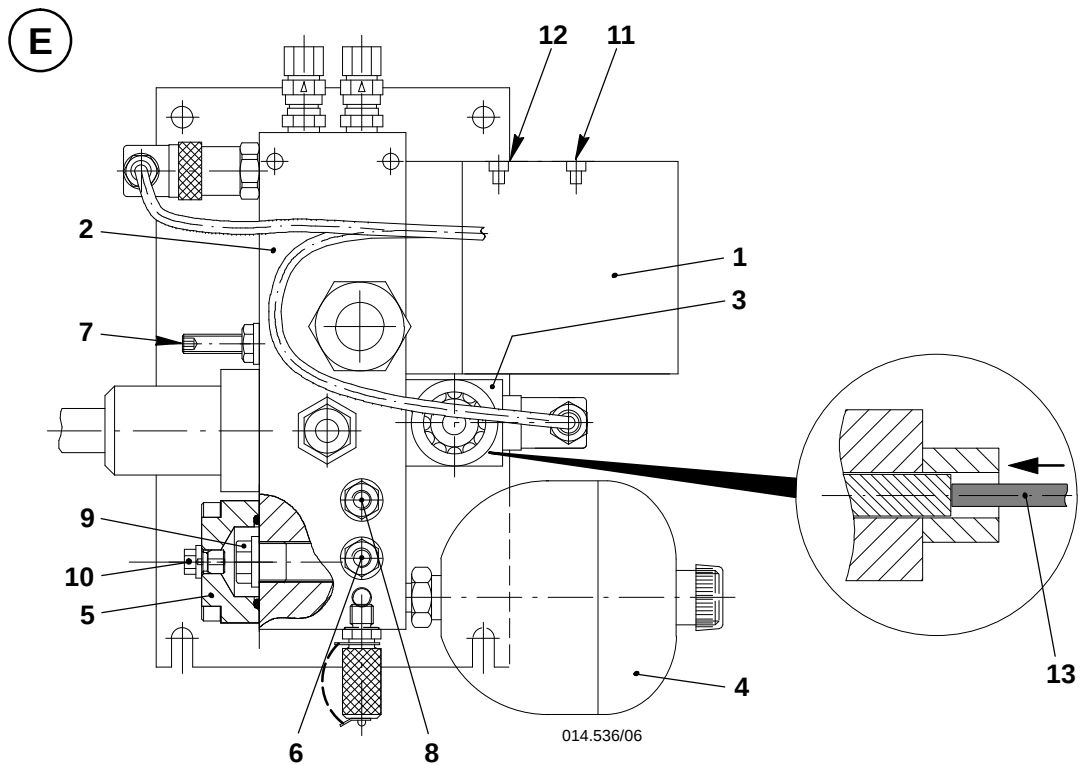
#### **Servo oil:**



**Attention!** The servo oil system is under high pressure. Therefore, always wear safety goggles, oil may spurt when loosening venting screw 11!

- ⇒ Place an oil tray beneath the lubricating pump.
- ⇒ Select corresponding cylinder number in field MANUAL LUBRICATION ON CYL. in the operator interface or actuate MANUAL EMERGENCY on 4/2-way solenoid valve (see Fig. 'E').
- ⇒ Open venting screw 11 **by max. three turns.**
- ⇒ Keep venting screw 11 open until oil flows bubble-free, then close and retighten it.
- ⇒ Remove the oil tray.

## Cylinder Lubrication

**Key to Illustration: 'E' Last Lubricating pump**

- |                                     |                                    |
|-------------------------------------|------------------------------------|
| 1 Pump body                         | 8 Relief valve                     |
| 2 Baseplate                         | 9 Screw plug                       |
| 3 4/2-way solenoid valve ZV7131-42C | 10 Screw plug                      |
| 4 Accumulator                       | 11 Venting screw (servo oil)       |
| 5 Blind flange                      | 12 Venting screw (lubricating oil) |
| 6 Shut-off valve (servo oil)        | 13 Assembly pin (max. Ø 3.5 mm)    |
| 7 Shut-off valve (lubricating oil)  |                                    |

**4.4 Venting the lubricating oil system**

After venting the filter, the measurement tube and lubricating pumps, the pipings to the lubricating quills must be vented.

- ⇒ Loosen all cap nuts of the pipings by approx. two turns (see Lubricating Quill [2138-1](#)).
- ⇒ Select corresponding cylinder number in field MANUAL LUBRICATION ON CYL. in the operator interface or actuate MANUAL EMERGENCY on 4/2-way solenoid valve (see Fig. 'E').
- ⇒ When oil flows bubble-free, retighten cap nuts.
- When all lubricating oil pipes are vented, by applying further lube pulses, the cylinder oil feed can be checked through the scavenge air ports in the cylinder liner with the piston in TDC.



**Remark:** When pushing assembly pin 13 inwards, a central piston stroke of the lubricating pump and therewith a single lube pulse is released.

## Cylinder Lubrication

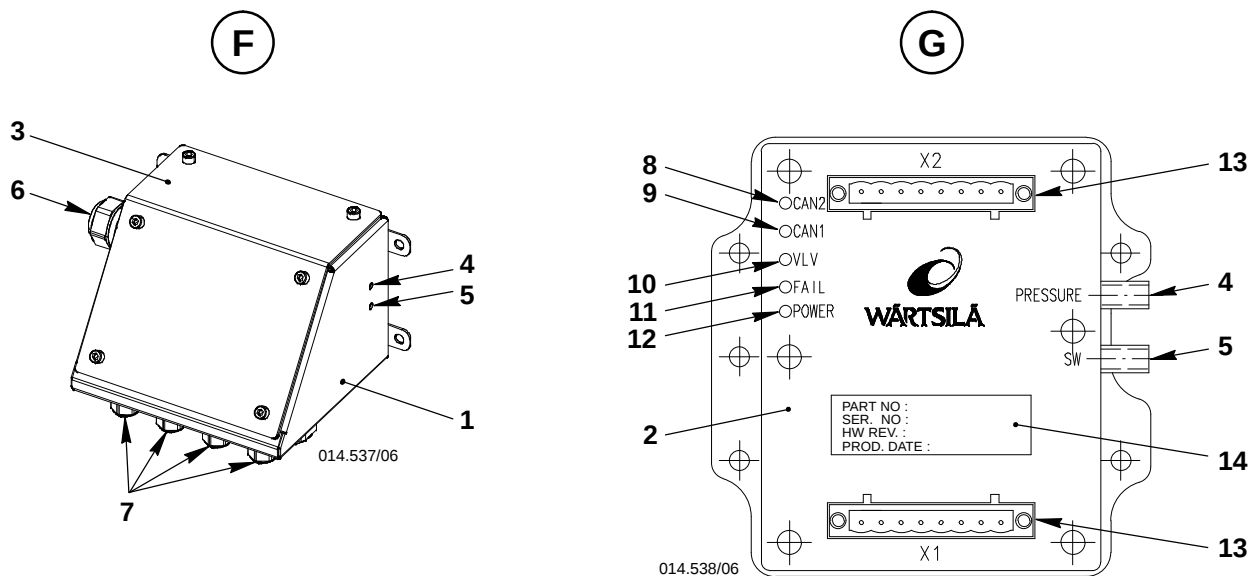
## 4.5 Maintenance on lubricating pump components

If, however, lubricating pump components must be overhauled or replaced, the works have to be performed and the corresponding tightening torques applied in compliance with the documentation of the lubricating pump supplier.

For faults, causes and remedies see [0820-1](#) 'Cylinder lubrication fails' and the documentation of the lubricating pump supplier.

## 5. ALM-20 module (control unit)

ALM-20 module actuates the 4/2-way solenoid valve releasing a lube pulse. By means of metering pressure, it checks also lubricating quill failures, air cavity, or any lubricating oil deficiency and driving problems (evaluation of pressure curves during oil flow).



**Key to Illustrations:** 'F' Control box  
'G' ALM-20 module

- |                                          |                   |
|------------------------------------------|-------------------|
| 1 Control box E41.01-12                  | 8 LED (CAN2)      |
| 2 ALM-20 module                          | 9 LED (CAN1)      |
| 3 Cover                                  | 10 LED (VLV)      |
| 4 LED (pressure)                         | 11 LED (FAIL)     |
| 5 LED (SW)                               | 12 LED (POWER)    |
| 6 Cable connection (to lubricating pump) | 13 Plug (X1 / X2) |
| 7 Cable connection (to control)          | 14 Name plate     |

## Cylinder Lubrication

## 5.1 LED indications

LEDs 4 and 5 visible from outside, indicate the function status of the lubricating pump and the control (see Fig. 'F' and 'G').

| LED                         | Indication      | Function status                                                          |
|-----------------------------|-----------------|--------------------------------------------------------------------------|
| LED 4<br>(pressure)<br>(SW) | blinking YELLOW | Indicates a successful lube pulse                                        |
|                             | lighting RED    | Indicates an electric short-circuit of pressure transmitter (PT3131-42C) |
| LED 5                       | blinking GREEN  | Module ready for software download                                       |
|                             | lighting GREEN  | Ready for operation                                                      |



**Remark:** Not upon each piston stroke is a lube pulse (yellow blinking LED) released, particularly at part load it starts after several strokes only.

After removing cover 3 from the ALM-20 module, further LEDs for detailed information can be viewed (see Fig. 'G').

| LED                         | Indication                | Function status                                                                                           |
|-----------------------------|---------------------------|-----------------------------------------------------------------------------------------------------------|
| LEDs 8 / 9<br>(CAN2 / CAN1) | lighting YELLOW           | Active CAN Bus                                                                                            |
|                             | lighting RED              | Failed CAN Bus (failure)                                                                                  |
| LED 10<br>(VLV)             | blinking YELLOW           | Indicates instantaneous lube pulse released                                                               |
|                             | lighting RED              | and LED 11 (FAIL) lighting RED: Indicates an electric short-circuit of 4/2-way solenoid valve             |
|                             | lighting RED              | and LED 11 (FAIL) blinking once RED: Indicates a cable failure on 4/2-way solenoid valve                  |
| LED 11<br>(FAIL)            | DARK                      | Injection circuit ok                                                                                      |
|                             | lighting RED              | and LED 10 (VLV) remaining DARK: Indicates an electric short-circuit of pressure transmitter (PT3131-42C) |
|                             | blinking RED, twice       | Indicates a cable failure of pressure transmitter (PT3131-42C)                                            |
|                             | blinking RED, three times | Indicates an identification failure of ALM-20 module                                                      |
| LED 12<br>(POWER)           | lighting GREEN            | Power supply on                                                                                           |
|                             | DARK                      | Power supply off                                                                                          |

## Cylinder Lubrication

## 5.2 Resistor in plug X1

A properly defined resistor is built-in plug X1 (terminals 16 and 17) for ALM-20 module, providing a corresponding value for each cylinder.



**Remark:** Before inserting a new resistor, it must be checked according to the following table:

| Cylinder No. | Control box No. | Resistor Ohm [ $\Omega$ ] |
|--------------|-----------------|---------------------------|
| 1            | E41.01          | 330                       |
| 2            | E41.02          | 390                       |
| 3            | E41.03          | 470                       |
| 4            | E41.04          | 560                       |
| 5            | E41.05          | 680                       |
| 6            | E41.06          | 820                       |
| 7            | E41.07          | 1.0K                      |
| 8            | E41.08          | 1.2K                      |
| 9            | E41.09          | 1.5K                      |
| 10           | E41.10          | 1.8K                      |
| 11           | E41.11          | 2.2K                      |
| 12           | E41.12          | 2.7K                      |

## 6. Lubricating quill

Lubricating oil is fed to the row of lubricating grooves via the lubricating quills located on the circumference of the supporting ring.

The function of the lubricating quill is described in [2138-1](#).

## Cylinder Lubrication

**7. Additional lubrication of exhaust valve spindle**

The additional lubrication of the exhaust valve spindle is normally cut out (stop valve 7 closed), however used during the first operating hours or after an exhaust valve overhaul (stop valve 7 open) (see also Exhaust Valve 2751-1, Fig. 'E').

This lubrication is ensured via an additional lubricating oil pipe, branched off from a pipe to lubricating quill 3.

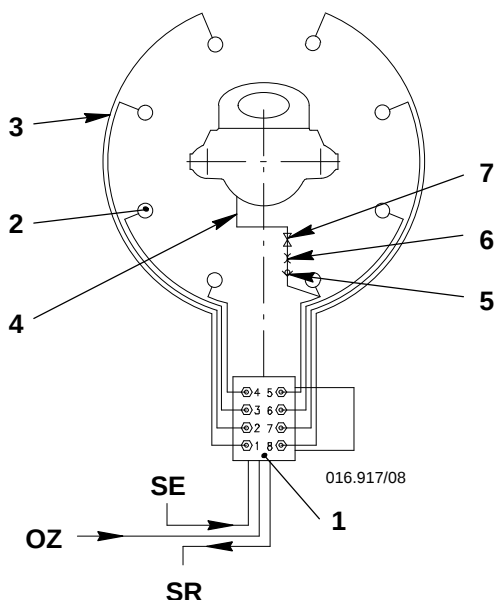
At every released lube pulse by lubricating pump 1, part of the lubricating oil feed rate to lubricating quill 2 reaches the exhaust valve spindle via non-return valve 5, orifice 6 and stop valve 7.



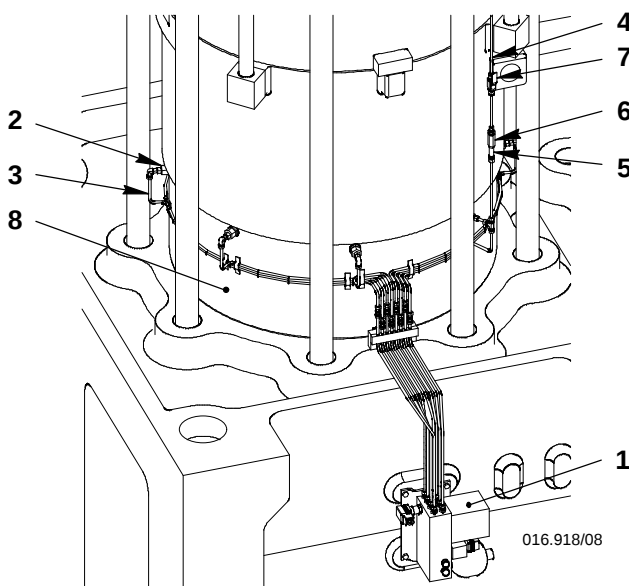
**Remark:** According to service experiences we recommend to handle the stop valve 7 as follows, i.e. to close it after:

- approx. 100 operating hours after conclusion of the sea trial.
- approx. 24 operating hours after an exhaust valve overhaul.

**H**



**I**



**Key to Illustrations:** 'H' Schematic presentation  
'I' Arrangement on cylinder No. 1

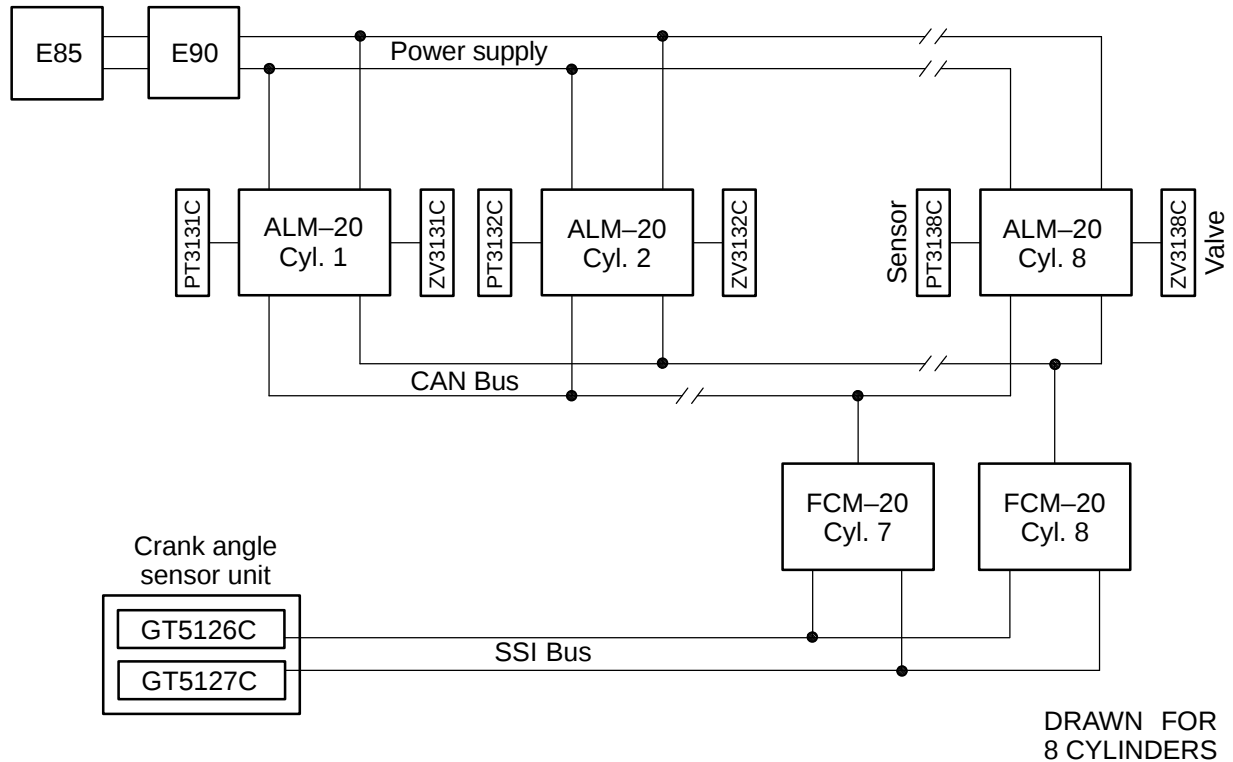
- |                                       |                     |
|---------------------------------------|---------------------|
| 1 Lubricating pump 8.06               | 7 Stop valve        |
| 2 Lubricating quill 8.09              | 8 Cylinder liner    |
| 3 Lubricating oil pipe to lubr. quill |                     |
| 4 Lubricating oil pipe to exh. valve  | OZ Oil supply       |
| 5 Non-return valve                    | SE Servo oil inlet  |
| 6 Orifice                             | SR Servo oil return |

## Cylinder Lubrication

## 8. Control of cylinder lubricating system

## 8.1 Control system

J



The control system consists of a row of ALM-20, one module for each cylinder. The communication is ensured via CAN Bus, however, for safety reasons a 2<sup>nd</sup> CAN Bus provides the redundancy. The power supply functions via power supply box E85 to control box E90 and then to the ALM-20 modules.

On each ALM-20 module there is a pressure transmitter for monitoring the metering pressure, and also a 4/2-way solenoid valve for the purpose of actuating the lubricating pump.

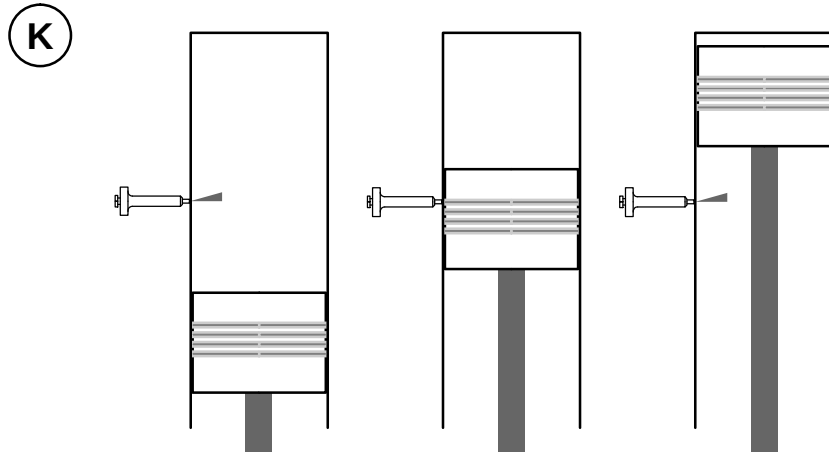
The above arrangement is controlled by the engine control system WECS-9520 via FCM-20 modules of the last and penultimate cylinders. Dual execution provides the redundancy of the CAN Bus, and also the communication to the crank angle sensors (see [4002-1](#)).

Cylinder Lubrication

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## 8.2 Vertical oil distribution

The feed timing determines the vertical oil distribution. It is adjusted, with its percentage distribution of the lubricating oil feed rate, by means of parameters in the engine control system WECS-9520 during the first commissioning (see Fig. 'K').



## 8.3 Adjusting the feed rate of lubricating oil

The lubricating oil feed rate can be adjusted between 3.0 g/kWh and 0.5 g/kWh, altering the range in steps of 0.1 g/kWh. This adjustment can be carried out by means of user parameters 'Lubrication' → 'Feed Rate' individually for each cylinder or globally for all cylinders.

The required feed rates for running-in of new cylinder liners & piston rings and the following operation are described in [0410-1](#) 'Cylinder lubricating oil feed rate, and 'Running-in programme'.

## Instructions Concerning Measurement of Cylinder Lubricating Oil Consumption

### 1. Determination of actual cylinder lubricating oil consumption

Basically the cylinder lubricating oil consumption can be measured at any engine power output.

As the engine is equipped with a load-dependent cylinder lubricating system, care should be taken that **during the measurement the engine speed and power are kept as constant as possible.**

The cylinder lubricating system is provided with a measurement tube which contains an indicating instrument permitting accurate measuring in a short time (see 7218–1 'Measurement of consumption at measurement tube')

In order to determine the actual cylinder lubricating oil consumption, the oil levels must be marked and the exact time recorded at the start and end of the measurement.

The consumed oil quantity can be determined by reading the distance between the two marks and converted into litres (litres x density = weight of oil in kg).

In order to calculate the specific cylinder lubricating oil consumption, the power output during the test must be known. This output can be established:

- from the curve fuel injection quantity (%) x engine speed (FQ x rpm). See acceptance records. However, the curve corresponds with the engine running on diesel oil.
- from the field 'Est. Power' displayed in the operator interface fuel injection quantity (%) x engine speed (FuelCmd x n)

#### 1.2 Calculation of specific cylinder lubricating oil consumption

for a) + b):

$$\text{Spec. cylinder lubricating oil consumption} = \frac{1000 \cdot G}{P} \text{ g/kWh [g/BHP h]}$$

$G$  = Cylinder lubricating oil consumption in kg/h

$P$  = Effective engine power output in kW [BHP] derived from curve FQ x rpm or nominal power and FuelCmd x n

### 2. Determination of theoretical cylinder lubricating oil consumption

The theoretical cylinder lubricating oil consumption is defined by parameters set in the engine control system WECS–9520.

By means of impulses, the cylinder lubricating oil consumption (kg/h) can be calculated using the following data:

$$G = \frac{3600 \cdot V \cdot \rho \cdot Z}{t}$$

- Delivery volume of the lubricating oil pump (V) per injection pulse (ml)
- Oil density ( $\rho$ ) (typical value 0.92 kg/l)
- Number of injection pulses (Z) during measurement period of time (t) in sec.

## Instructions Concerning Measurement of Cylinder Lubricating Oil Consumption

### 2.1. Determination of specific cylinder lubricating oil consumption of a consumption measurement

Parameter settings and function of the cylinder lubricating system can be checked using a consumption measurement (parallel measurement).

The procedure is described in 7218-1 'Measurement of consumption'.

The specific cylinder lubricating oil consumption (feed rate) can be calculated according to this formula:

$$R = \frac{3600 \cdot (h \cdot k) \cdot \rho}{f \cdot t \cdot P}$$

$R$  = Specific cylinder lubricating oil consumption (g/kWh)

$h$  = Measuring height (cm)

$k$  = Conversion factor (l/cm)

$\rho$  = Oil density (g/l) (typical value 920 g/l)

$f$  = Correction factor (see table below)

$t$  = Measurement period of time (seconds)

$P$  = Engine power output (kW during measurement)

( $V$  = Oil volume (l) [ $h \cdot k$ ])

| Engine power output<br>% | Correction factor<br>$f$ |
|--------------------------|--------------------------|
| 100                      | 1.00                     |
| 75                       | 1.02                     |
| 50                       | 1.06                     |
| 20                       | 1.25                     |
| 10                       | 1.56                     |

#### Example 10 RT-flex82C:

$$R = \frac{3600 \cdot (44.5 \cdot 0.196) \cdot 920}{1.02 \cdot 1050 \cdot 33\,900} = 0.8 \text{ g/kWh}$$

- Meas. period of time      17 min. 30 sec. = 1050 sec.
- Measuring height      44.5 cm
- Conversion factor      0.196 l/cm
- Oil density      920 g/l
- Correction factor      1.02
- Output at 75%      33 900 kW

## Instructions Concerning Measurement of Cylinder Lubricating Oil Consumption

---

### 3. Recommended cylinder lubricating oil feed rate

We recommend to reduce the cylinder lubricating oil feed rate in steps after completion of the running-in period (see 0410–1).

This value is relative to the nominal output at nominal speed. The value so set remains – due to the load-dependent cylinder lubricator control – approximately constant over a wide power output range relative to the engine service power in operation.

Experience gained from evaluating the running surfaces of pistons, piston rings and cylinder liners, will determine what cylinder lubricating oil quantity is most economical for a given engine.

When information is given to us about the consumption of cylinder lubricant, it should always be related to litre or kg per hour or per 24 hours, indicating at the same time (as far as known):

- Engine type and number of cylinders
- Engine speed
- Fuel injection quantity
- Set lubricating oil volume
- Number of pulses during measurement
- Engine power output during measurement
- Delivery volume of lubricating pump
- Description of lubricating oil used
- Specification of fuel oil
- Fuel oil consumption in metric tons per 24 hours



## Lubricating Oil System

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### Overview

|    |                                              |       |
|----|----------------------------------------------|-------|
| 1. | General .....                                | 1/11  |
| 2. | Bearing and turbocharger oil system .....    | 1/11  |
| 3. | Leakage oil pipes exhaust valve .....        | 4/11  |
| 4. | Servo oil system .....                       | 6/11  |
| 5. | Servo oil leakage system .....               | 9/11  |
| 6. | Filling and draining of servo oil rail ..... | 11/11 |

### 1. General

The oil necessary for the engine control and lubrication (with the exception of cylinder lubrication) is raised by pump 1 to the necessary bearing oil pressure (pressure values see Operating Data Sheet [0250–1](#)).

The oil distribution to the various lubricating points is shown on the following schematic lubricating oil diagram.

The cylinder lubrication is described in [7218–1](#).

The arrangement of pumps, filters, heat exchangers, etc. is shown on the plant diagram which is supplied separately from the engine documentation.

### 2. Bearing and turbocharger oil system ([Fig. 'A'](#))

Bearing oil is supplied to oil distributing pipe 6 and main bearings 8 through bores in the bearing covers via oil inlet pipe 4 on exhaust side.

Bearing oil is also used to cool the pistons via distributing pipe 5 to toggle levers 13, to lubricate crosshead pins 12 and bottom end bearings.

For actuating the exhaust valves, oil ('hydraulic rod') is led to the exhaust valve control units via the servo oil system (see section 4 and Control Diagram 4003–2).

Integrated axial damper 7, and if there is a vibration damper 27, the intermediate wheels 19 and 20 are supplied or cooled with bearing oil.

Via distributing pipe 16 and internal bores in fuel pump unit 17 ensuring oil supply of the bearings, spray nozzles and fuel pumps (see Fuel Pump Unit 5581–1 and Fuel Pump 5556–1).

Moreover, internal bores and spray nozzles in servo pump unit 18 ensure an additionally oil supply to the bearings and the gear wheels (see Servo Pump Unit 5591–1).

Bearing oil is supplied to turbochargers 30 through oil inlet pipe 29 via oil distributing pipe 4 on exhaust side. The oil flows back into oil drain tank 'OA' via venting unit 31 (air separator arranged in outlet pipe 32) and leakage oil pipes exhaust valve (see also [Fig. 'B'](#)).

## Lubricating Oil System

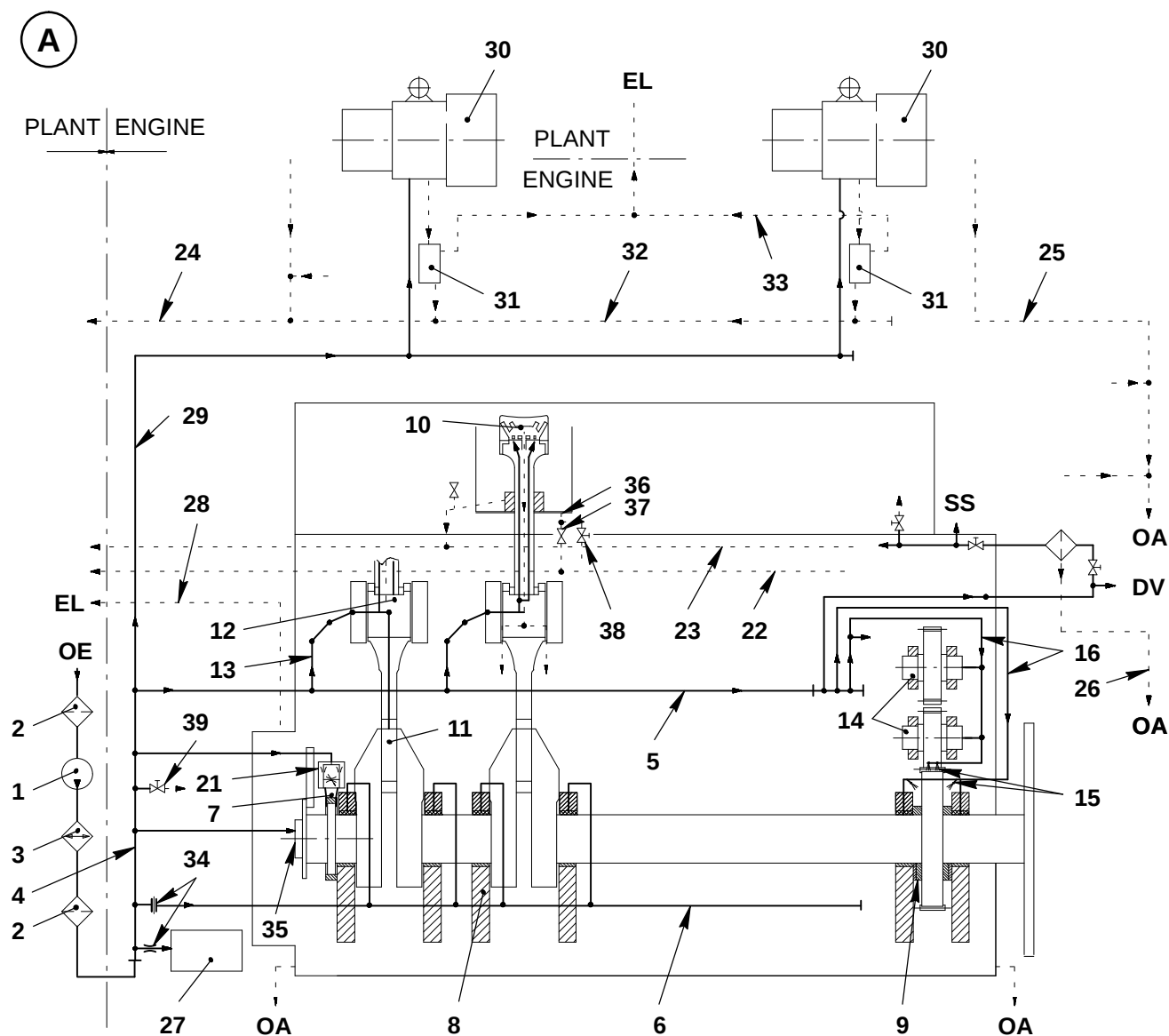
A device (ball valves 37 and 38) for taking oil samples is arranged in the outlet (drain) for dirty oil 36 from piston underside (see also 0750-1 'Cylinder lubricating oil').



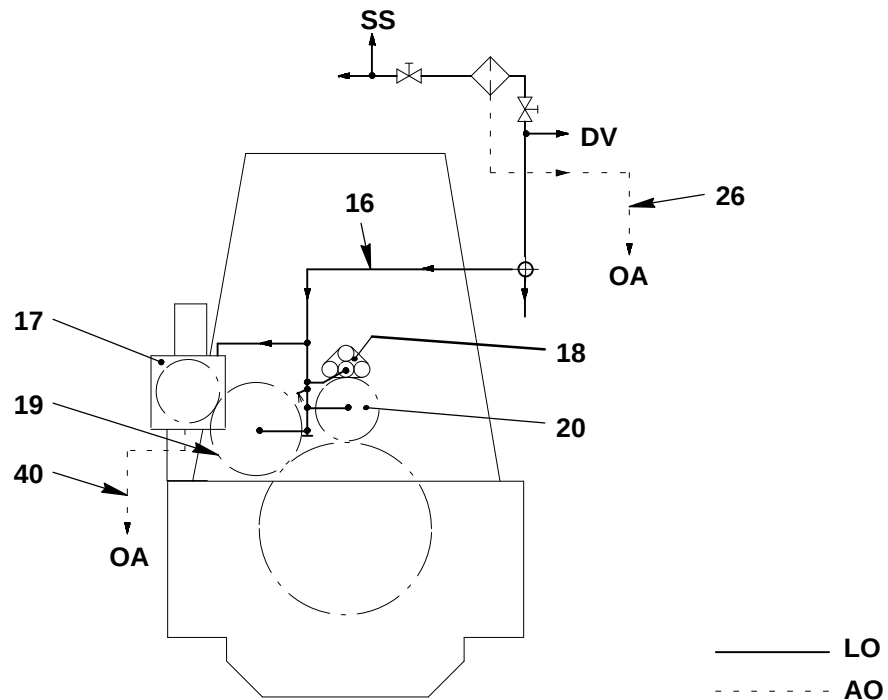
**Remark:** Ball valves 37 remain open and ball valves 38 closed during operation.

**Taking dirty oil samples:**

- ⇒ Close ball valve 37.
- ⇒ After about ½ hour open ball valve 38 and take dirty oil sample.
- ⇒ Close ball valve 38 and reopen ball valve 37 (operating position).



## Lubricating Oil System

**Key to Illustrations: 'A' Bearing and turbcharger oil system**

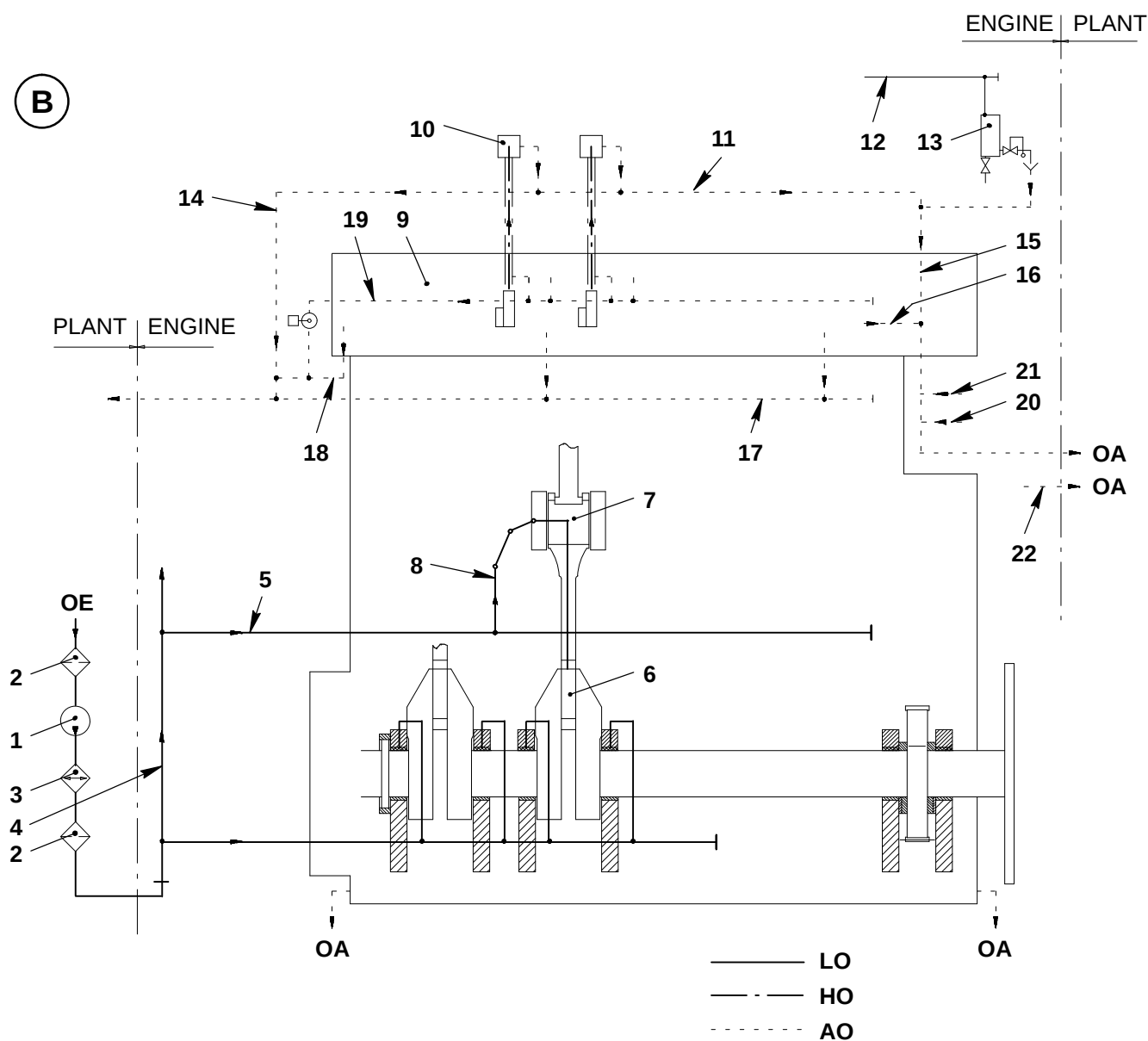
- |                                                              |                                                              |
|--------------------------------------------------------------|--------------------------------------------------------------|
| 1 Oil pump                                                   | 25 Leakage oil pipe exhaust valve DE                         |
| 2 Oil filter                                                 | 26 Flushing oil drain f. automatic filter                    |
| 3 Oil cooler                                                 | 27 Vibration damper                                          |
| 4 Oil inlet pipe on exhaust side                             | 28 Crankcase venting pipe                                    |
| 5 Oil distributing pipe                                      | 29 Oil inlet pipe                                            |
| 6 Oil distributing pipe main bearing                         | 30 Turbocharger                                              |
| 7 Axial damper                                               | 31 Venting unit                                              |
| 8 Main bearing                                               | 32 Outlet pipe                                               |
| 9 Thrust bearing                                             | 33 Venting pipe                                              |
| 10 Piston                                                    | 34 Throttle                                                  |
| 11 Bottom end bearing                                        | 35 Crank angle sensor unit                                   |
| 12 Crosshead pin                                             | 36 Outlet (drain) pipe for dirty oil                         |
| 13 Toggle lever for piston cooling and crosshead lubrication | 37 Ball valve                                                |
| 14 Intermediate wheel bearing                                | 38 Ball valve (for taking oil samples from piston underside) |
| 15 Spray nozzle                                              | 39 Ball valve (for taking oil samples of system oil)         |
| 16 Distributing pipe                                         | 40 Oil drain from fuel pump unit                             |
| 17 Fuel pump unit                                            |                                                              |
| 18 Servo pump unit                                           |                                                              |
| 19 Intermediate wheel fuel pump unit                         |                                                              |
| 20 Intermediate wheel servo pump unit                        |                                                              |
| 21 Axial damper monitoring                                   |                                                              |
| 22 Dirty oil collector main from piston underside            |                                                              |
| 23 Leakage oil collector main from piston rod gland          |                                                              |
| 24 Leakage oil pipe exhaust valve FE                         |                                                              |
|                                                              | AO Drain and vent                                            |
|                                                              | DV to fuel pressure control valve 3.06                       |
|                                                              | EL Vent                                                      |
|                                                              | LO Bearing and turbocharger oil                              |
|                                                              | OA to oil drain tank                                         |
|                                                              | OE from oil drain tank                                       |
|                                                              | SS to servo oil service pump 4.88                            |

**3. Leakage oil pipes exhaust valve (Fig. 'B')****3.1 Leakage oil pipes exhaust valve**

The following oil drains are combined in leakage oil pipes exhaust valve 14 and 15 leading back to the bearing oil system via oil drain tank in the plant:

- Leakage oil from exhaust valve 11
- Leakage oil from air spring 12 via leakage oil return 13
- Oil drain 16 from fuel pressure control valve 3.06
- Turbocharger oil return 17
- Servo oil return 18 piping 4.63
- Leakage oil pipe 19 from actuator pipe 4.66
- Servo oil return 21 from cylinder lubrication pumps
- Return 20 of servo oil service pump 4.88

## Lubricating Oil System

**Key to Illustration: 'B' Leakage oil pipes exhaust valves**

- |                                                             |                                                     |
|-------------------------------------------------------------|-----------------------------------------------------|
| 1 Oil pump                                                  | 16 Oil drain from fuel pressure control valve 3.06  |
| 2 Oil filter                                                | 17 Turbocharger oil return                          |
| 3 Oil cooler                                                | 18 Servo oil return piping 4.63                     |
| 4 Oil inlet pipe on exhaust side                            | 19 Leakage oil pipe from actuator pipe 4.66         |
| 5 Oil distributing pipe                                     | 20 Return of servo oil service pump 4.88            |
| 6 Bottom end bearing                                        | 21 Servo oil return from cylinder lubrication pumps |
| 7 Crosshead pin                                             |                                                     |
| 8 Toggle lever for piston cooling and crosshead lubrication |                                                     |
| 9 Rail unit                                                 |                                                     |
| 10 Exhaust valve                                            |                                                     |
| 11 Leakage oil collecting main exhaust valve                | AO Drain                                            |
| 12 Leakage oil pipe from air spring                         | HO Hydraulic oil                                    |
| 13 Leakage oil return                                       | LO Bearing oil                                      |
| 14 Leakage oil pipe exhaust valve FE                        | OA to oil drain tank                                |
| 15 Leakage oil pipe exhaust valve DE                        | OE from oil drain tank                              |

#### 4. Servo oil system (Fig. 'C' and 'D')

The servo oil system is provided for controlling the exhaust valve movement and the injection control units. The required oil is branched off from the bearing oil system.

##### 4.1 Servo oil service pump

The electrically-driven servo oil service pump 3 must be switched on and off manually. It can be used to generate the required pressure for the function of the exhaust valve movement and performing a leak test, prior to the first commissioning or after maintenance work on the servo oil system.

Moreover the servo oil service pump increases the pressure in the fuel rail when required via tool 94583 (pipe) (see 8019–1 'High pressure circuit' and 0120–1 'Venting and leak test of fuel oil system on engine').

The function of the servo oil service pump is, however, neither necessary for engine start nor engine operation.



**Remark:** Stop valves 14 and 15 must be open prior to commissioning (see also 0130–1 'Checks to be carried out on servo oil system').

Prior to engine start the servo oil service pump should be switched off.

##### 4.2 Servo oil system

Oil reaches the servo oil pumps 4 via automatic filter 1, supply pipe 5 and distributor pipe 13.



Do **not** operate the engine with the oil supply to the servo oil pumps interrupted. Stop valves 14 and 15 must always be open during operation!

Dependent on the electrically controlled pressure regulating system (nominal pressure value depending on engine load), the servo oil pumps deliver oil to servo oil rail 7 via rising pipe 6. A leakage oil pipe 32 as well as leakage inspection points 25 are arranged at collector block 3 of the rising pipes (see section 5).



**Remark:** Flow sensors 26 (installed before every servo oil pump) ensure the oil supply of the servo oil pumps and in case of a pump failure an alarm is triggered via the alarm and monitoring system (see Servo Pump Unit 5591–1).

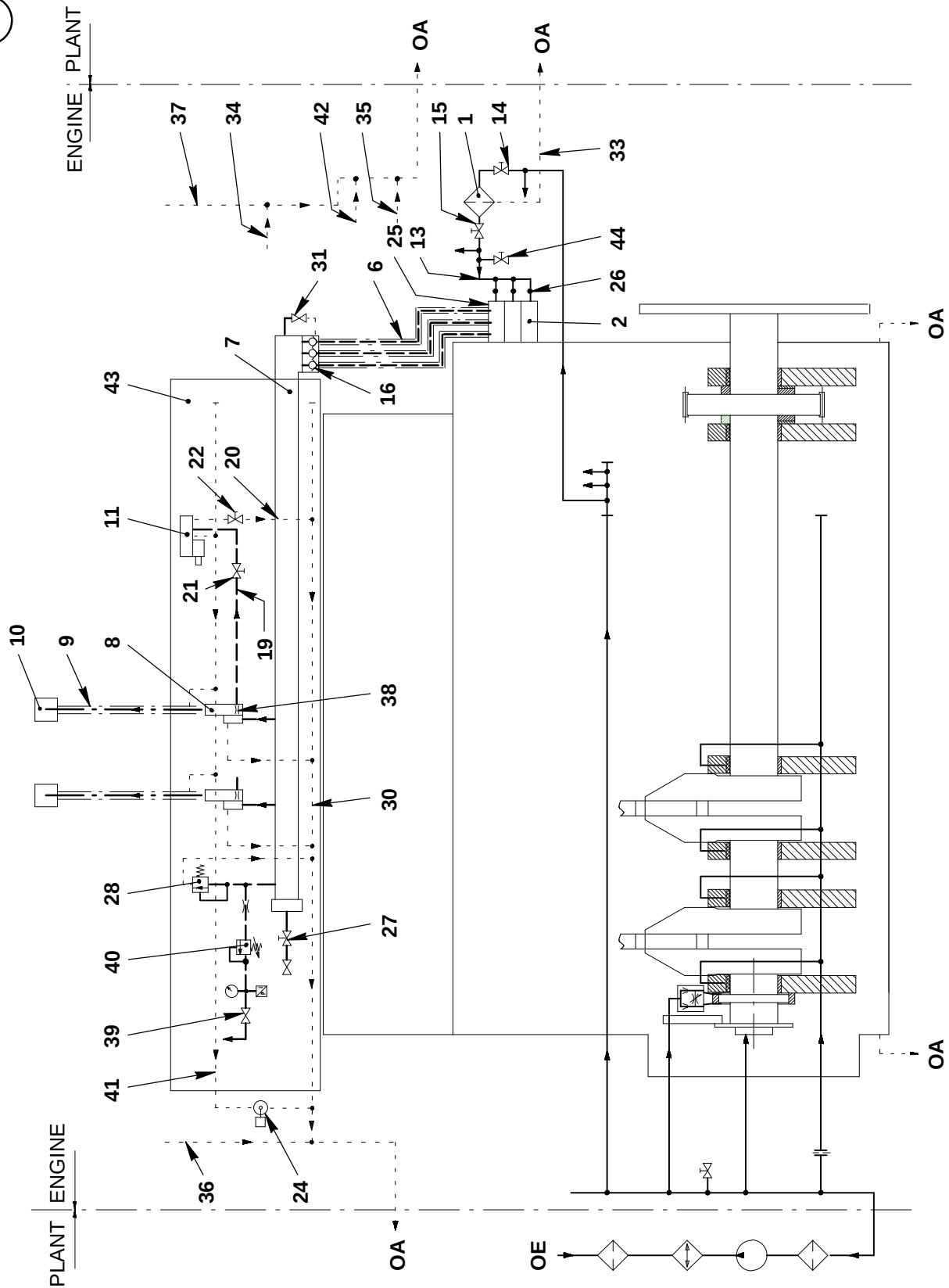
For controlling the exhaust valve spindle movement ('hydraulic cam') servo oil is used which flows to exhaust valve control units 8 and their control valves (rail valves) via the servo oil rail, and then into leakage oil pipe exhaust valve FE 36 via return piping 30.

For actuating ('hydraulic cam') the injection control units 11 and their control valves (rail valves) oil is used which flows from the exhaust valve control unit to the injection control units via flexible hoses 19, and then into leakage oil pipe exhaust valve FE 36 via return piping 30.

Defective rail valves can be replaced during operation by means of ball valves 21 and 22 (see 0515–1 'Defective injection control unit').

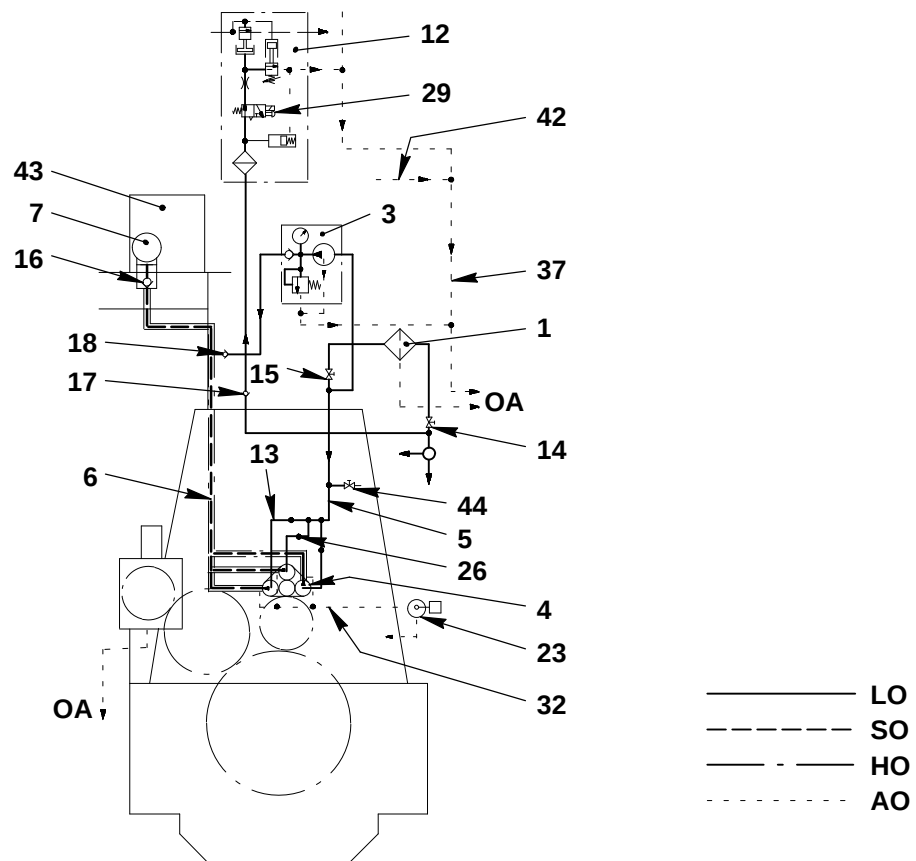
Lubricating Oil System

(C)



## Lubricating Oil System

D

**Key to Illustrations: 'C' and 'D' Servo oil system**

- |                                     |                                                     |
|-------------------------------------|-----------------------------------------------------|
| 1 Automatic filter 4.20             | 27 Stop valve 3.40                                  |
| 2 Servo pump unit                   | 28 Safety valve 4.23                                |
| 3 Servo oil service pump 4.88       | 29 Fuel shut-down pilot valve 3.08                  |
| 4 Servo oil pump 4.15               | 30 Servo oil return piping 4.63                     |
| 5 Supply pipe 4.51                  | 31 Drain screw 4.82                                 |
| 6 Servo oil rising pipe 4.55        | 32 Leakage oil pipe from rising pipes               |
| 7 Servo oil rail 4.11               | 33 Flushing oil drain from automatic filter         |
| 8 Exhaust valve control unit 4.10   | 34 Drain from fuel pressure control valve 3.06      |
| 9 Actuator pipe 4.66                | 35 Return from servo oil service pump               |
| 10 Exhaust valve 4.01               | 36 Leakage oil pipe exhaust valve FE                |
| 11 Injection control unit 3.02      | 37 Leakage oil pipe exhaust valve DE                |
| 12 Fuel pressure control valve 3.06 | 38 Throttle 4.19                                    |
| 13 Distributing pipe                | 39 Stop valve 4.30-5                                |
| 14 Stop valve 4.37                  | 40 Pressure reducing valve 8.11-1                   |
| 15 Stop valve 4.80                  | 41 Leakage oil pipe from actuator pipes 4.66        |
| 16 Non-return valve 4.24-1, -2, -3  | 42 Servo oil return from cylinder lubricating pumps |
| 17 Non-return valve 3.67            | 43 Rail unit                                        |
| 18 Non-return valve 4.53            | 44 Stop valve for taking oil samples                |
| 19 Flexible hose (inlet)            |                                                     |
| 20 Flexible hose (outlet)           |                                                     |
| 21 Ball valve 3.38                  | AO Drain                                            |
| 22 Ball valve 3.27                  | HO Hydraulic oil                                    |
| 23 Level switch LS2055A             | LO Bearing oil                                      |
| 24 Level switch LS2076A             | OA to oil drain tank                                |
| 25 Leakage inspection point 4.17    | OE from oil drain tank                              |
| 26 Flow sensor FS2061-63A           | SO Servo oil                                        |
|                                     | ZS to cylinder lubricating pumps                    |

## Lubricating Oil System

## 5. Servo oil leakage system

All important leakages in the servo oil system are monitored by level switches (LS).

In case of excessive quantity the corresponding alarm is triggered:

| Level switch                   | Monitored components                                               |
|--------------------------------|--------------------------------------------------------------------|
| LS3444A                        | Leakages (fuel and servo oil) from rail unit                       |
| LS3445A<br>(9 to 12 cylinders) |                                                                    |
| LS2055A                        | Leakages from rising pipes                                         |
| LS2076A                        | Leakages from actuator pipes, leak oil from injection control unit |
| LS2077A<br>(9 to 12 cylinders) |                                                                    |

### 5.1 Leakage inspection points

A leakage inspection point is provided for the proper leakage localization of rising pipes 6 (see Fig. 'E').

If an alarm has been triggered by level switch 23 (LS2055A), the leakage inspection point allows the location of the leakage and corresponding measures can be taken.

A leakage inspection point is provided for the proper leakage localization of actuator pipes 9 (see Fig. 'F').

If an alarm has been triggered by level switch 24 (LS2076 or LS2077A), the leakage inspection point allows the location of the leakage and corresponding measures can be taken.

#### Procedure:



**Risk of injury!** Always use gloves when working on hot components! And always wear safety goggles; oil may spurt out when opening drain screws.

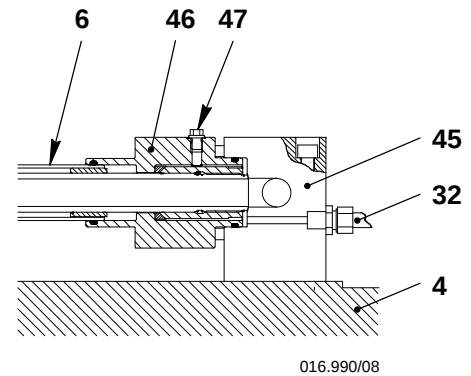
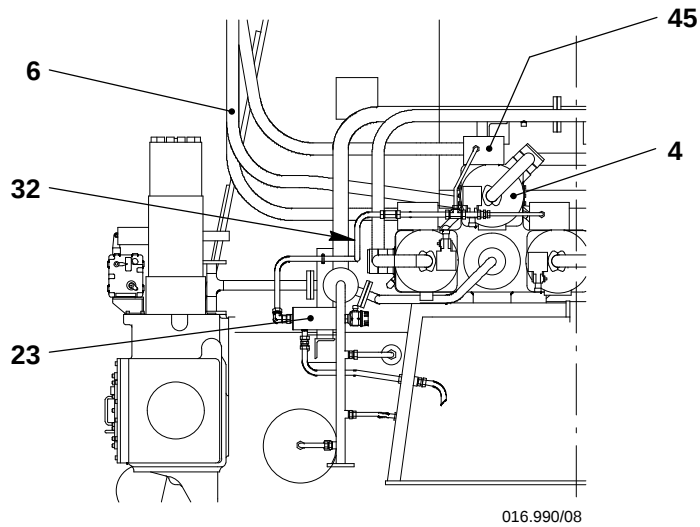
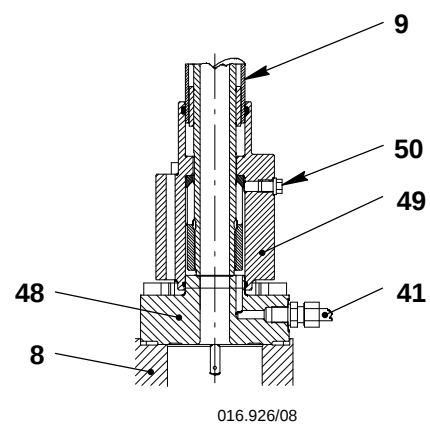
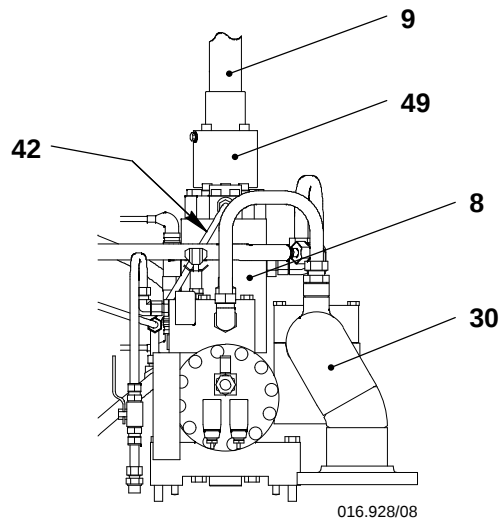
⇒ Loosen carefully the drain screw (leakage inspection point 47) by max. one turn and check if oil flows out or not (see Fig. 'E').



**Remark:** By means of the pressure controller, the pressure regulation should be adjusted to minimum of the servo oil pump belonging to the defective rising pipe. With the remaining rising pipes, the engine may be maintained in unrestricted operation until the defective pipe has been replaced.

⇒ Loosen carefully the drain screw 50 by max. one turn and check if oil flows out or not (see Fig. 'F' and Operation with Exhaust Valve Control Unit Cut Out 0520-1).

## Lubricating Oil System

**E****F**

**Key to Illustrations:** 'E' Leakage inspection point of rising pipes  
 'F' Leakage inspection point of actuator pipes

- |    |                                    |    |                                             |
|----|------------------------------------|----|---------------------------------------------|
| 4  | Servo oil pump 4.15                | 41 | Oil leakage pipe from actuator pipes        |
| 6  | Servo oil rising pipe 4.55         | 45 | Collector block                             |
| 7  | Servo oil rail 4.11                | 46 | Flange                                      |
| 8  | Exhaust valve control unit 4.10    | 47 | Drain screw (leakage inspection point 4.17) |
| 9  | Actuator pipe 4.66                 | 48 | Cover                                       |
| 23 | Level switch LS2055A               | 49 | Flange                                      |
| 30 | Servo oil return piping 4.63       | 50 | Drain screw (leakage inspection point 4.17) |
| 32 | Leakage oil pipe from rising pipes |    |                                             |

## Lubricating Oil System

## 6. Filling and draining of servo oil rail

### 6.1 Filling and venting (see Fig. 'C', 'D' and 'G')

- ⇒ Check whether stop valves 14 and 15 are open before and after automatic filter 1.
- ⇒ Check whether drain screw 31 in servo oil rail 7 is closed and tightened with a torque of 200 Nm (see Fig. 'G').
- ⇒ Start bearing oil pump.
- Bearing oil is delivered into the rising pipes 6 via the servo oil pumps and the automatic filter. The non-return valves 16 are opened due to the delivery pressure and oil flows into the servo oil rail 7 and subsequently to the upper exhaust valve housings via exhaust valve control units 8 and actuator pipes 9. The whole system is vented by orifices (see also Exhaust valve 2751-1).



**Remark:** To carry out a function check of the exhaust valve movement or leak test of the servo oil system, the servo oil service pump 3 must be switched on.

### 6.2 Draining (see Fig. 'C' and 'G')

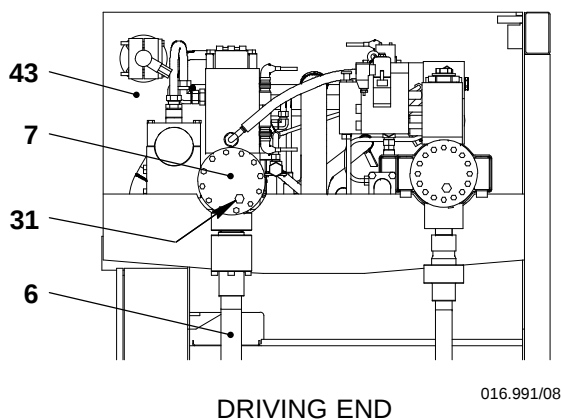
The servo oil rail 7 can be drained with drain screw 31.

- ⇒ Open drain screws 31.



**Attention!** After draining the servo oil rail the drain screw 31 must be closed and tightened to a torque of 200 Nm.

G



**Key to Illustration: 'G'**  
**Servo oil rail 4.11**

- 6 Servo oil rising pipe 4.55
- 7 Servo oil rail 4.11
- 31 Drain screw 4.82
- 43 Rail unit

## Cooling Water System

---

### 1. General

The schematic diagram shows the cylinder cooling water system on the engine.

The arrangement of pumps, coolers, fresh water generator, heater, expansion tank, valves and throttling discs for flow control etc. are found in the separate documentation for the plant layout (shipyard side). Also the layouts of raw water (sea-water) for the scavenge air, lubricating oil and jacket cooling water coolers are shown in the layout diagram.

The cooling water system is a closed circuit, which, connected to an expansion tank, is subject to a static pressure. The cooling of cylinder liners, cylinder covers and exhaust valve cages is effected by treated cooling water.

In order to bring the cooling water to operating temperature even before the engine has started a cooling water heater is installed in the plant.

The cooling water must be treated with an approved cooling water inhibitor to prevent corrosive attack, sludge formation and scale deposits in the system (see Cooling Water / Cooling Water Treatment [0760-1](#)).



**Attention!** Should the engine be taken out of operation for a longer period of time, please consider when frost threatens that the cooling water system must be drained. Thereby it must be kept in mind that it is chemically treated water which must be decontaminated in accordance with local laws or rulings. For the new filling the instructions for water treatment must be observed.

#### ***Automatic cooling water temperature control:***

In order to avoid undue tensions in the combustion chamber components, such as cylinder liners and cylinder covers, the cooling water outlet temperature must be maintained under all load conditions as steady as possible; max. admissible temperature fluctuations are:

- $\pm 2$  °C at constant load: at constant load
- $\pm 4$  °C during load changes (transient conditions)

With regard to pressures, temperature ranges, alarm and safety setting points see Operating Data Sheets [0250-1](#) and [0250-2](#).

## Cooling Water System

---

### 2. Function

The cooling water pump delivers cooling water, via the distributing pipe 1 arranged on the exhaust side, to the various cylinders, where it flows successively through cylinder liner 2, water guide jacket 3, cylinder cover 4 and exhaust valve cage 5. The venting unit 16 ensures continual venting of the system.



**Remark:** If troubles occur, pay attention to the instruction plate at the venting unit.

The water flows from the outlet piping 9 via a temperature regulating valve to the cooler and back to the pump. The suction side of the pump is joined to the expansion tank by a balance pipe. This balance pipe ensures the static pressure and also compensates any water losses and water expansion.

A throttling disc 6 is fitted in the outlet piping of each cylinder and dimensioned to let pass a certain flow of cooling water through the cylinder. The operating pressure can be adjusted in the system with throttling disc 10 in the outlet piping 9.

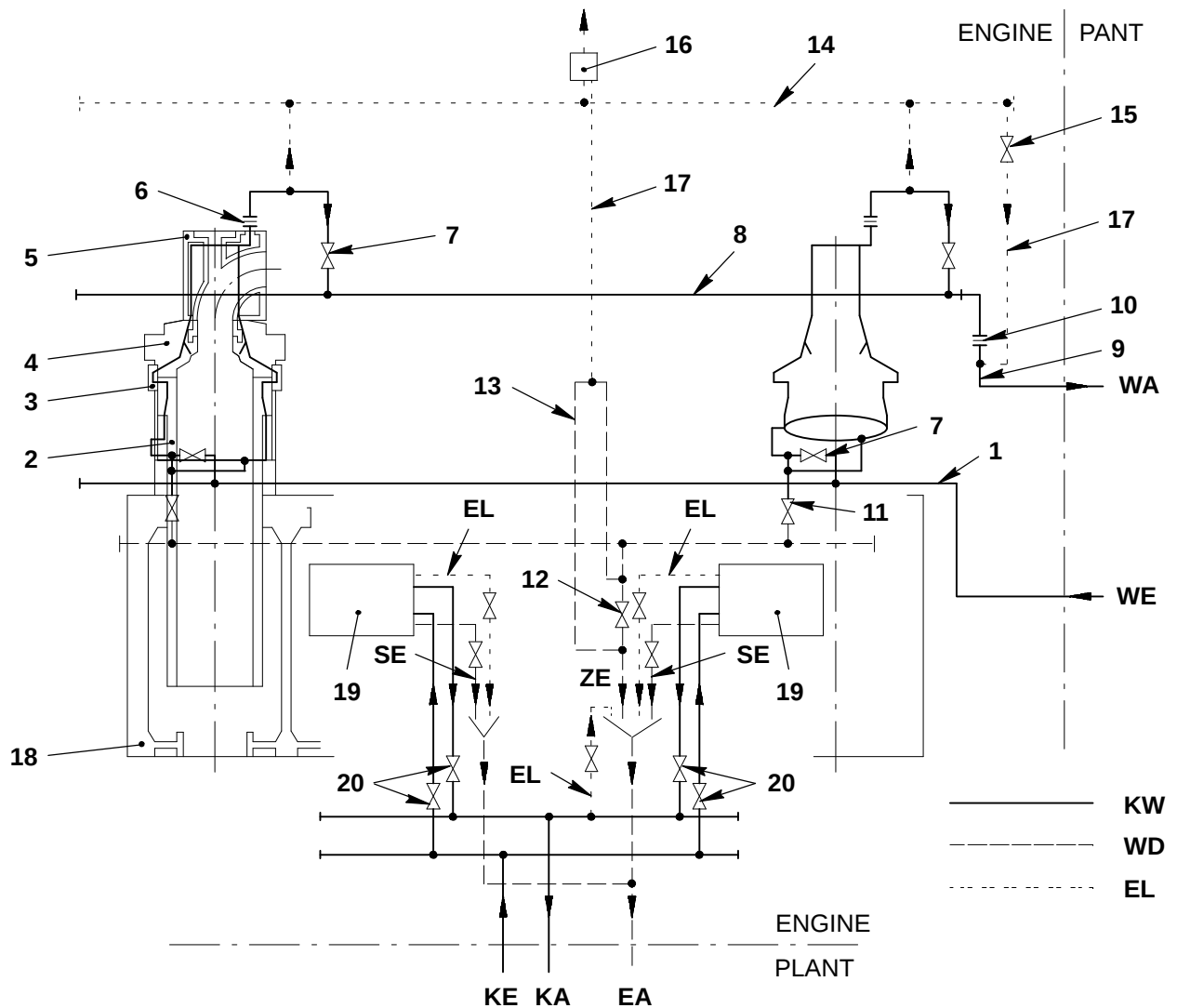
#### **Draining:**

With shut-off valves 7 and 11 the cylinders can be separated individually from the cooling water system and drained using ball cock 12.



**Remark:** However, ball cock 12 does not have to be opened, if only the cylinder cover must be removed, as in this case the cooling water flows off via level bypass pipe 13.

## Cooling Water System



**Key:**

- |    |                                  |    |                          |
|----|----------------------------------|----|--------------------------|
| 1  | Distributing pipe                | 17 | Condensate drain pipe    |
| 2  | Cylinder liner                   | 18 | Cylinder jacket          |
| 3  | Water guide jacket               | 19 | Scavenge air cooler      |
| 4  | Cylinder cover                   | 20 | Shut-off valve           |
| 5  | Exhaust valve cage               |    |                          |
| 6  | Throttling disc, cylinder outlet |    |                          |
| 7  | Shut-off valve at cylinder       | EA | Water drain              |
| 8  | Outlet collecting main           | EL | Vent                     |
| 9  | Outlet piping                    | KA | SAC cooling water outlet |
| 10 | Throttling disc, water outlet    | KE | SAC cooling water inlet  |
| 11 | Shut-off valve for draining      | KW | Cooling water            |
| 12 | Ball cock for draining           | SE | SAC cooling water drain  |
| 13 | Level bypass pipe                | WA | Cooling water outlet     |
| 14 | Vent collecting main             | WE | Cooling water inlet      |
| 15 | Ball cock                        | WD | Drain pipe               |
| 16 | Venting unit                     | ZE | Cylinder drain           |

## Starting Air Diagram

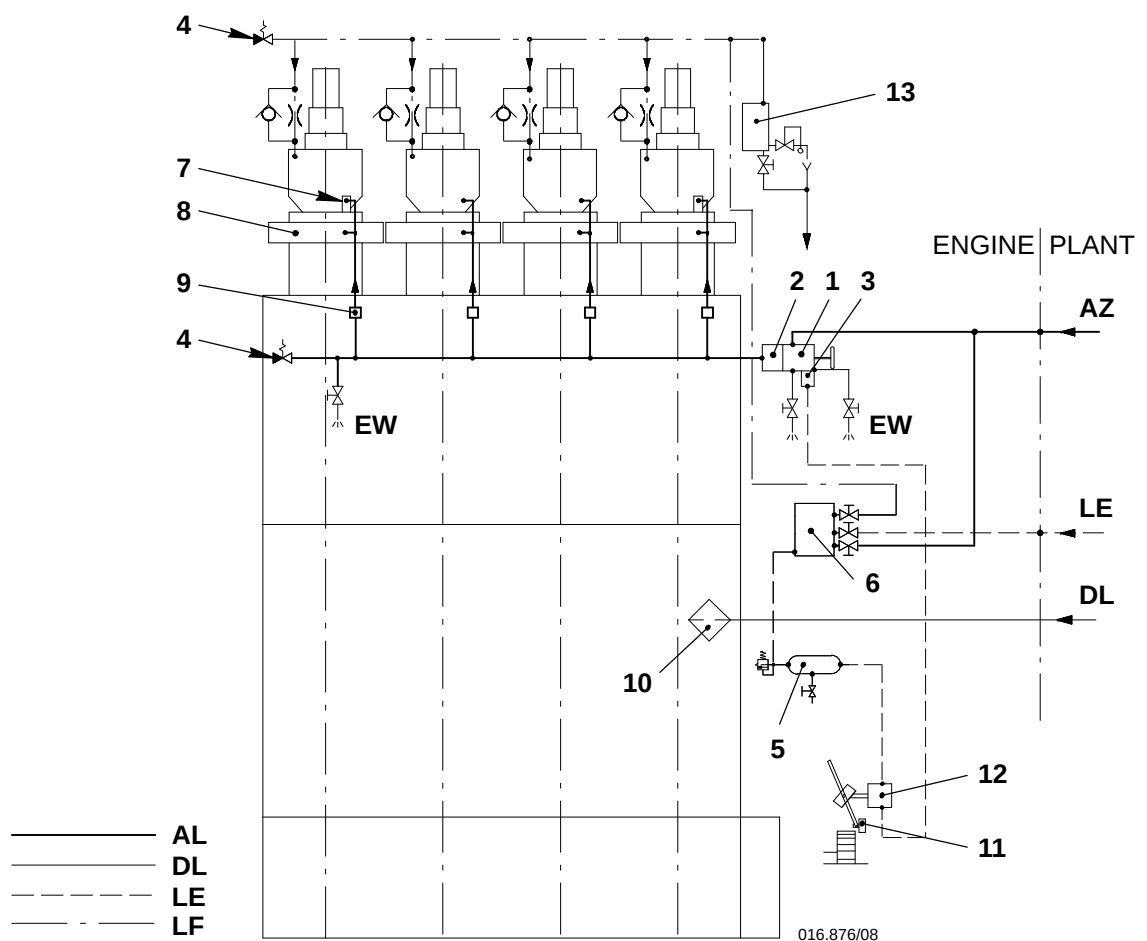
## 1. General

The piping arrangement of the starting air system is shown on the schematic diagram.

The control air required for the control of the engine is supplied by control air supply unit 6 and control air bottle 5. The correlation with the engine control is depicted in control diagrams 4003-2 and 4003-3.

The compressed air used should be clean and dry.

The starting air system must be cleared of condensed water by opening the drain valves at regular intervals.



## Key to Diagram:

- |                                                   |                                       |
|---------------------------------------------------|---------------------------------------|
| 1 Shut-off valve for starting air                 | 11 Turning gear                       |
| 2 Non-return valve                                | 12 Blocking valve on turning gear     |
| 3 Control valve and valve unit for start <b>E</b> | 13 Oil leakage return from air spring |
| 4 Safety valve                                    | AL Starting air                       |
| 5 Air bottle for control air supply unit <b>A</b> | AZ Starting air inlet                 |
| 6 Control air supply unit <b>A</b>                | DL Compressed air from board system   |
| 7 Starting valve                                  | EW Vent and drain                     |
| 8 Cylinder cover                                  | LE Control air (board supply)         |
| 9 Flame arrester                                  | LF Air spring air                     |
| 10 Automatic fine filter                          |                                       |

## Fuel Oil System

---

### 1. General

For heavy fuel operation the pre-heating as well as keeping warm during a short engine stop must be ensured.

For this reason all pipes to injection control units 14 are provided with heating pipes and insulated accordingly.

For safety reasons rail unit 38 is provided, and all pipes are double-walled designed in the high pressure circuit outside the rail unit.

### 2. Low pressure circuit

The fuel oil is delivered via fuel inlet pipe 1 to fuel pumps 3 by a booster pump installed in the plant. The delivered fuel quantity is considerably greater than actually required by the engine. The specified booster pressure is adjusted by pressure retaining valve 6. The surplus fuel is led back to the system via fuel outlet pipe 4.

#### 2.1 Setting the pressure retaining valve

The setting values of the fuel pressure have to be adjusted in accordance with the indications on Operating Data Sheet [0250-1](#) for 'fuel pump inlet' and 'fuel pump return' (after pressure retaining valve).

The pressure to be adjusted on pressure gauge 7 'fuel pump return' is raised when adjusting spindle 39 is turned in a clockwise direction (+) and, when it is turned in an anti-clockwise rotation, lowered (-). Both locking nuts 40 and 41 must be loosened for adjusting the spindle.

If the low pressure circuit must be drained (i.e. due to removal of a fuel pump), it can be drained by means of drain valves 33 and 34 (see Fig. 'A' and 'C').

### 3. High pressure circuit

Prior to the first commissioning or after maintenance works on the high pressure circuit, fuel rail 13 can be connected to the servo oil rail (4.11) by tool 94583 (pipe). The servo oil service pump generates the required pressure via the servo oil system for a leak test and quick venting the high pressure circuit (see [0120-1](#) 'Venting and leak test of fuel system on engine').

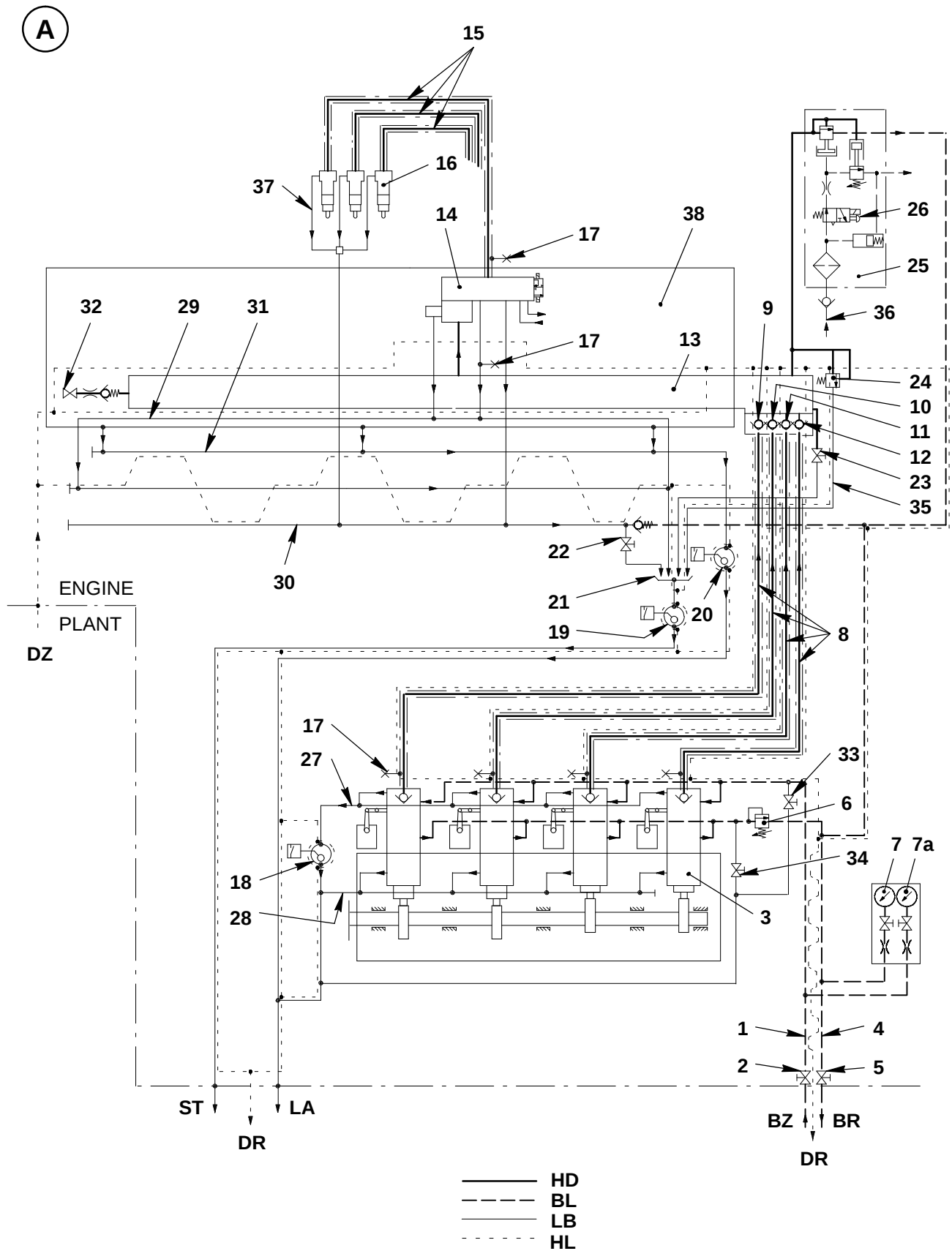
The pumps 3 deliver fuel under high pressure into the fuel rail via rising pipes 8. They supply as much fuel as necessary to maintain the required pressure (load-dependent) in the fuel rail (see Fuel Pump [5556-1](#)).

The injection control units 14 control the fuel injection volume to each injection valve 16.

Non-return valves 9, 10, 11 or 12 are provided to prevent a pressure drop in the fuel rail by breakage of a fuel rising pipe 8.

Leakage inspection points 17 are provided on the flanges of rising pipes 8 and injection pipes 15 in order to localize easily possible leakages (see section 4).

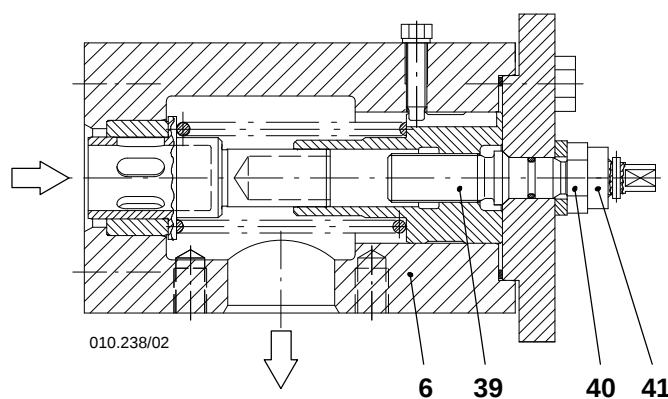
## Fuel Oil System



## Fuel Oil System

**Key to Illustrations: 'A' Fuel oil system on engine**  
**'B' Pressure retaining valve**

- |                                                                |                                                       |
|----------------------------------------------------------------|-------------------------------------------------------|
| 1 Fuel inlet pipe 3.24                                         | 28 Leakage fuel from fuel pumps                       |
| 2 Shut-off valve                                               | 29 Leakage fuel (collecting) pipe 3.46                |
| 3 Fuel pump 3.14                                               | 30 Leakage fuel collecting pipe from injection valves |
| 4 Fuel outlet pipe                                             | 31 Leakage drain from rail unit                       |
| 5 Shut-off valve                                               | 32 Plug 3.39                                          |
| 6 Pressure retaining valve 3.53                                | 33 Drain valve (fuel inlet)                           |
| 7, 7a Pressure gauge                                           | 34 Drain valve (fuel outlet)                          |
| 8 Fuel rising pipe 3.29 (high pressure)                        | 35 Drain pipe from item 24                            |
| 9 Non-return valve 3.81-1                                      | 36 Connection from bearing oil system                 |
| 10 Non-return valve 3.81-2                                     | 37 Fuel leakage pipe 3.49                             |
| 11 Non-return valve 3.81-3                                     | 38 Rail unit (casing)                                 |
| 12 Non-return valve 3.81-4                                     | 39 Adjusting spindle                                  |
| 13 Fuel rail 3.05                                              | 40 Locking nut                                        |
| 14 Injection control unit 3.02                                 | 41 Locking nut                                        |
| 15 Injection pipe 3.47                                         |                                                       |
| 16 Injection valve 3.01                                        |                                                       |
| 17 Leakage inspection point 3.17                               |                                                       |
| 18 Level switch LS3426A                                        |                                                       |
| 19 Level switch LS3446A                                        | BL Fuel piping system                                 |
| 20 Level switch LS3444A                                        | BR Fuel return                                        |
| 21 Leakage inspection device 3.12                              | BZ Fuel supply                                        |
| 22 Drain valve 3.65                                            | DR Steam outlet                                       |
| 23 Drain valve 3.82                                            | DZ Steam inlet                                        |
| 24 Fuel overpressure safety valves 3.52                        | HD High pressure piping system                        |
| 25 Fuel pressure control valve 3.06                            | HL Heating (tracing) pipe                             |
| 26 Fuel shut-down pilot valve 3.08                             | LA to fuel overflow tank                              |
| 27 Leakage fuel collecting pipe of rising pipes and fuel pumps | LB Leakage fuel pipe                                  |
|                                                                | ST to sludge tank                                     |

**B**

## 4. Fuel leakage system

All important leakages in the fuel oil system are monitored by level switches (LS).

In case of excessive leakage quantity the corresponding alarm is triggered:

| Level switch                   | Monitored components                                                                         |
|--------------------------------|----------------------------------------------------------------------------------------------|
| LS3444A                        | Leakages (fuel and servo oil) from the rail unit                                             |
| LS3445A<br>(9 to 12 cylinders) |                                                                                              |
| LS3446A                        | Injection pipes 15, injection control units 14, responding fuel overpressure safety valve 24 |
| LS3426A                        | Rising pipes 8, fuel pumps 3                                                                 |

### 4.1 Leakage monitoring and inspection points

Leakage inspection device 21 and several leakage inspection points 17 are provided for proper leakage localization (see Fig. 'A').

If an alarm has been triggered by level switch 18 (LS3426A) or 19 (LS3446A), the leakage can be localized by means of loosening the corresponding drain screws 42, nut with conical plug 36 and the corresponding measures can be taken (see Fig. 'C' to 'E').



**Risk of injury!** Always use gloves when working on hot components! Always wear safety goggles; fuel may spurt on drain screws and nuts with conical plugs when opening them.

### 4.2 Leakage localization at fuel rising pipes 8 (3.29)

- Alarm by level switch 18 (LS3426A).

#### Procedure:

- ⇒ Carefully loosen the drain screw 42 on flange 43 of the fuel rising pipe by approx. two turns and check whether fuel flows out or not (see Fig. 'C').
- ⇒ Replace defective fuel rising pipe (see [0515-1](#) 'Exchange of defective fuel rising pipe' and Maintenance Manual [8752-1](#)).



A defective fuel rising pipe may only be replaced at engine standstill!  
If the fuel rising pipe cannot be replaced immediately, then the corresponding fuel pump must be cut out (see Cutting Out and Cutting In of the Fuel Pump [5556-2](#)).

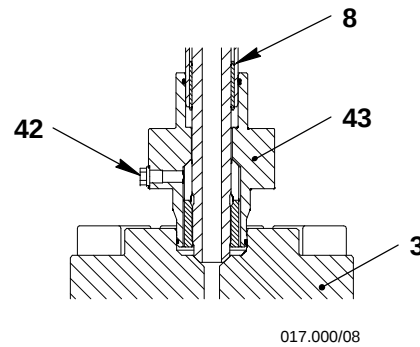
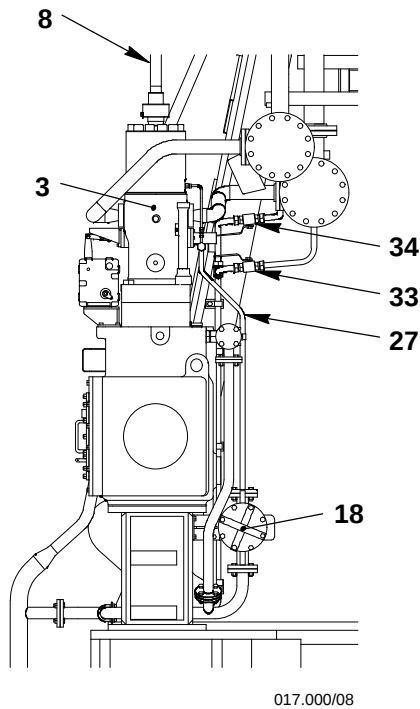


**Remark:** If the engine may not be stopped, the fuel supply must be interrupted by means of cutting out the corresponding fuel pump in Pos. '0' using tool 94555 (see Faults in High Pressure Fuel System [0515-1](#)).

With a cut out fuel pump, the engine can not anymore be operated at full load (see Cutting Out and Cutting In of the Fuel Pump [5556-2](#)).

## Fuel Oil System

C



017.000/08

**Key to Illustration: 'C'****Leakage inspection point of rising pipes**

- 3 Fuel pump 3.14
- 8 Fuel rising pipe 3.29
- 18 Level switch LS3426A
- 27 Leakage fuel collecting pipe of rising pipes and fuel pumps
- 33 Drain valve (fuel inlet)
- 34 Drain valve (fuel outlet)
- 42 Drain screw 3.17
- 43 Flange

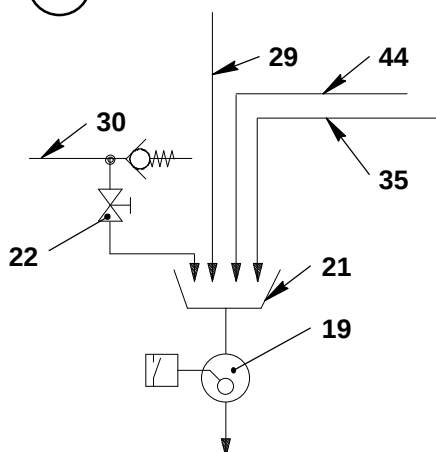
**4.3 Leakage inspection device 21 (3.12)**

Leakages from the rail unit or emtyings can be ascertained at leakage inspection device 21 (see Fig. 'A' and 'B').

Should a cylinder cover or injection valves to be removed, fuel leakage pipes 3.49 must be drained by means of drain valve 22 (see Fig. 'A' and also Injection Valve 2722-1).

Fuel rail 13 can be depressurized or emptied via drain pipe 44 using drain screw 23.

D

**Key to Illustration: 'D'****Leakage inspection point**

- 19 Level switch LS3426A
- 21 Leakage inspection device 3.12
- 22 Drain valve 3.65
- 29 Fuel leakage pipe 3.46
- 30 Leakage fuel collecting pipe from injection valves
- 35 Drain pipe from fuel overpressure safety valves 3.52
- 44 Drain pipe

Fuel Oil System

---

**4.4 Leakage localization at injection pipes 15 (3.47)**

- Alarm by level switch 19 (LS3446A).

**Procedure:**

⇒ Carefully loosen drain screw 45 on flange 46 of injection pipe 15 by approx. two turns and check whether fuel flows out or not (see Fig. 'E').



**Remark:** The affected cylinder can be mostly ascertained at the exhaust temperature deviation after cylinder.

⇒ Replace defective injection pipe (see 0510-1 'Exchange of defective injection pipe' and Maintenance Manual 8733-1).



A defective injection pipe may only be replaced at engine standstill! If the injection pipe cannot be replaced immediately, then the injection of the corresponding cylinder must be cut out (see Operation with Injection Cut Out 0510-1).



**Remark:** With injection cut out (Inj. CUT OFF), the engine can only be operated at reduced load.

**4.5 Leakage localization at injection control units 14 (3.02)**

- Alarm by level switch 19 (LS3446A).
- No leakage was ascertained during checking injection pipes 15.

**Procedure:**

⇒ **Carefully loosen** nut with conical plug 47 on return pipe 48 **by max. two turns** and check whether fuel flows out or not (see Fig. 'F').



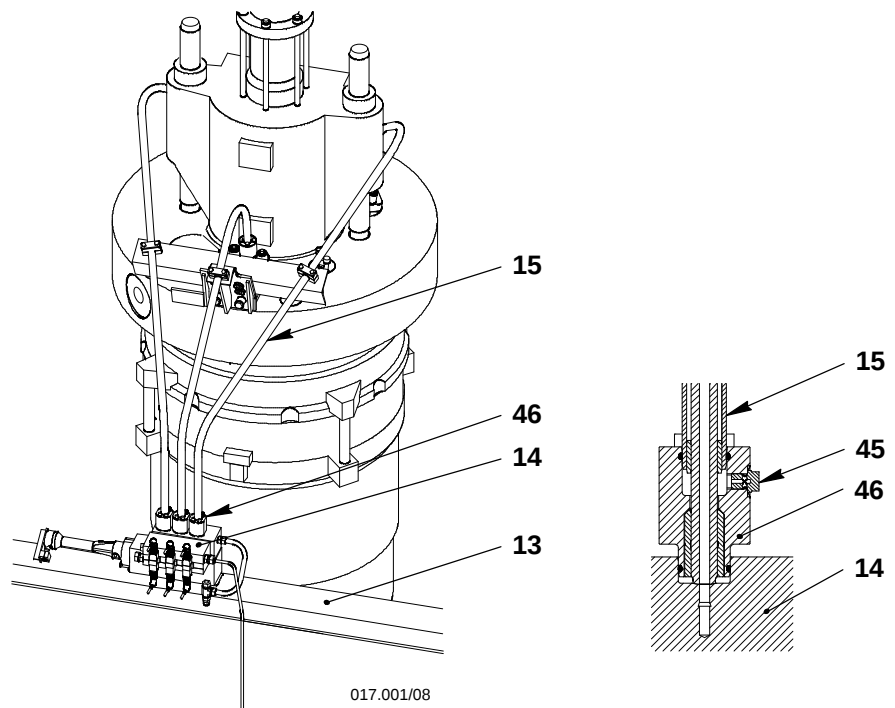
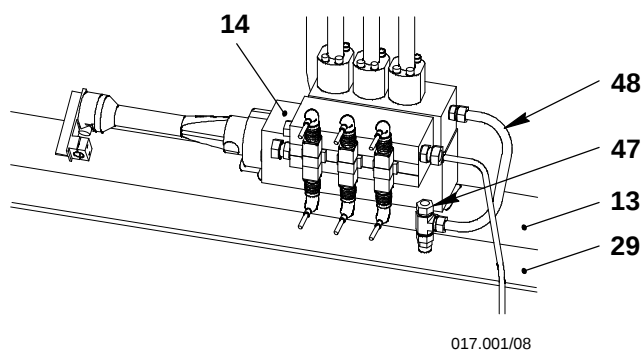
**Risk of injury! Never** remove nut with conical plug during operation; hot fuel may spurt!

⇒ Replace defective injection control unit (see 0510-1 'Exchange of defective injection control unit' and Maintenance Manual 5564-1).



A defective injection control unit may only be replaced at engine standstill! If the injection control unit cannot be replaced immediately, then the injection of the corresponding cylinder must be cut out (see Operation with Injection Cut Out 0510-1).

## Fuel Oil System

**E**

**F**


**Key to Illustrations:** 'E' Leakage inspection point of injection pipes  
'F' Leakage inspection point of injection control units

- |                                |                                 |
|--------------------------------|---------------------------------|
| 13 Fuel rail 3.05              | 45 Drain screw (4.17)           |
| 14 Injection control unit 3.02 | 46 Flange                       |
| 15 Injection pipe 3.47         | 47 Nut with conical plug (4.17) |
| 29 Fuel leakage pipe 3.46      | 48 Return pipe                  |
| 38 Rail unit (casing)          |                                 |



## Drainage System and Wash-water Piping System

---

### 1. General

All drain pipings, in particular those from piston underside 10 and piston rod glands 8 must be periodically checked for free passage.

Condensate may flow out before and after the cooler at the water drain 11, depending on ambient temperature and humidity. Under extreme ambient conditions a quantity of up to 0.16 kg/kWh of condensate may result.

### 2. Condensate drain

A perfect functioning of this drain must be ensured.

The following important points have to be taken into account:

The butterfly valves 26 and 26a must always be open during operation.

- All perhaps existing valves must be fully open in the drain pipe.



**Remark:** 3-way ball cock 17 must be usually in position NORMAL OPERATION (see Fig. 'B').

- Dirt particles (rust residue) are collected in the condensate collectors 20 and 20a; they must be removed periodically at engine standstill (see Maintenance Manual 0380-1).
- Check periodically the water flow at the sight glasses of condensate collectors 20 and 20a.

See also 0240-1 'Checks and precautions'.



**Remark:** If an alarm 'Condensate level too high' has been triggered via one or both level switch(es) 7 and 7a, the reason for it must be **investigated and remedied immediately**.

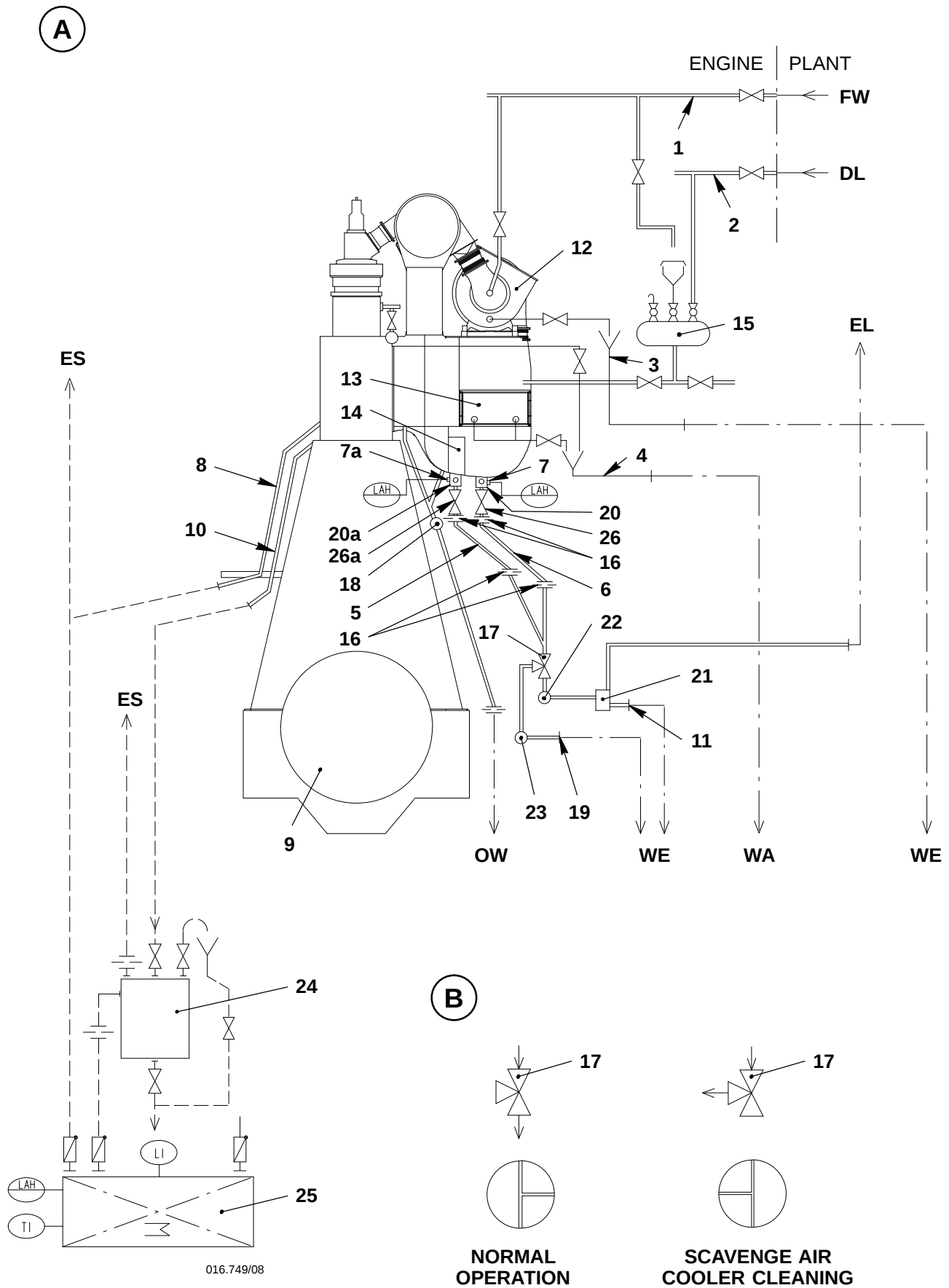
- 3-way ball cock 17 in position CLOSED (see Fig. 'B').
- Butterfly valves 26 and/or 26a closed.
- Defective scavenge air cooler (see 0550-1).
- Throttling disc(s) 16 choked.
- Excessive dirt deposits in the condensate collectors 20 and 20a (filter clogged)



**Attention!** The filters in the condensate collectors and the throttling discs must be cleaned as soon as possible. Cleaning the throttling disc may only be carried out at engine standstill.

No-one or inadequate drain leads to an excessive collection of condensate in the scavenge air receiver. Water in liquid or evaporated state swept along by the air flow has a negative influence on the piston running behaviour and leads to wear increase of piston rings and cylinder liners.

## Drainage System and Wash-water Piping System



## Drainage System and Wash-water Piping System

---

### Key to Illustrations: 'A' Diagram 'B' Positions of 3-way ball cock 17

|       |                                                               |         |                                                              |
|-------|---------------------------------------------------------------|---------|--------------------------------------------------------------|
| 1     | Wash-water distributing pipe                                  | 19      | Cleaning agent and wash-water drain from scavenge air cooler |
| 2     | Compressed air distributing pipe                              | 20, 20a | Condensate collector (with sight glass and filter)           |
| 3     | Wash-water drain from turbocharger (for TPL type)             | 21      | Venting unit                                                 |
| 4     | Cylinder cooling water and scavenge air cooler drain          | 22      | Condensate collector main                                    |
| 5     | Condensate pipe from water separator                          | 23      | Dirty water collector main                                   |
| 6     | Condensate and wash-water pipe from scavenge air cooler       | 24      | Sludge oil trap (with heating coil)                          |
| 7, 7a | Level switch for condensate drain                             | 25      | Sludge oil tank                                              |
| 8     | Dirty oil from piston rod gland                               | 26, 26a | Butterfly valve                                              |
| 9     | Engine                                                        |         |                                                              |
| 10    | Dirty oil drain from piston underside                         |         |                                                              |
| 11    | Condensate drain from water separator and scavenge air cooler | DL      | Air line from board system                                   |
| 12    | Exhaust gas turbocharger                                      | EL      | Vent                                                         |
| 13    | Scavenge air cooler                                           | ES      | to venting collector                                         |
| 14    | Water separator                                               | FW      | from fresh-water system                                      |
| 15    | Scavenge air cooler washing plant                             | LAH     | Level alarm high                                             |
| 16    | Throttling disc                                               | LI      | Level indicator                                              |
| 17    | 3-way ball cock                                               | OW      | Drain to oil / water drain tank                              |
| 18    | Water drain from scavenge air receiver (oily water)           | TI      | Temperature indicator                                        |
|       |                                                               | WA      | Drain to water drain tank                                    |
|       |                                                               | WE      | Drain to bilge water tank                                    |



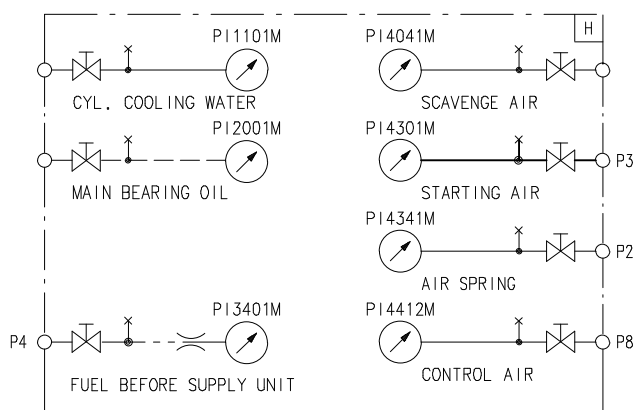
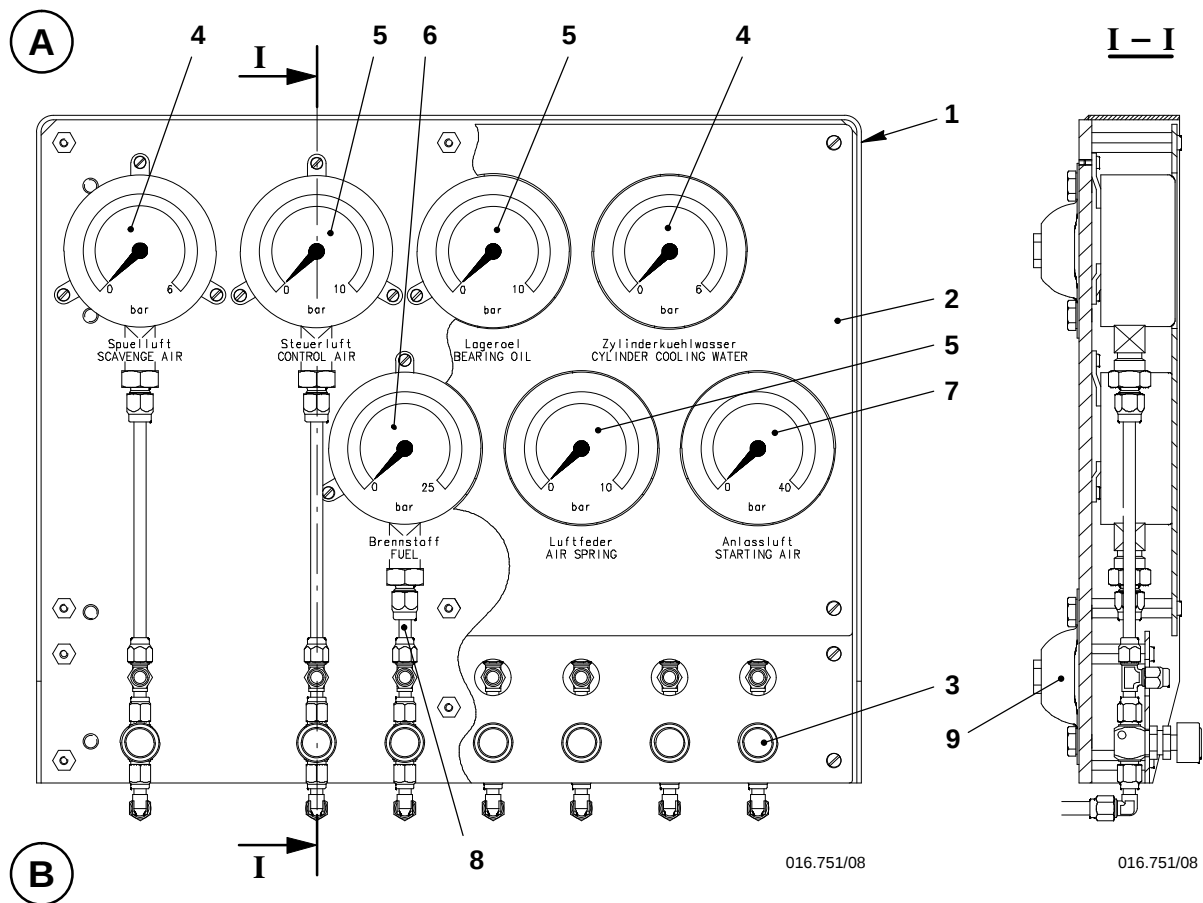
## Instrument Panel

## 1. General

Instrument panel 1 is arranged beside to the control box. It contains pressure gauges required for the visual observation of the pressures. Pressure indications for fuel and servo oil are provided in the local control panel (see 4618-1).

Fig. 'B' shows the schematic arrangement of instrument panel **H** with the same indications also contained in the Control Diagram 4003-2.

The corresponding pressure switches and pressure transmitters have been described in 9258-1.



### Key to Illustrations Fig. 'A' and 'B':

- 1 Instrument panel
- 2 Cover plate
- 3 Precision control valve
- 4 Manometer 6 bar
- 5 Manometer 10 bar
- 6 Manometer 25 bar
- 7 Manometer 40 bar
- 8 Throttle piece
- 9 Anti-vibration mounting

## Crank Angle Sensor Unit

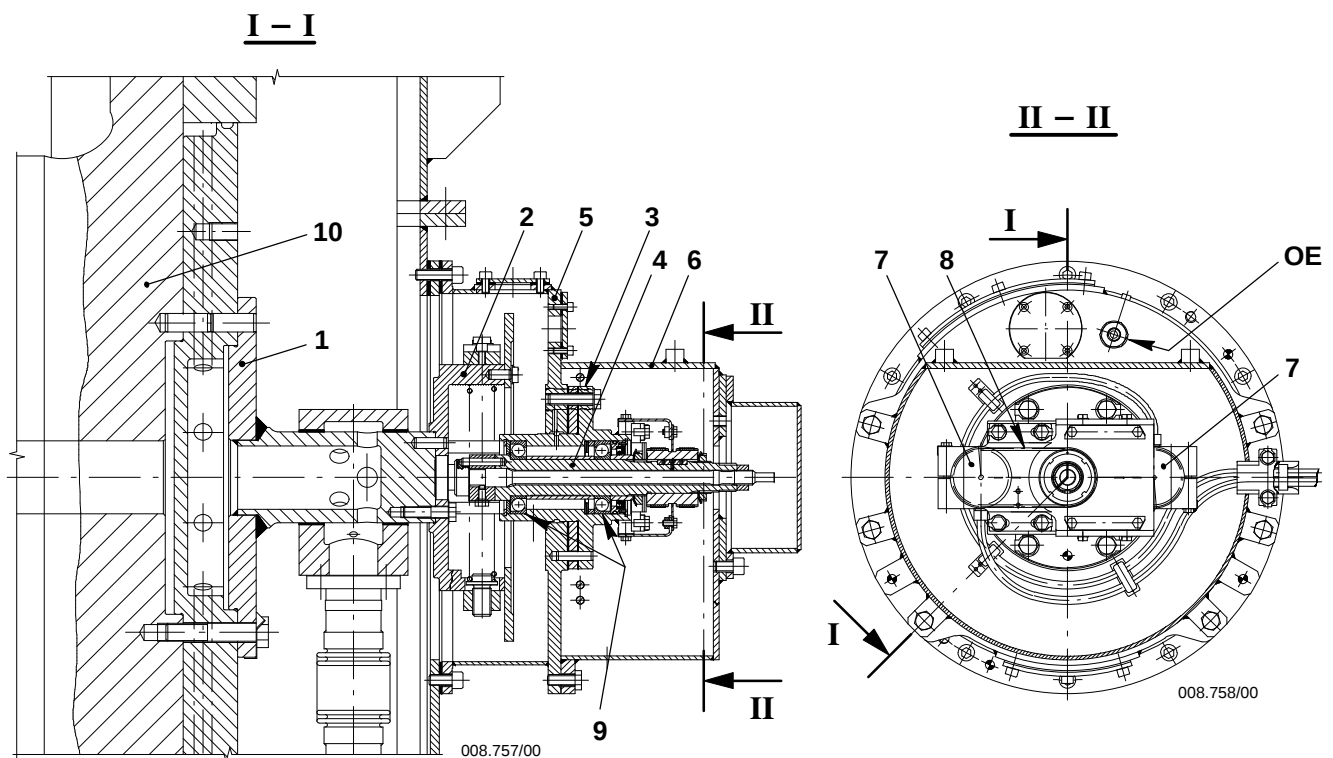
## 1. General

The crank angle sensor unit is arranged at the free end. The connecting unit 2 is fastened to the crankshaft 10 over the driving shaft 1. It receives all unwanted radial and axial movements of the crankshaft.

Indicating the crank angle position, both crank angle sensors 7 are driven by the toothed belt 8. The position of the TDC signal is monitored by a separate proximity sensor (see Pick-up for Speed Measurement [4628-1](#)).

All deviations are monitored and indicated with an alarm, slow-down or shut-down.

Lubrication of the ball bearing 9 must be ensured by carrying out periodical checks at engine standstill (see Maintenance Manual [0380-1](#) and [9223-1](#)).



## Key to Illustrations:

- |                       |                                     |
|-----------------------|-------------------------------------|
| 1 Driving shaft       | 7 Crank angle sensor (GT5126C, 27C) |
| 2 Connecting unit     | 8 Toothed belt                      |
| 3 Shaft encoder drive | 9 Ball bearing                      |
| 4 Shaft               | 10 Crank shaft                      |
| 5 Housing             |                                     |
| 6 Protection hood     | OE Oil inlet                        |

## Pressure Switches and Pressure Transmitters

### 1. General

The pressure switches and transmitters are mounted on a common plate at the driving end. They fulfil monitoring functions of the pressure systems in case of too low a pressure or in the case of a pressure loss.

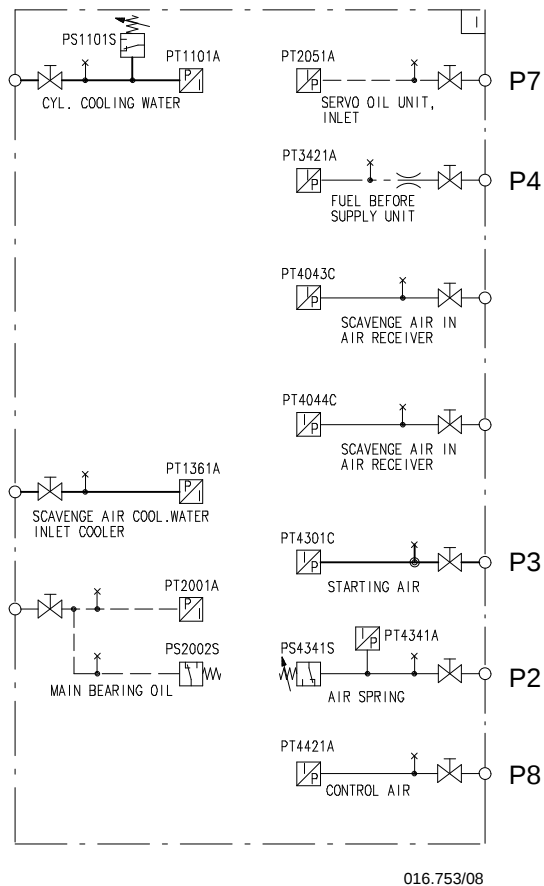
Their control signals effect the following commands:

- Alarm (ALM)
- Slow-down (SLD)
- Shut-down (SHD)

See Alarms and Safeguards at Continuous Service Power [0250-2](#).

Fig. 'A' gives a schematic diagram of the pressure switches and pressure transmitters  with the indications, as also determined in the control diagram [4003-2](#).

**A**



#### Key to Illustrations:

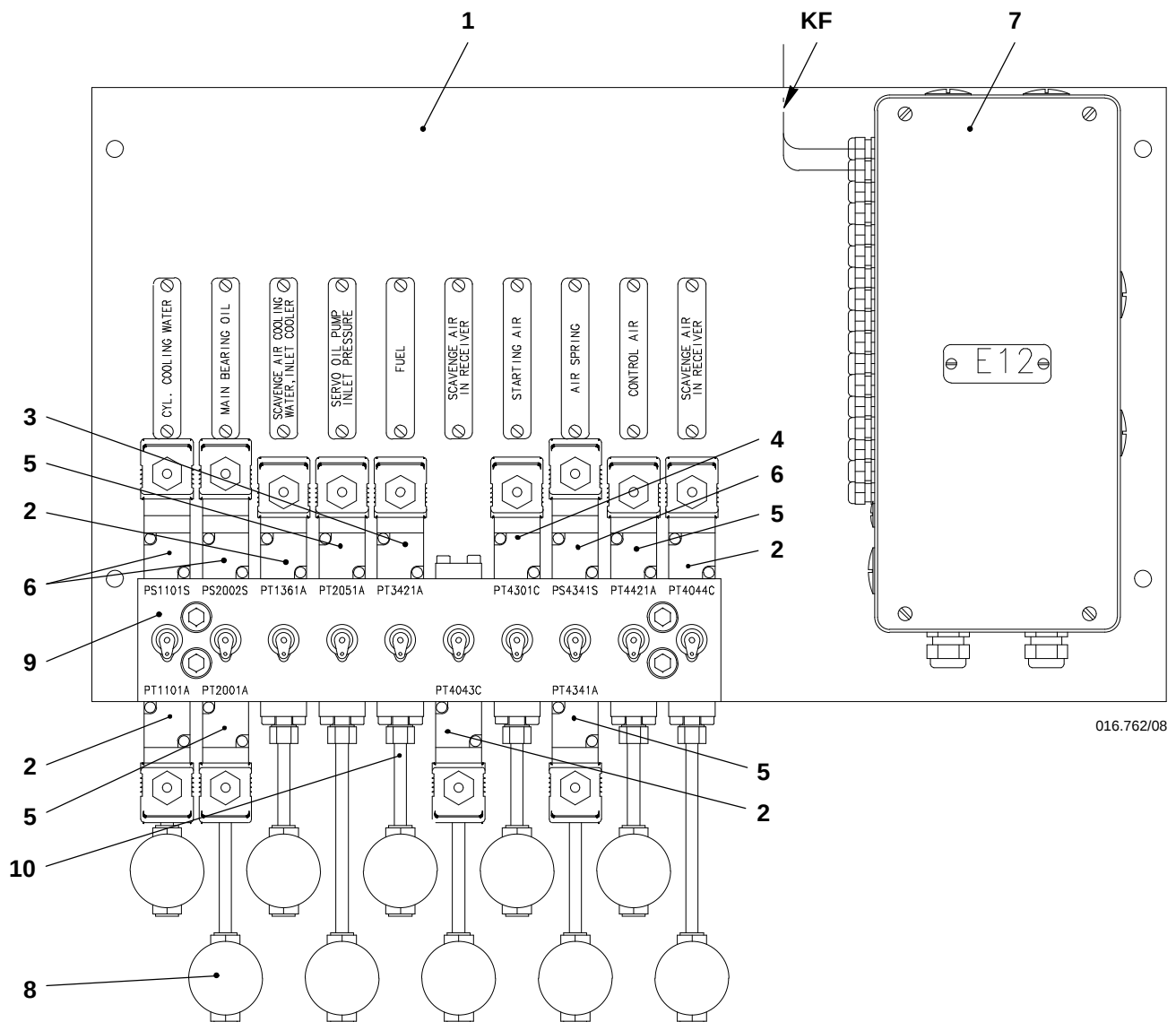
- 'A' Diagram of unit  (pressure switches and pressure transmitters)
- 'B' Arrangement of pressure switches and pressure transmitters

- |    |                      |        |
|----|----------------------|--------|
| 1  | Plate                |        |
| 2  | Pressure transmitter | 6 bar  |
| 3  | Pressure transmitter | 16 bar |
| 4  | Pressure transmitter | 40 bar |
| 5  | Pressure transmitter | 10 bar |
| 6  | Pressure switch      | 6 bar  |
| 7  | Switch box           |        |
| 8  | Needle valve         |        |
| 9  | Terminal bar         |        |
| 10 | Throttle piece       |        |

KF Cable

## Pressure Switches and Pressure Transmitters

B.



## Oil Mist Detector

### 1. General

The engine is equipped with an oil mist detector. The oil mist detection system includes control panel 1 located in the control room, sensors 2 and junction boxes 3 on the engine. The system continuously measures the density of oil mist in the crankcase and triggers an alarm when the oil mist intensity is too high. With this, possible bearing damages can be detected at an early stage and explosions in the crankcase can be prevented (see also Instructions Concerning the Prevention of Crankcase Explosions 0460-1).

There are sensors mounted on fuel side of the engine provided for every cylinder of the divided crankcase, for the fuel pump drive and in the fuel pump unit 10 (see Fig. 'B').

### 2. Function

Every single sensor monitors optically the density of oil mist and, in addition checks itself for any internal faults.

Data communication occurs from junction box to control panel (see Fig. 'A').

The adjustments can be programmed in the control panel.

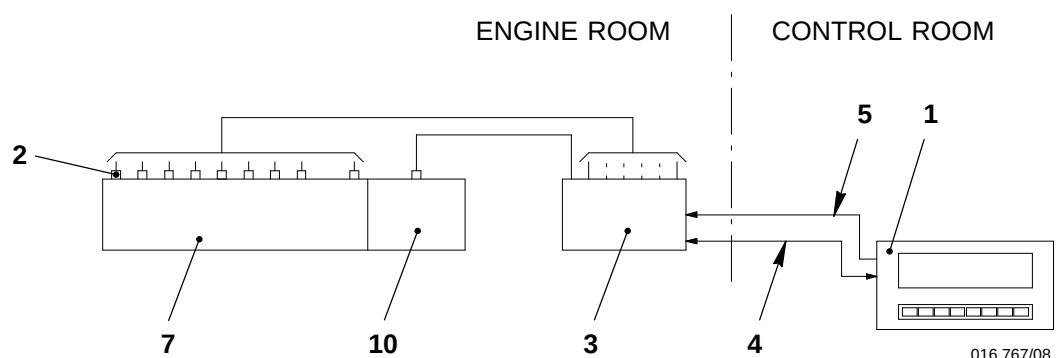
The menu-driven software contains three user levels:

- USER: Read-out of data only.
- OPERATOR: Password-protected level for access to most adjustments and functions.
- SERVICE: Password-protected level for authorized staff of manufacturer and service personnel.

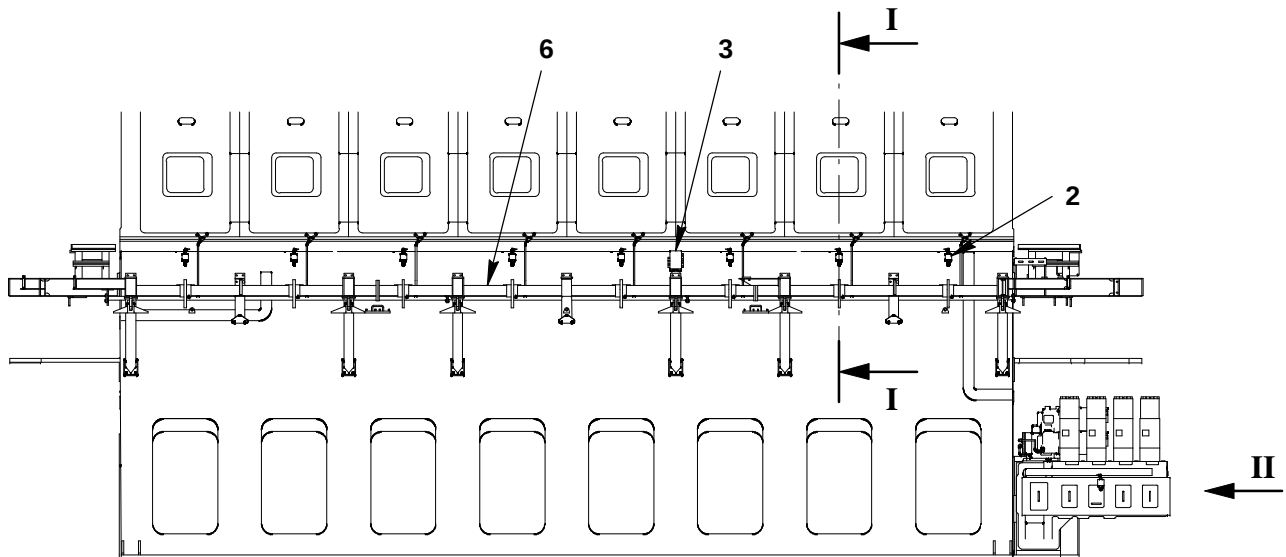


**Remark:** Detailed instructions regarding adjustments, commissioning and fault detection, as well as servicing and maintenance work, are contained in the respective Manual of the manufacturer.

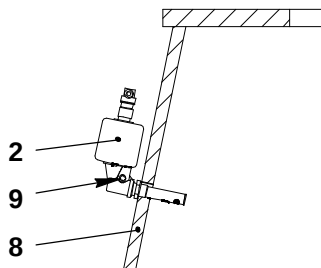
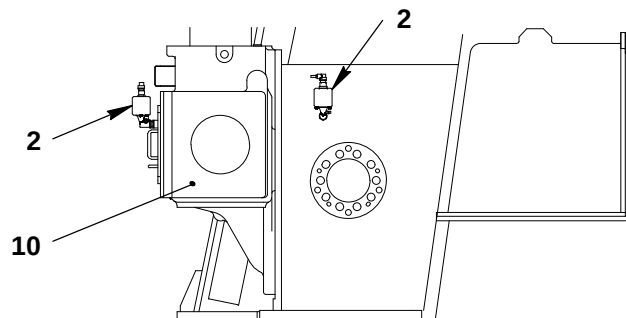
A



## Oil Mist Detector

**B**

016.768/08

**I - I****II**

**Key to Illustrations:**

|            |                               |
|------------|-------------------------------|
| <b>'A'</b> | <b>Schematic presentation</b> |
| <b>'B'</b> | <b>Arrangement of sensors</b> |

- |                 |                           |
|-----------------|---------------------------|
| 1 Control panel | 6 Cable guide             |
| 2 Sensor        | 7 Engine                  |
| 3 Junction box  | 8 Engine housing (column) |
| 4 Data cable    | 9 Test connection         |
| 5 Power cable   | 10 Fuel pump unit         |

## Location of flex Electronic Components

---

### 1. General

The electronic components required for the engine control system WECS-9520 are mainly arranged on the engine (Fig. 'A').

Exception is the power supply box which is placed nearby the engine (Fig. 'B').

### 2. Control boxes

The most important control and power supply boxes are described as follows:

#### **E90 (SIB):**

Control box serves as communication to the external systems and contains a FCM-20 as 'Online Spare Module'.  
Arranged in the middle of rail unit.

#### **E95.01 to E95.12:**

Control boxes (depending on number of cylinders) contain a FCM-20 module each.  
Arranged on rail unit at every cylinder.

#### **E41.01 to E41.12:**

Control boxes (depending on number of cylinders) contain a ALM-20 module each for controlling the cylinder lubricating system.  
They are arranged nearby the lubricating pumps at every cylinder.

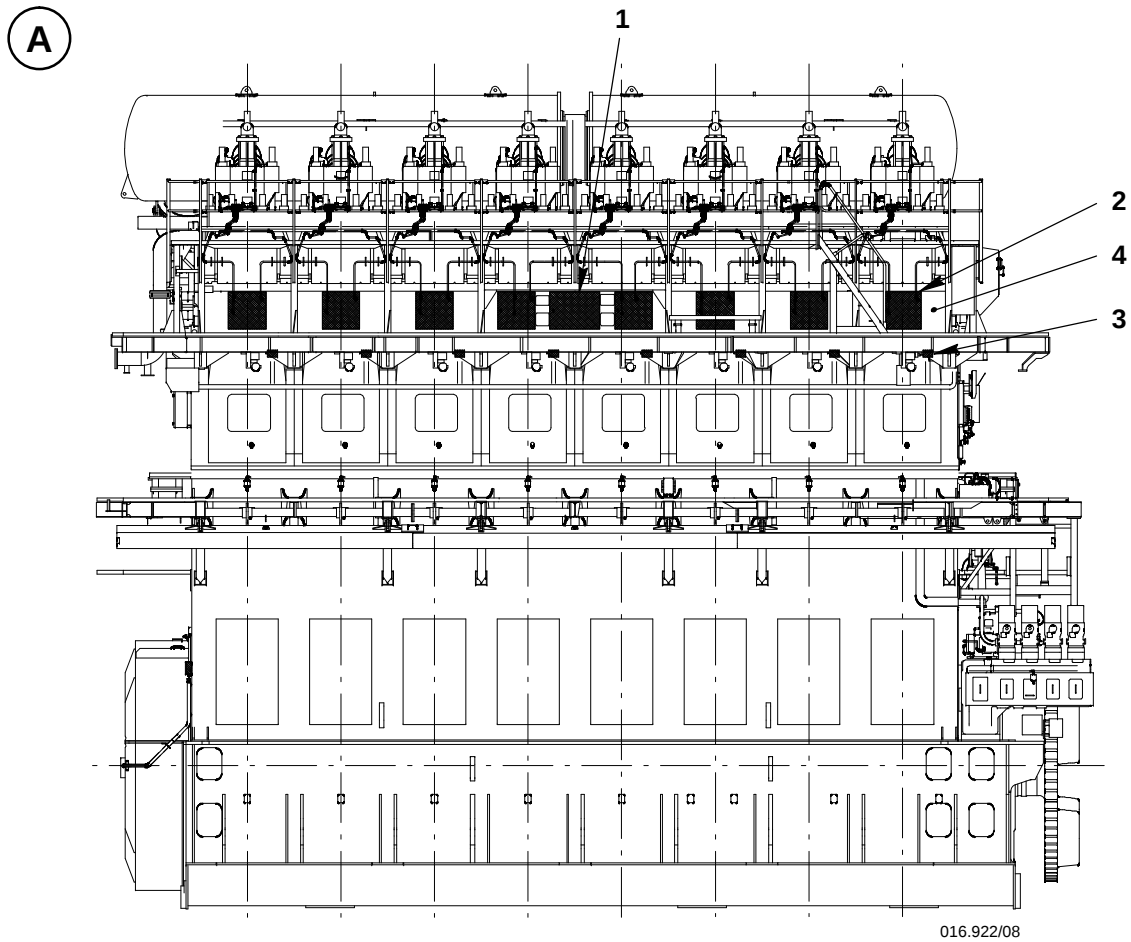
#### **E85:**

Power supply box for FCM-20 modules, fuel pump actuators and ALM-20 modules is placed in the engine room nearby the engine.  
Among other parts there are circuit breakers able to interrupt the power to FCM-20 modules or fuel pump actuators when required individually or completely or to all ALM-20 modules.



**Remark:** The power supply is redundant. To interrupt the whole WECS-9520, make sure that both power inputs are switched off (see also block diagram in the control box).

## Arrangement of flex Electronic Components



**B**

**Power supply box  
located in engine room  
nearby engine**

**E85**



**Key to Illustrations: Fig. 'A'**

- 1 Control box E90
- 2 Control box E95.01 (Cyl. 1)
- 3 Control box E41.01 (Cyl. 1)
- 4 Rail unit

|                                |           |
|--------------------------------|-----------|
| For Particular Attention ..... | 0000–1/A1 |
|--------------------------------|-----------|

## ▽ General

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| – Slow Turning .....                                          | 0220–1/A1 |
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| – Viscosity - Temperature Diagram .....                                | 0270–2/A1 |
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## Bedplate and Tie Rod

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|                      |                           |
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## Cylinder Liner and Cylinder Cover

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|                                            |                           |
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| Injection Valve .....                      | <a href="#">2722-1/A1</a> |
| Starting Valve .....                       | <a href="#">2728-1/A1</a> |
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|                                                 |                           |
|-------------------------------------------------|---------------------------|
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| Fuel Pump Unit .....                              | <a href="#">5581-1/A1</a> |
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|                             |                           |
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