Winterthur Gas & Diesel

WIN GD	RT-flex48T-D

Operation Manual

“Marine” Pulse Lubrication

Vessel:

Type:

Engine No.:

Document ID: DBAC350924

Winterthur Gas & Diesel Ltd.
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RT-flex48T-D Pulse Lubrication				**Summary for Operation Manual (OM)**		
Page No.	Modification		Title	Subject	Page or Manual	
	Date	No.			new	exch.
	2012			**Operation Manual, Issue 2012**	x	
				Date of publication 2012-03-21		
0220-1/A1	2012-08		Operation under Normal Conditions	Crank angle algorithm sentence added		x
0850-1/A1 (38, 39, 42)			Failures and Defects of WECS Components	The word 'check' removed from ACM row, Data added to page 42.		x
4002-1/A1 (3, 13, 14)		DAAD023059	Engine Control System WECS-9520	Correction made to Fig.B. Crank angle algorithm data added		x
4628-1/A1			Pickup for Speed Measurement	Proximity sensor data changed in text and illustration		x
9223-1/A1 (1)			Crank Angle Sensor Unit	Illustration detail changed. Attention paragraph added,		x
				Date of publication 2012-08-14		
OM_2015-07	2015-07		Cover page, Disclaimer and all related pages	Data about Winterthur Gas & Diesel (WinGD) and Wärtsilä Services Switzerland (WSCH) added; New Layout WinGD; New disclaimer and data about WinGD and WSCH added;		x
0000-1/A1	2015-07		For Your Attention	Data updated (WinGD and WSCH added);		x
0020-1/A1	2015-07		Table of Contents	New Chapter 7218-3/A1 added		x
0030-1/A1	2015-07		Subject Index	New Chapter 7218-3/A1 added		x
0035-1/A1	2015-07	Service Bulletin RT-138 (Version 4)	Abbreviations	Abbreviations added		x
0210-1/A1	2015-07		Safety Precautions and Warnings	Chapter updated, new structure;		x
0270-1/A1	2015-07	Service Bulletin RT-82	Changing Over from Diesel Oil to Heavy Fuel Oil and Vice Versa	Temperature gradient changed from 15°C/min to 2°C/min related to the Service Bulletin;		x
0280-1/A1	2015-07	Service Bulletin RT-138 (Version 4)	Operation at Low Load	Reference to 0750-1 paragraph 3.3 added		x
0320-1/A1	2015-07		Engine Shutdown	Chapter updated: Controlled English paragraph 1.3: Data about pressure release starting air manifold added		x
0410-1/A1	2015-07	Service Bulletin RT-161	Running-in New Cylinder Liners and Piston Rings	Paragraph 1: Latest data from the Service Bulletin; Chapter updated: Controlled English Paragraph 1: latest data related to the Service Bulletin RT-161 added; Paragraph 5: Note updated; Running-in sequence diagram data about FPP and CPP removed;		x
0710-1/A1	2015-07	EAAD085468 Service Bulletin RT-126	Diesel Engine Fuels	Latest data from fuel specification added; Table 1: maximum sulfur value changed from 4.5 to 3.5 m/m[%]; Fig. 1: Viscosity/Temperature Diagram updated; Note 2) to Fig. 1: min. value for fuel viscosity changed from 13 cSt to 10 cSt; Table 2: Pour point (upper) winter max. value changed from 0 to -6; Carbon residue max. value removed; minor changes in the text; Data about Wärtsilä Service Switzerland Ltd and WinGD added;		x

RT-flex48T-D Pulse Lubrication				**Summary for Operation Manual (OM)**		
Page No.	Modification		Title	Subject	Page or Manual	
	Date	No.			new	exch.
0720-1/A1	2015-07	EAAD085468	Operating Media - Fuel Treatment and Fuel System	Fig. 1: Schematic Diagram - Fuel System updated; Key to Fig. 1: Items 31, 32, 33 added; para 3: minor text changes; para 4: text changed; data about additional leakage collection tank added; Structure of the document changed;		x
0750-1/A1	2015-07	Service Bulletins RT-138 (Version 4) RT-138_1 (Version 4) RT-161	Operating Media	paragraph 2.1: additional data added Table 1: data FZG gear machine test added Table 2: data FZG gear machine test added paragraph 2.4: Sample point added paragraph 3.1: updated Fig. 1: illustration updated paragraph 3.2: new data and Fig. 2 added paragraph 3.3: new paragraph added paragraph 3.4: new paragraph added paragraph 7: new paragraph added paragraph 8.1: new paragraph added paragraph 8.2: list of approved lubricating oils updated paragraph 8.3: new table added added Chapter updated (latest data from Revision 4 of the Service Bulletin RT-138); Fig. 1 and Fig. 2: new illustration with latest data; Table 4: List of Validated Lubricating Oils updated (latest data from January 2015); Table 5: List of Validated System Oils updated (latest data from January 2015);		x
6500-1/A1	2015-07	Service Bulletin RT-162	Turbocharging	Caution added (new data related to the Service Bulletin RT 162, Issue 1)		x
Group 7	2015-07		Group TOC	New Chapter 7218-3/A1 added		x
7218-3/A1	2015-07	Service Bulletin RT-161	Feed Rate - Adjustment	New Chapter added, related to the Service Bulletin RT-161	x	
8016-1/A1	2015-07	Service Bulletin RT-138	Lubricating Oil System	New data about taking dirty oil samples related to the Service Bulletin RT-138; Figure numbers updated;		x
8016-1/A2	2015-07	Service Bulletin RT-138	Lubricating Oil System	New data about taking dirty oil samples related to the Service Bulletin RT-138; Figure numbers updated;		x
				Date of publication 2015-07-14		
All pages	2017-11	Update WinGD	All documents	Engine brand changed from Wärtsilä to WinGD RT-flex48T-D		x
0250-1/A1	2017-04	Update WinGD	Operating Data Sheet Pressure and Temperature Ranges	Torisional vibration damper (damper inlet): Min. pressure value changed from 1.0 bar to 2.8 bar; max. pressure 5.0 bar (value added); Note added;		x
0250-2/A1	2017-04	Update WinGD	Operating Data Sheet Alarms and Safeguards	PT2711A: ALM value changed from 1.0 bar to 2.2 bar; Medium name changed to 'Torsional vibration damper oil (steel spring damper)'; Note added		x
				Date of publication 2017-11-15		
0250-2/A1	2018-01	Update WinGD	Operating Data Sheet Alarms and Safeguards	Cylinder cooling water: values changed acc. RT-174		x
0270-1/A1	2018-01	Update WinGD	Changing Over from Diesel Oil to Heavy Fuel Oil and Vice Versa	Changed procedures		x

RT-flex48T-D Pulse Lubrication				**Summary for Operation Manual (OM)**		
Page No.	Modification		Title	Subject	Page or Manual	
	Date	No.			new	exch.
0410-1/A1	2018-01	Update WinGD	Running-in New Cylinder Liners and Piston Rings	Changed procedures		x
0710-1/A1	2018-01	Update WinGD	Diesel Engine Fuels	Updated specifications		x
0750-1/A1	2018-01	Update WinGD	Lubricating Oil	Updated specifications and new structure		x
7218-3/A1	2018-01	Update WinGD	Feed Rate - Adjustment	Chapter completely deleted, text integrated in 0750-1/A1		x
8016-1/A2	2018-01	Update WinGD	Lubricating Oil System	Procedure for Oil Sampling moved to 0750-1/A1		x
				Date of publication 2018-01-18		

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Operating Descriptions Group 0

1. General

This manual is for the operator and is for use only for the related type of diesel engine (the engine described in this manual). The data in this manual is confidential.

Make sure that you read carefully the Operation Manual before you operate the engine.

Make sure that you know the Inspection and Overhaul intervals in the Maintenance Manual before you operate the engine.

Make sure that you read the data in Group 0 in the Maintenance Manual before you do maintenance work on the engine.

2. Spare Parts

Use only original spare parts and components to make sure that the engine will continue to operate satisfactorily. All equipment and tools for maintenance and operation must be serviceable and in good condition.

The extent of all supplies and services is set exclusively to the related supply contract.

3. Data

The specifications and recommendations of the classification societies, which are essential for the design, are included in this manual.

The data, instructions, graphics and illustrations etc. in this manual are related to drawings from Winterthur Gas & Diesel Ltd. (WinGD). These data relate to the date of issue of the manual (the year of the issue is shown on the title page). All instructions, graphics and illustrations etc can change because of continuous new development and modifications.

4. Personnel

Only qualified personnel that have the applicable knowledge and training must do work on the engine, its systems and related auxiliary equipment.

Data related to protection against danger and damage to equipment are specified in this manual as Warnings and Cautions.

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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 WinGD 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

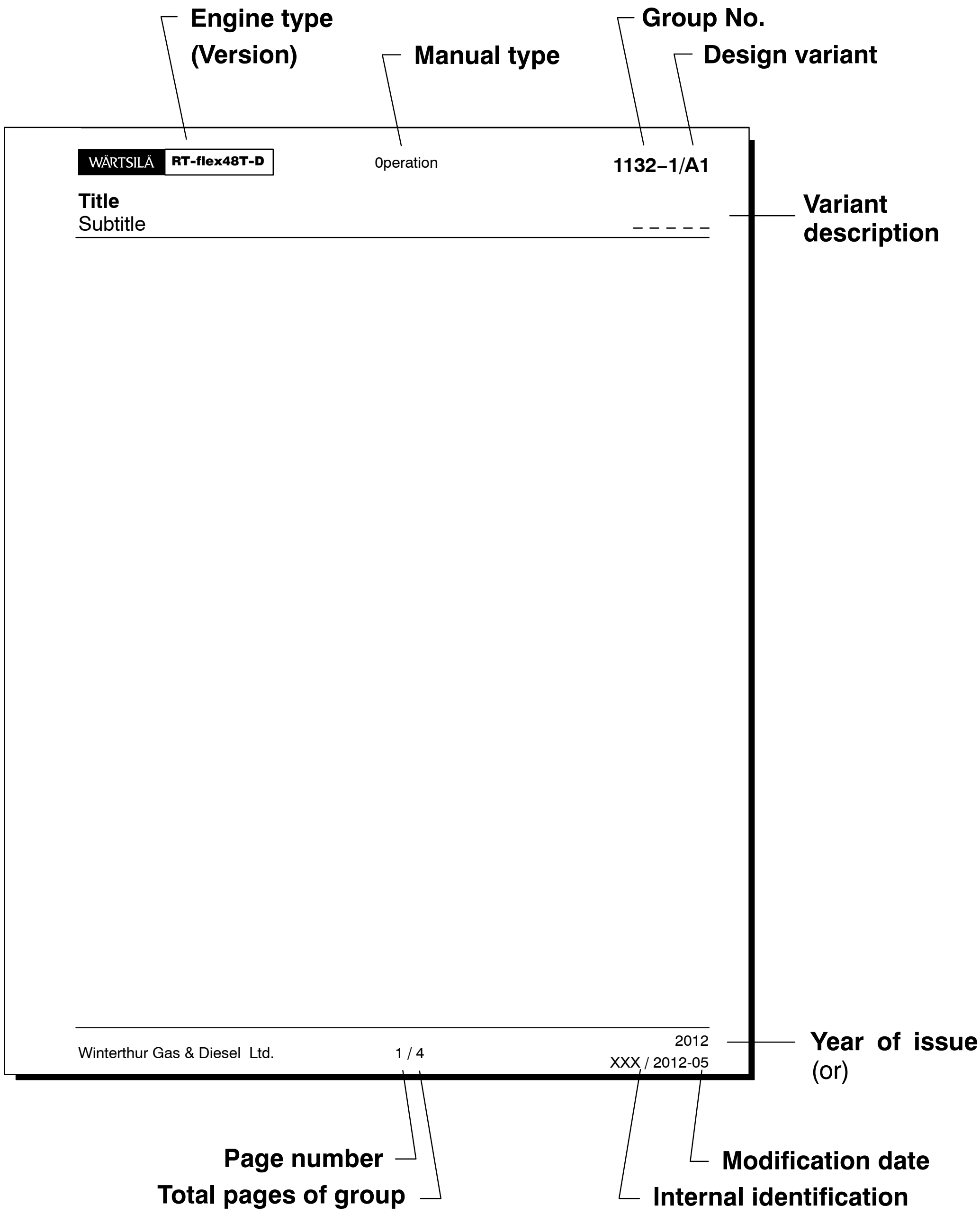
Generally the manuals have to be regarded as **Basic Manuals**. They describe particularly the standard engine with all cylinder numbers, alternative design executions and special equipment.

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.

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.

CHECK

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

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).

Not withstanding 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
- Form of documentation (printed Manuals or CD-ROM)

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Operating Descriptions — Group 0

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Subject Index

Alphabetical Table of Contents

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Alphabetical Table of Contents

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1. Symbols

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

Symbols	Explanations
A	Control air supply unit
B	Fuel supply
C	Fuel injection
D	Servo oil supply
E	Valve unit for start
F	Exhaust valve drive
H	Instrument panel
I	Pressure switches and pressure transmitters
K	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
ASTM	**A**merican **S**ociety for **T**esting and **M**aterials
BDC	**B**ottom **D**ead **C**enter
BFO	**B**unker **F**uel **O**il
BN	**B**ase **N**umber
BSFC	**B**rake **S**pecific **F**uel **C**onsumption
CCAI	**C**alculated **C**arbon **A**romaticity **I**ndex
CMCR	**C**ontract **M**aximum **C**ontinuous **R**ating
COC	**C**leveland **O**pen **C**up
EAL	**E**nvironmentally **A**cceptable **L**ubricants
ECA	**E**mission **C**ontrol **A**rea
HFO	**H**eavy **F**uel **O**il
IMO	**I**nternational **M**aritime **O**rganisation
ISO	**I**nternational **S**tandard **O**rganisation
JIS	**J**apanese **I**ndustrial **S**tandards
LSHFO	**L**ow **S**ulphur **H**eavy **F**uel **O**il
MARPOL	International Convention for the Prevention of Pollution from Ships

Abbreviations	Explanations
MCR	**M**aximum **C**ontinuous **R**ating
MCR	**M**icro **C**arbon **R**esidue
MDO	**M**arine **D**iesel **O**il
mep	**m**ean **e**ffective **p**ressure
MGO	**M**arine **G**as **O**il
PMCC	**P**ensky **M**artens **C**losed **C**up method
RCS	**R**emote **C**ontrol **S**ystem
SCR	**S**elective **C**atalytic **R**eduction
SHD	**SH**ut **D**own
SHF	**S**ediment by **H**ot **F**iltration
SIPWA−TP	**S**ulzer **I**ntegrated **P**iston ring **W**ear detecting **A**rrangement with **T**rend **P**rocessing
SLD	**SL**ow **D**own
TDC	**T**op **D**ead **C**enter

2.2 Concerning engine control system WECS−9520

Abbreviations	Explanations
ACM-20	**A**ngle **C**alculation **M**odule-20
ALM-20	**A**dvanced **L**ubrication **M**odule-20
AMS	**A**larm and **M**onitoring **S**ystem
CAN−Bus	**C**ontroller **A**rea **N**etwork
CAN M	CAN **M**odul bus
CAN S	CAN **S**ystem bus
COM−FN	**COM**on **F**u**N**ction (engine-related control functions)
CYL−FN	**CYL**inder **F**u**N**ction (cylinder-related control functions)
DENIS−9520	**D**iesel **E**ngine Co**N**trol and Opt**I**mizing **S**pecification for WECS−9520
ECR	**E**ngine **C**ontrol **R**oom
FCM-20	**F**lex **C**ontrol **M**odule-20
FQS	**F**uel **Q**uality **S**etting
LED	**L**ight **E**mitting **D**iode
SCS	**S**peed **C**ontrol **S**ystem
Modbus	Gould−**Mod**icon Field**bus**
OPI	**OP**erator **I**nterface (user interface in control room)
PCS	**P**ropulsion **C**ontrol **S**ystem
RCS	**R**emote **C**ontrol **S**ystem
SIB	**S**hipyard **I**nterface **B**ox (engine / remote control interface)
SSI	**S**ynchron **S**erial **I**nterface
VEC	**V**ariable **E**xhaust valve **C**losing
VEO	**V**ariable **E**xhaust valve **O**pening
VIT	**V**ariable **I**njection **T**iming
WECS	**W**ärtsilä **E**ngine **C**ontrol **S**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.

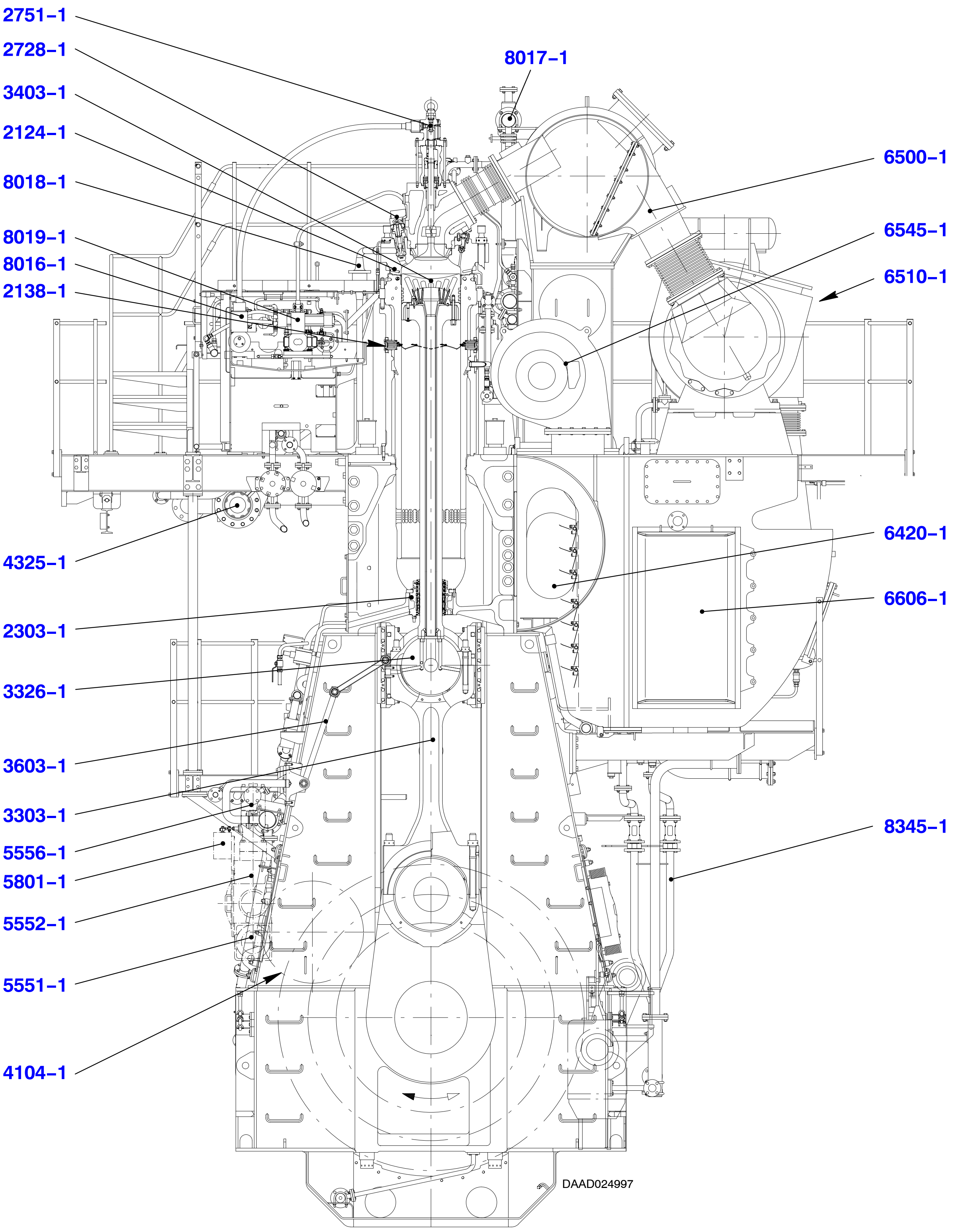
Cross section and longitudinal section see pages 2 and 3.

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.

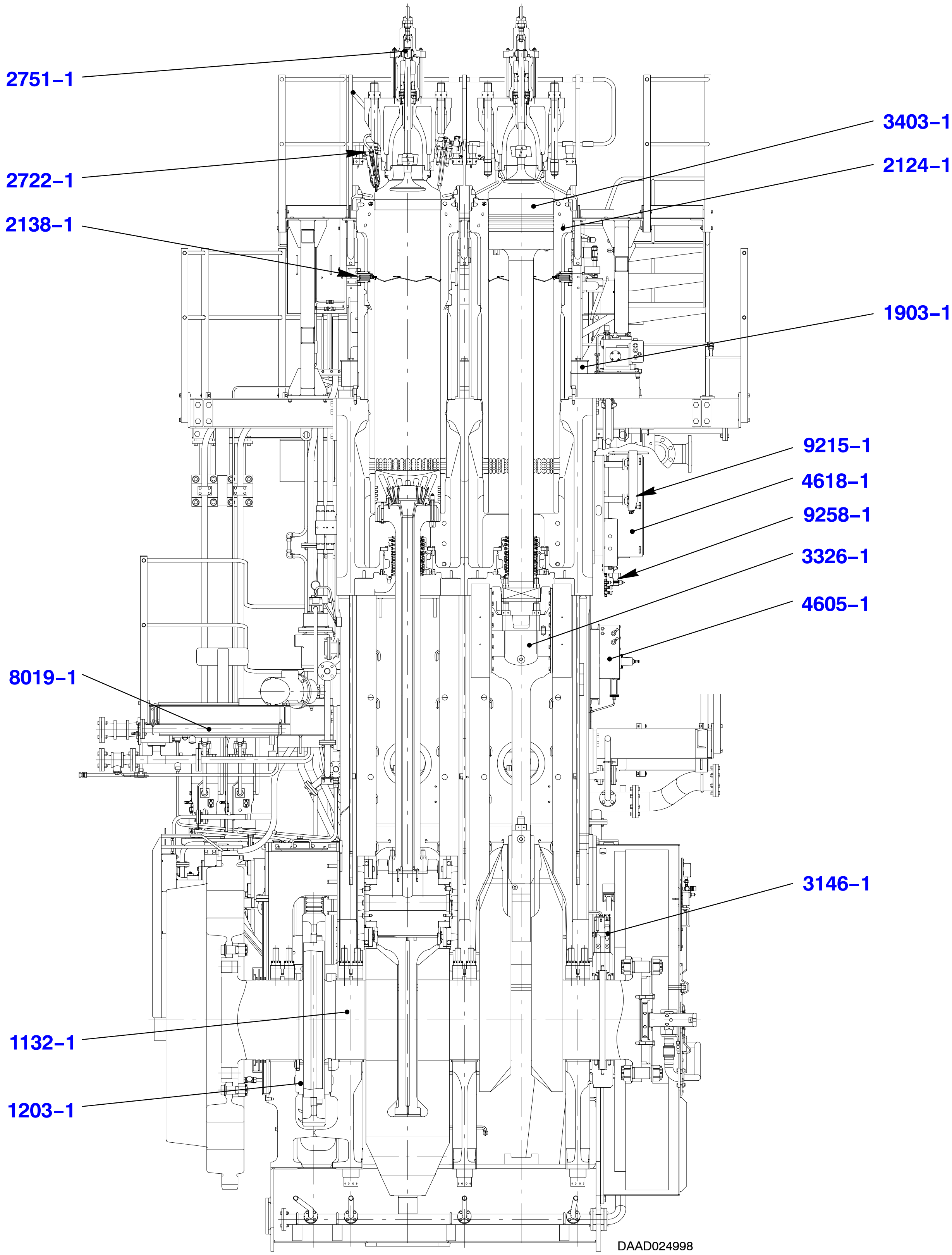
Explanations on the Use of the Operating Manual

Cross Section:



Explanations on the Use of the Operating Manual

Longitudinal Section:



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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 Common Rail System, 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 block together.
– Crankcase and cylinder block 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, the electronic injection and cylinder lubricating system 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 supply unit provides the servo oil rail with the required pressure via two rising pipes.
– The pistons are cooled by bearing oil.

– Fuel pumps in the supply 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.

- The exhaust gases flow from the cylinders through the exhaust valves into an exhaust gas manifold.
- The exhaust gas turbocharger works on the constant pressure charging principle.
- The scavenge air delivered by the turbocharger 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 turbocharger.
- 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).

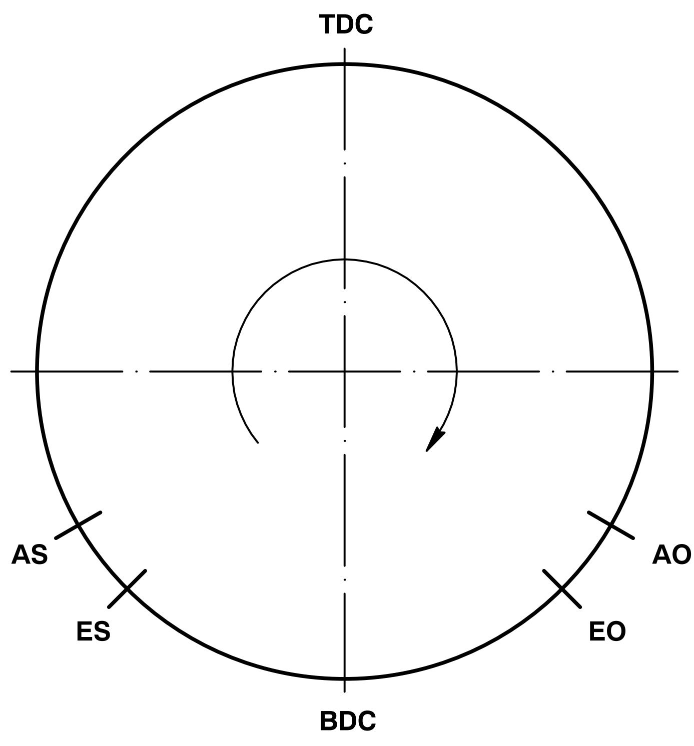
Point AO:

- 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)



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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 (**C**ontract **M**aximum **C**ontinuous **R**ating), 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.

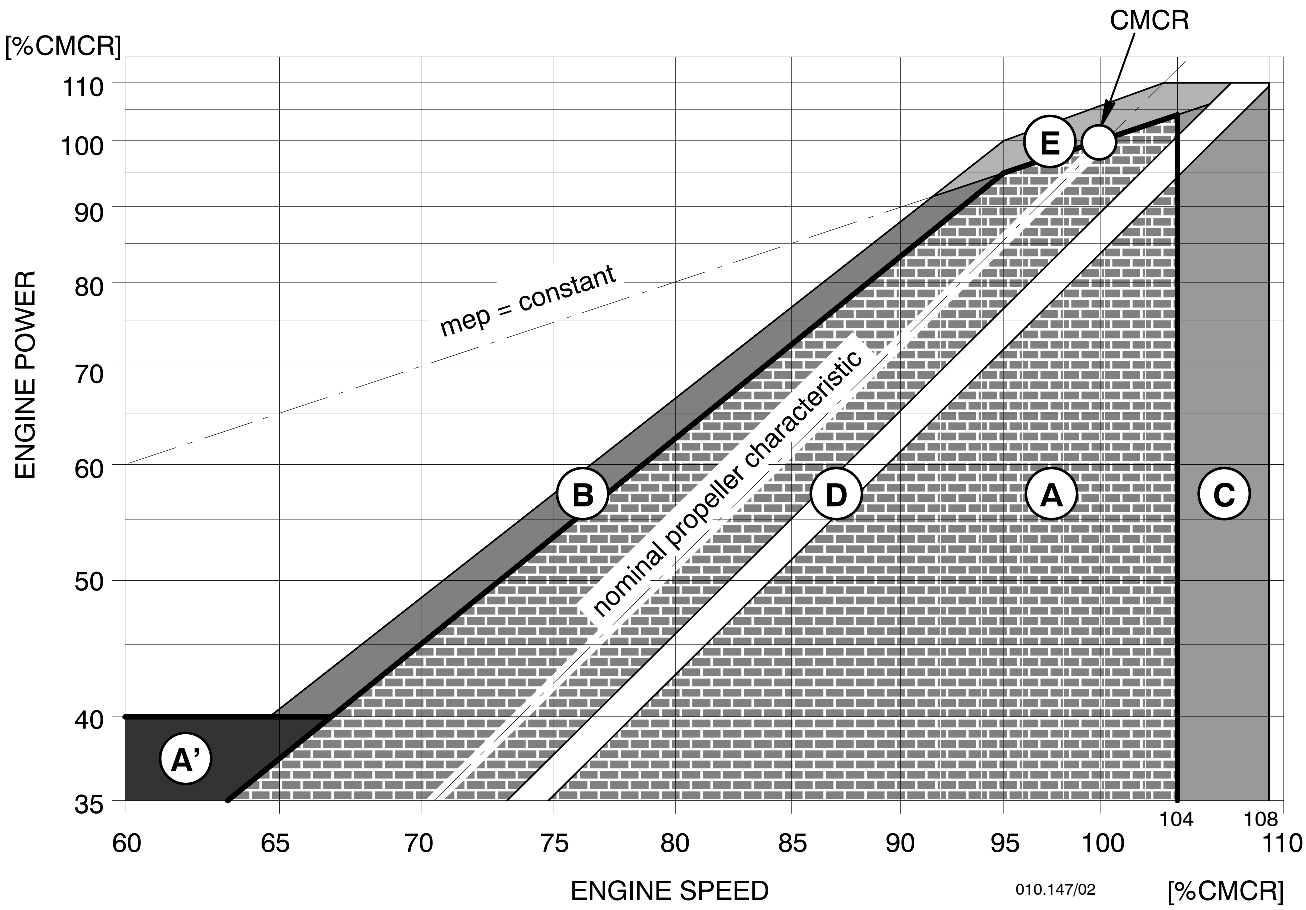
In order to attain optimum working conditions, the operating point of the engine for continuous service should lie in range A on the right side of the nominal propeller characteristic.

Explanations:

CMCR	=	**C**ontract **M**aximum **C**ontinuous **R**ating
P	=	Power
n	=	speed
mep	=	**m**ean **e**ffective **p**ressure

See also Guide for Symbols and Abbreviations 0035−1.

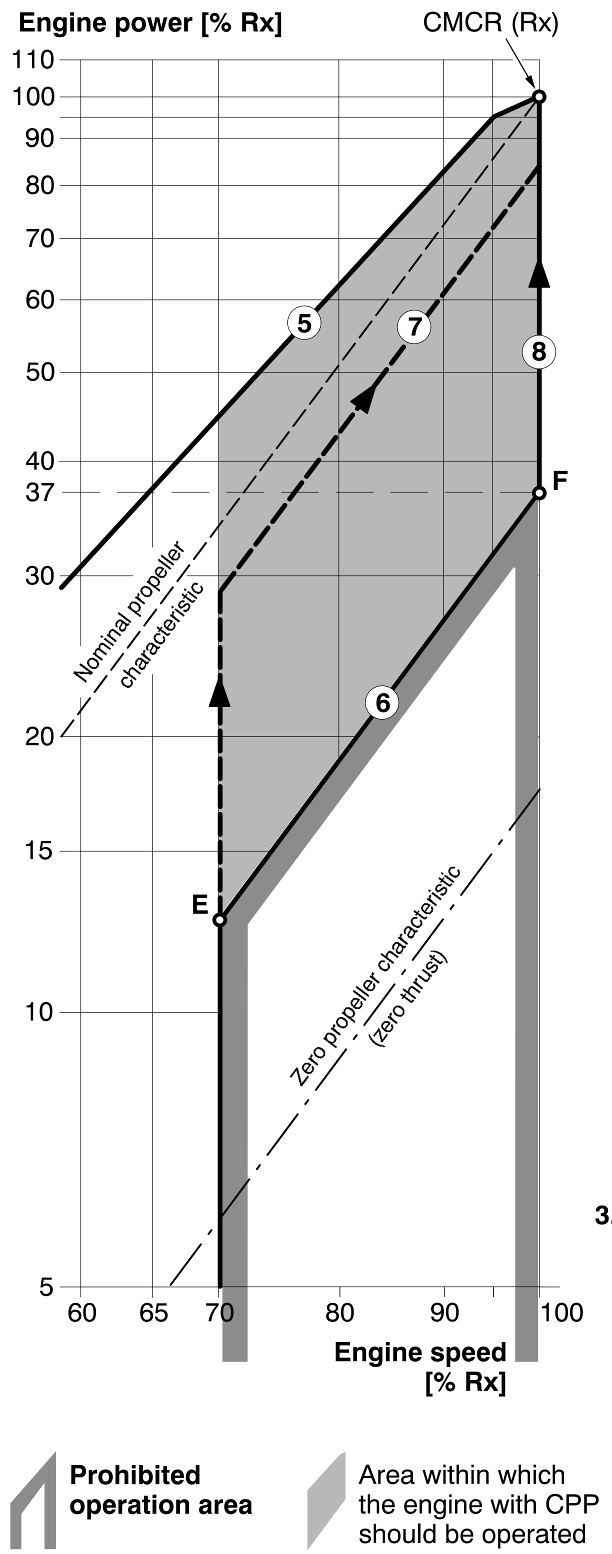
2. Fixed pitch propeller (FPP)



2.1 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. 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: $P \approx n^{2.45}$. 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.

3. Controllable pitch propeller (CCP)



3.1 Load ranges

- After starting, the engine is operated at an idle speed of up to 70 % of the rated engine speed with zero pitch. From idle running the pitch is to be increased with constant engine speed up to at least point E, the intersection with the line (6).
- Line (6) is the lower load limit between 70 and 100 % speed, with such a pitch position that at 100 % speed a minimum power of 37 % is reached, point F. It is defined by the same equation shown on page 1.
- Along line (8) the power increase from 37 % power (point F) to 100 % power (CMCR) at 100 % speed is the constant speed mode for shaft generator operation, covering electrical sea load with constant frequency.
- Line (5) is the upper load limit and corresponds to the admissible torque limit.
- The area formed between 70 and 100 % speed and between lines (5) and (6) represents the area within which the engine with CPP has to be operated.

Line (7) represents a typical combinator curve for variable speed mode.

Therefore, manoeuvring at nominal speed with low or zero pitch is not allowed. Thus installations with main engine-driven generators must be equipped with a frequency converter when electric power is to be provided (e.g. to thrusters) at constant frequency during manoeuvring. Alternatively, power from auxiliary engines may be used for this purpose.

For test purposes, the engine may be run at rated speed and low load during a one-time period of 15 minutes on testbed (e.g. NO_x measurements) and 30 minutes during dock trials (e.g. shaft generator adjustment) in the presence of authorized representatives of the engine builder. Further requests must be agreed by WCH.

3.2 Control system

The CPP control functions are normally integrated into the engine control system and include the following functions:

Combinator mode 1:

Combinator mode for operation without shaft generator. Any combinator curve including a suitable light running margin may be set within the permissible operating area, typically line (7).

Combinator mode 2:

Optional mode used in connection with shaft generators. During manoeuvring, the combinator curve follows line (6). At sea the engine is operated between point F and 100 % power (line (8)) at constant speed.

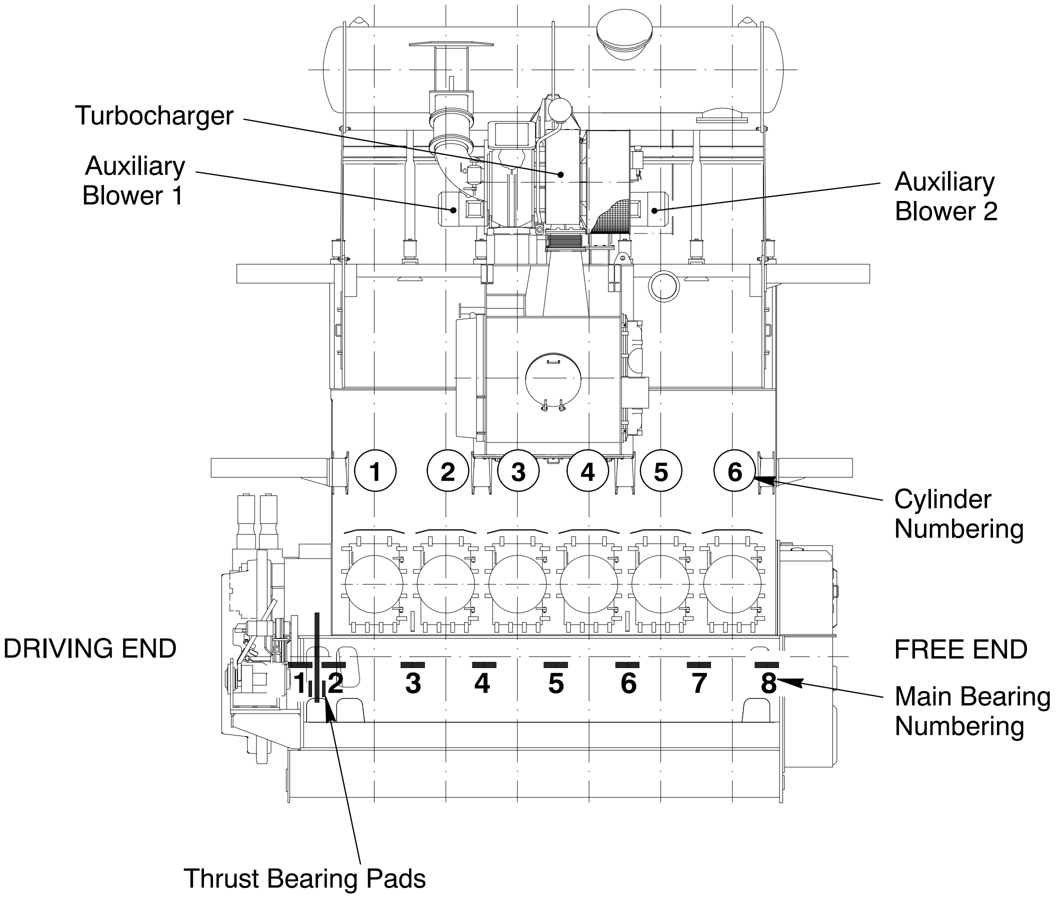
For manual and/or emergency operation, separate setpoints for speed and pitch are usually provide.

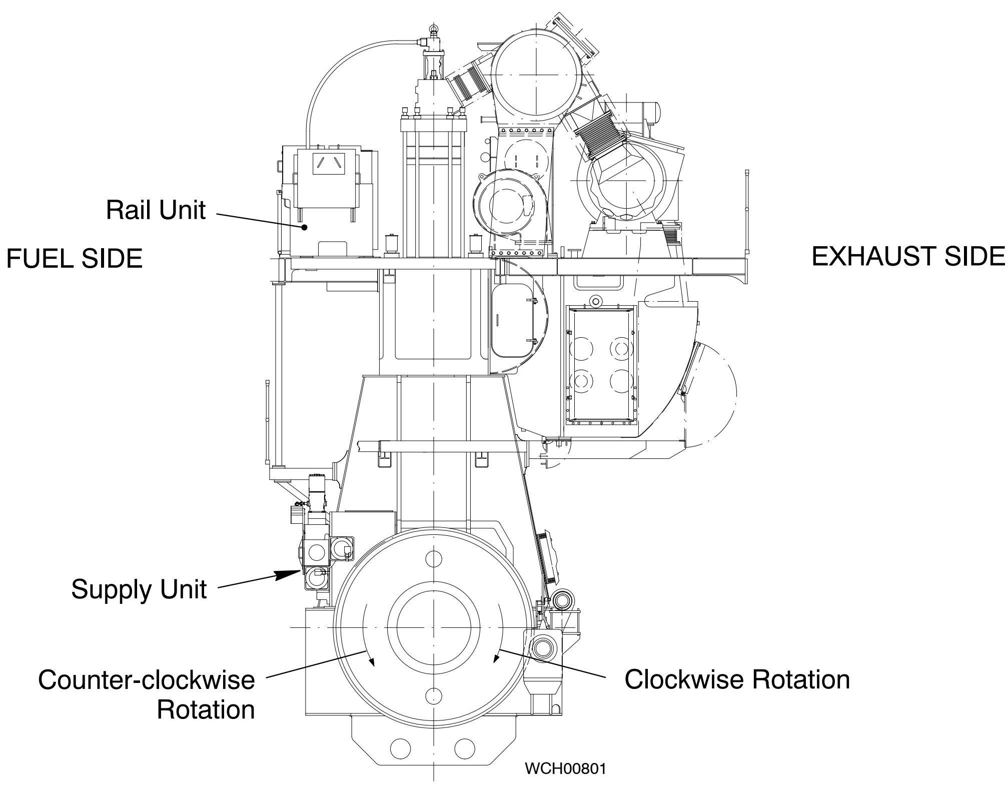
An alarm is also normally provided in either the main engine safety system or the vessels alarm and monitoring system when the engine is operated for more than 3 minutes in the prohibited operation area. Is the engine operated for more that 5 minutes in the prohibited operation area, the engine speed must be reduced to idle speed (below 70 % speed).

General

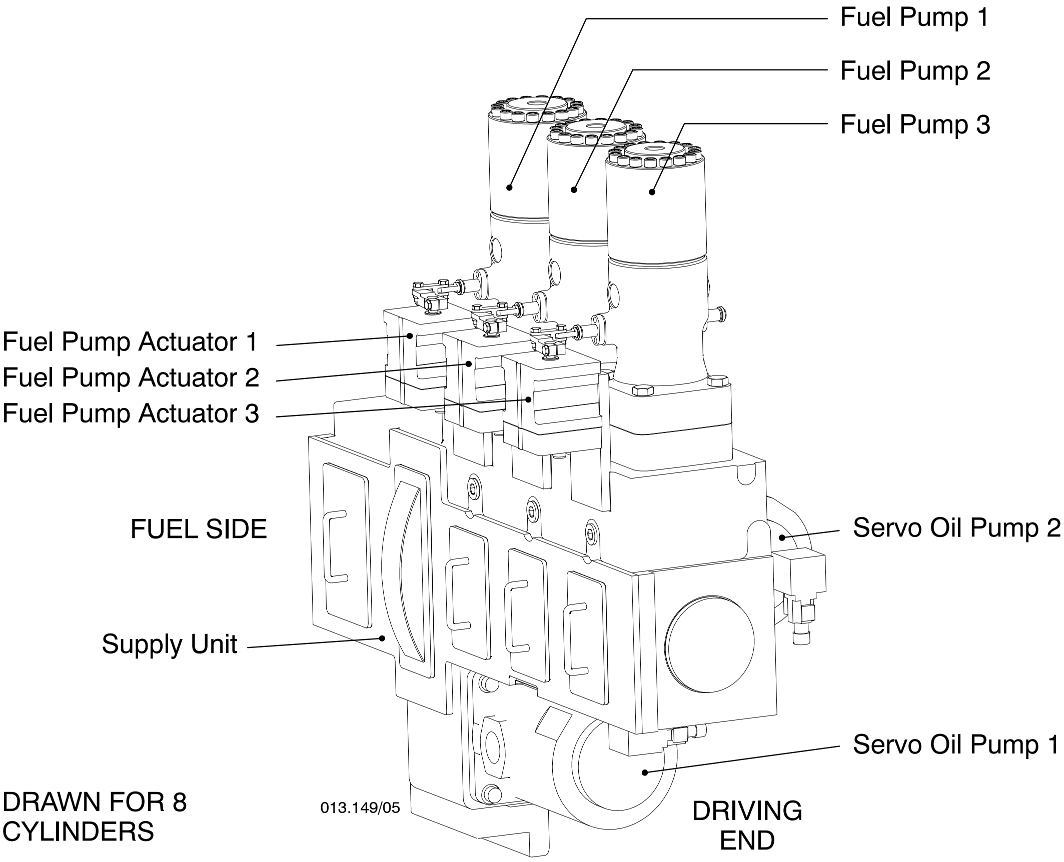
Engine Numbering and Designations

General:

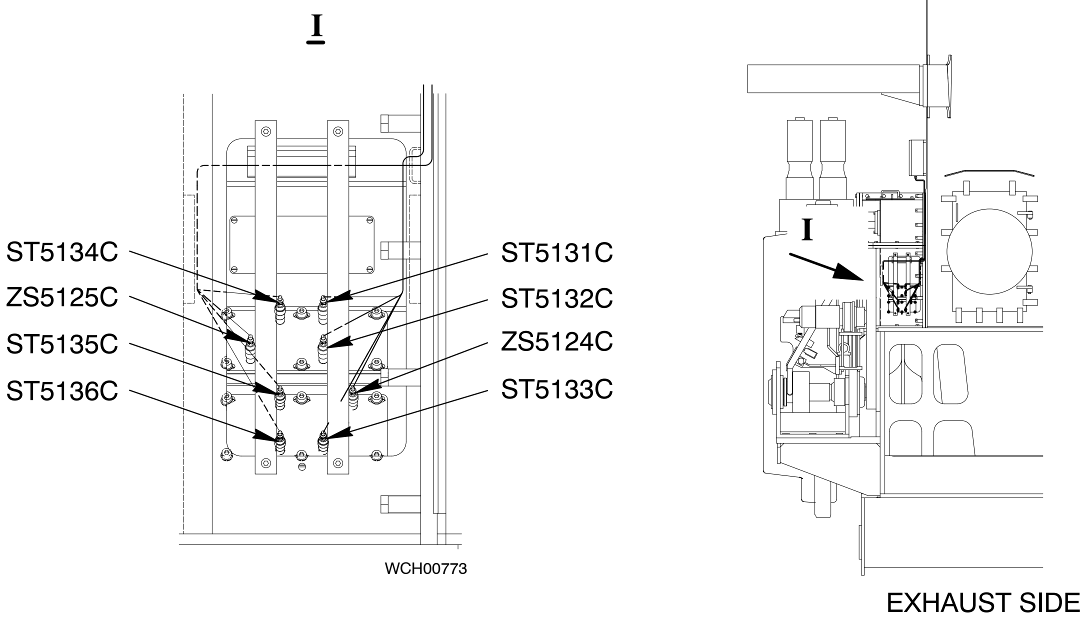




***flex* Parts:**



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.

⇒ 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. 70 °C.

⇒ Switch on the engine and remote control system WECS–9520.

– 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.

⇒ Prepare the servo oil system (see 0130–1).

⇒ Start up the pumps for cylinder cooling water and 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 pump.

⇒ 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.

⇒ 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 ’Exv. A/M Cmd’).

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

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

⇒ 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.

- 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

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 WECS−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); for 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 0710−1 ’Viscosity-Temperature Diagram’).
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 12 (3.05), fuel rising pipes 8 (3.29) and 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); for pressure difference before/after pressure retaining valve see Operating Data Sheet 0250−1.

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 12 (3.05) is filled via fuel rising pipes 8 (3.29).

⇒ By means of hand lever on emergency stop valve 22 (fuel shut-down pilot valve 3.08) the fuel rail can be vented via fuel pressure control valve 21 (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 28 (3.39) and the nut with conical plug on stop valve (3.40) and connect tool 94583 (pipe) between fuel rail 12 (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 28 (3.39) and tighten it with a torque of 300 Nm. Refit and tighten the nut with the conical 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 valve 14 (4.37) opened after automatic filter 1 (4.20).

⇒ Stop valve 23 (3.40) on servo oil rail 7 (4.11) at free end closed and nut with conical plug fitted.

⇒ Drain screw 33 (4.82) tightened with a torque of 200 Nm in servo oil rail 7 (4.11) at driving end (see 8016−1 ’Filling and pressure relief of servo oil rail’).

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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 4 (4.30−5) open (Fig. 'B').
- Ball valve 5 open after lubricating oil filter 8.17 (Fig. 'C').
- Ball valve 8 open after measurement tube 4 (Fig. 'C').
- Lubricating oil filter 8.17 and measurement tube 4 vented (Fig. 'C').
- Shut-off valve 6 open to servo oil inlet of lubricating pumps 8.06 (Fig. 'D').
- Lubricating pumps 8.06 vented (servo and lubricating 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).

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Operation under Normal Conditions

Summary

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'.

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Operation during Usual Conditions

Safety Precautions and Warnings (General Information)

Overview

1. General

A correctly maintained engine gives problem–free and safe operation. Use the data given below as a guide to the maintenance personnel.

For more data about the general maintenance procedures, see the Maintenance Manual 0011–1 and 0012–1.

2. Warnings

***Injury Hazard:* When you remove valves from the cylinder cover, do not let oil or fuel fall on to the hot piston. This can cause an explosion.**

***Injury Hazard:* Be careful when you disassemble the engine without the correct tools and/or the necessary precautions. Compressed springs can suddenly expand and cause injury.**

***Injury Hazard:* When you open valves and shut–off devices, hot fluids or gases can be released. To prevent injury, always open slowly the valves and shut-off devices and look at the direction the medium is released.**

3. Lighting

There must be good permanent lighting. Also, hand lamps must be available at different locations in the engine room.

4. Clean areas

Attention! Do not use water or any cleaning fluid to clean the WECS electronic control boxes on the rail unit. Damage can occur if fluids go into these control boxes.

Always keep the engine as clean as possible.

Keep the WECS electronic control boxes on the rail unit clean and dry.

You must repair all leaks as soon as possible.

Dust, sand and chemical vapors must not go into the engine room.

5. Fire

***Injury Hazard:* Be careful when you use paints and solvents in the engine room. These materials are flammable.**

***Injury Hazard:* Insulation material that is soaked with oil or fuel is flammable and must be replaced.**

Make sure that you know the fire fighting instructions.

Before you do welding work or work that causes sparks, make sure that there are no explosive fluids in the work area.

Make sure that fire fighting equipment is immediately available if you must do work that causes sparks in the engine room.

Some components e.g. the turbocharger silencer and WECS electronic control boxes, must be protected with an applicable cover.

Keep covers and casings closed until the engine has cooled to decrease the risk of fire or explosions.

The engine room and the area below the floor plates must be kept clean. This will help prevent a fire in the engine room and in different areas.

Make sure that no fire extinguisher gases can be automatically released when personnel are in the engine room.

Make sure that the emergency exits are clearly marked.

6. Tools

Put hand–tools in locations where you can easily get access to them. Put special tools and devices in positions in the engine room near the area where you use them.

All tools must be prevented from unwanted movement and must have protection from corrosion.

7. Spare parts

Keep large spare parts as near as possible to the position where they will be installed and near the engine room crane.

You must prevent the unwanted movement of large spare parts.

All the spare parts must have corrosion protection. The corrosion protection agent must be easy to remove. Examine the corrosion protection agent at regular intervals and replace if necessary.

The spare parts must also have protection from mechanical damage.

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

8. Crankcase doors – Open

***Danger:* If you think that parts of the running gear or bearings have become too hot, it is possible that the engine must be shut down. Before you open the crankcase doors, you must wait for a minimum of 20 minutes. This will prevent an explosion.**

***Injury Hazard!* Be careful when you touch hot parts with your hands. This can cause injury.**

9. Temperature

***Danger:* If you think that parts of the running gear or bearings have become too hot, it is possible that the engine must be shut down. Before you open the crankcase doors, you must wait for a minimum of 20 minutes. This will prevent an explosion.**

***Injury Hazard!* Be careful when you touch hot parts with your hands. This can cause injury.**

When commissioning an engine after an overhaul of its running gear, do a temperature check to find unusually high temperatures in areas of the engine. Do this temperature check after 10 minutes of engine operation.

Do the temperature check again after approximately one hour of engine operation.

After a short period of operation at full load, do the temperature check again.

10. Crankcase, cylinder, exhaust pipes and scavenge air receiver

Before you go into the spaces of the crankcase, cylinder, exhaust pipes and scavenge air receiver, make sure that:

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

***Attention!* Other ships in the water cause currents, which will make the propeller and the engine turn. The engine and propeller cannot turn when the turning gear is engaged.**

11. Carbon Dioxide (CO_2) gas

***Injury Hazard!* Where CO_2 is used to extinguish a fire in the engine, there is a risk of suffocation. Make sure that all related spaces have good airflow to remove all CO2 gas before you go into the engine.**

12. Crankcase doors – Close

Make sure that all crankcase doors are closed and locked before you operate the engine. This is also applicable to short periods of engine operation e.g. running-in, after the replacement of bearings, etc.

13. Turning gear

When the turning gear is used, the indicator valves in the cylinder covers must be open. If the air spring system is not pressurized, the indicator valves can stay closed.

The lubricating oil pump must operate if possible, but the oil pressure cannot fully increase when the exhaust valves are open.

Injury Hazard! Make sure that no personnel and components are in the danger areas (crankcase, piston underside, propeller shaft, etc). The propeller coupling also turns.

Remark: If the engine is stopped for overhaul, you must engage the turning gear to prevent engine movement.

If the engine is ready for maneuvering, the turning gear must not be engaged.

Before the you start the engine, make sure that the turning gear is disengaged and the lever is locked. It is possible that the blocking valve 2.13 (see 4003−2 Control Diagram) can prevent engine start.

14. Instruments

Calibrate the instruments (and gages) at regular intervals before you use them.

15. Frost hazard

If the temperature decreases below 0°C and the engine is not in service, it is possible that water in the engine, pumps, coolers and pipe systems will freeze. To prevent this, drain the systems, increase the temperature in the engine room or use an antifreeze (see 0760−1 Cooling Water / Cooling Water Treatment, paragraph 5).

Operation under Normal Conditions

Slow Turning

1. General

To make sure that the running gear turns freely, we recommend (as long as the classification society did not make more primary specifications) to turn the crankshaft a minimum of one full revolution before start-up. This does not apply if the engine was at standstill during a manoeuvring period.

2. Turn with the turning gear

The turning gear is used to turn the crankshaft (approximately one turn in 10 minutes). An arrow next to the flywheel shows the direction and distance that the crankshaft has turned.

3. SLOW TURNING with starting air

To turn the running gear at approximately 5 to 10 rpm, a controlled quantity of starting air must be released.

The engine control system WECS−9520 has the command SLOW TURNING for this operation.

The active control stand is used to start the SLOW TURNING operation:

- from the remote control
- at the ECR manual control panel in the control room
- at the local control panel (see 4618−1 'WECS−9520 Manual control panel').
- with the crank angle algorithm (see 4002−1 'Engine Control System WECS−9520, paragraph 4.6)

3.1 Conditions

Before you start the SLOW TURNING operation, make sure that:

- The turning gear is disengaged
- The WECS−9520 engine control system is set to on
- The oil pumps are in operation (bearing oil and crosshead oil)
- The necessary control stand is active
- The indicator valves are closed
- The handwheel 2.10 on the shut-off valve for starting air 2.03 is in the position AUTOMAT
- The shut-off valves on the starting air bottles are open
- The air pressure for the air spring is correctly set (see Operating Data Sheet 0250−1)
- The cylinder lubrication is set to on.

Remark: For the designation numbers e.g. 2.10, see the Control Diagram 4003−2.

3.2 Function

The function below is almost the same as the engine start function.

- The control valve 2.05 opens the shut-off valve for the starting air 2.03 and starting air flows to the starting valves 2.07 in the cylinder covers.
- The FCM−20 modules control the 3/2-way solenoid valves upstream of the starting valves 2.07. The starting valves open and close for short intervals only.
- In the remote control, you can change the timing (open/close) of the starting valves to optimize the slow turning speed of the engine.

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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 and Control 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').

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Operation
Normal Running

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.

- 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 0710−1 ’Viscosity-Temperature Diagram’).
- 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.
- Open shortly butterfly valves 18 and 18a (weekly) in the water drains of water separator and scavenge air cooler to flush off possible dirt particles. Check additionally the water flow through the sight glasses 20 and 20a (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.

- 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.

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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	5	70	–	max. 15 3)
		Outlet each cylinder	–	–	80	90	
	SAC, low temperature circuit LT (single-stage scavenge air cooler)	Inlet	2	4	25	36	
		Outlet	–	–	–	–	
Lubricating oil	Servo oil	Pumps inlet	3.6	5.0	–	–	–
	Main bearing	Inlet	3.6	5.0	40	50	–
	Piston cooling	Inlet	3.6	5.0	40	50	max. 30
		Outlet	–	–	–	80	
	Thrust bearing	Outlet	–	–	–	65	–
	Torsional vibration damper	Supply	3.6	5.0	–	–	–
	(steel spring damper)	Damper inlet	2.8 4)	5.0 4)	–	–	–
	Axial vibration damper	Supply	3.6	5.0	–	–	–
	(chamber pressure)	Monitoring	1.7	–	–	–	–
	Turbocharger bearing (ABB, TPL type)	Inlet	1	2.5	–	–	–
	(with internal oil supply)	Housing outlet	–	–	–	110	–
	Turbocharger bearing (ABB, TPL type)	Inlet	1.3	2.5	–	–	–
	(with external oil supply)	Housing outlet	–	–	–	120	–
	Turbocharger bearing (MHI, MET type)	Inlet	0.7	1.5	–	–	–
		Housing outlet	–	–	–	85	–
Fuel oil	Supply unit (fuel pump)	Inlet	7 1)	10 2)	–	150	–
	After pressure retaining valve (fuel pump)	Return	3	5	–	–	–
Scavenge air	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. 4 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).

4) The value can be different. For the applicable setting value, refer to the specification of the damper manufacturer.

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Operating Data Sheet

Alarms and Safeguards at Continuous Service Power

Medium Performance	Physical unit	Location	Signal No. 1)	Function 2)	Kind of signal 3)	Setting value [bar / °C]	Function time delay [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	70 °C	0
		Outlet each cylinder	TE1121–28A	ALM	H	95 °C	0
				SLD	H	97 °C	60
LT circuit	Pressure	Cooler inlet	PT1361A	ALM	L	2 bar	0
Single-stage SAC Fresh water 6)	Temperature	Cooler inlet	TE1371A	ALM	L	25 °C	0
		Cooler outlet	TE1381A	ALM	H	70 °C 11)	0
Lubricating oil **Bearing and piston cooling**	Pressure	Engine inlet	PT2001A	ALM	L	3.6 bar	0
				SLD	L	3.4 bar	60
			PS2002S	SHD	L	2.9 bar	10
	Temperature	Engine inlet	TE2011A	ALM	H	50 °C	0
				SLD	H	55 °C	60
Servo oil (for cylinder lubrication)	Pressure	Lubricating pump Inlet FE	PT2041A	ALM	L	40 bar	3
					H	70 bar	3
	Pressure (leakage)	Lubricating pump Inlet FE	PT2046A	ALM	H	10 bar	0
Servo oil	Failure	Automatic filter	XS2053A	ALM	F	–	0
	Flow	Servo oil pump	FS2061–62A 9)	ALM	L	no flow	0
Oil leakage monitoring	Level	Supply unit 7)	LS2055A	ALM	H	max.	0
Thrust bearing oil	Temperature	Thrust bearing outlet	TE2121A	ALM	H	65 °C	0
				SLD	H	70 °C	60
			TS2121S	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	TE2501–08A	ALM	H	80 °C	0
				SLD	H	85 °C	60
	Diff. pressure	Inlet each cylinder	PS2541–48S	SHD	H	0.4 bar	15
	Flow	Inlet each cylinder	FS2521–28S	SHD	L	no flow	15
Turbocharger oil (ABB, TPL type)	Pressure	Inlet	PT2611A	ALM	L	1 bar	5
				SLD	L	0.8 bar	60
			PS2611S	SHD	L	0.6 bar	5
	Temperature	Housing outlet	TE2601A	ALM	H	110 °C	0
				SLD	H	120 °C	60
	Pressure (with external oil supply)	Inlet	PT2611A	ALM	L	1.3 bar	5
				SLD	L	1.1 bar	60
			PS2611S	SHD	L	0.9 bar	5
	Temperature	Housing outlet	TE2601A	ALM	H	120 °C	0
				SLD	H	130 °C	60
Additional requirement with external oil supply		Inlet	TE2621A	ALM	H	80 °C	0
				SLD	H	85 °C	60
Turbocharger oil (MHI, MET type)	Pressure	Inlet	PT2611A	ALM	L	0.7 bar	5
				SLD	L	0.6 bar	60
			PS2611S	SHD	L	0.4 bar	5
	Temperature	Housing outlet	TE2601A	ALM	H	85 °C	0
				SLD	H	90 °C	60
Additional requirement with external oil supply		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. 1)	Function 2)	Kind of signal 3)	Setting value [bar / °C]	Function time delay [sec]
Torsional vibration damper oil (steel spring damper) 5)	Pressure	Casing inlet	PT2711A	ALM	L	2.2 bar Note (13)	0
Axial vibration 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	0.5 bar	0
Fuel oil	Temperature 4)	before supply unit	TE3411A	ALM	H	50–160 °C	0
(see 0710–1 'Viscosity-Temperature				ALM	L	20–130 °C	0
Diagram')	Pressure	before supply unit	PT3421A	ALM	L	7 bar	0
	Viscosity 4)	before supply unit	5)	ALM	H	17 cSt	0
				ALM	L	13 cSt	0
Fuel leakage monitoring	Level	Rail/supply unit 7)	7)	ALM	H	max.	0
Exhaust gas	Temperature	after each cylinder	TE3701–08A	ALM	H	515 °C	0
			10)	ALM	D	±50 °C	0
				SLD	H	530 °C	60
				SLD	D	±70 °C	60
		before TC 6)	TE3721A	ALM	H	515 °C	0
			10)	SLD	H	530 °C	60
		after TC 6)	TE3731A	ALM	H	480 °C	0
			10)	SLD	H	500 °C	60
Scavenge air	Temperature	Scavenge air	TE4031A	ALM	L	25 °C	0
		receiver after cooler		ALM	H	60 °C	0
				SLD	H	70 °C	60
	Temperature	each piston underside	TE4081–88A	ALM	H	80 °C	0
		(fire detection)		SLD	H	120 °C	60
Condensate	Level	Water separator	LS4071A	ALM	H	max.	0
				SLD	H	max.	60
		before	LS4075A	ALM	H	max.	0
		water separator		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	L	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
stand by supply 12)			PT4411A	ALM	L	5.5 bar	0
	Pressure	Engine inlet	PT4421A	ALM	L	5 bar	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

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

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) Alarm is effective only above 30% engine power.

10) Signal designation changes after amplifier (on engine) from T**E**xxxxA to T**T**xxxxA.

11) Setting value:
IMO TIER II = 80 °C

12) 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.

13) The alarm value can be different. For the applicable setting value, refer to the specification of the damper manufacturer.

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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 rang 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.

With controllable pitch propellers, where the speed and torque can be freely selected, the same recommendations as for fixed pitch propellers apply during manoeuvring with respect to power limitation over the manoeuvring range. Nevertheless, the **time period** to change the propeller pitch from zero to FULL position must be a **minimum of 20 seconds**.

Should the engine be accelerated quickly to FULL manoeuvring speed or the propeller blades brought to FULL pitch 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 0710–1 'Viscosity-Temperature Diagram'. 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).

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').

2.3 In installation with controllable pitch propeller or clutch coupling additionally to observe

The speed cannot be readjusted immediately by the electronic speed control system. If the propeller pitch were reduced it would rise possibly high enough to activate the overspeed monitoring.

Attention! We strongly recommend:

- To start the engine only when the propeller is in an end position (AHEAD or ASTERN).
- Not to alter the pitch while the engine is running.
- To manoeuvre, either: (assuming the engine can be reversed) to reverse the engine with the propeller in an end position.

  or: to stop the engine first, then to bring the propeller to the other end position and to restart the engine.

On installations having clutch couplings these must **not be disengaged** as long as the engine is running under such mode of operation. The engine may only be started with the coupling engaged.

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 in the engine room:

With fixed pitch propeller installations:

- speed setting

With controllable pitch propeller installations: *(depending on arrangement)*

- speed setting
- propeller pitch setting lever
- speed and propeller pitch setting lever (combinator)

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.

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Operation

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

1. General

When you change from heavy fuel oil (HFO) to marine diesel oil (MDO) or back, you must keep the thermal stresses of the related fuel components as low as possible. Thermal stress occurs because of the large temperature changes. Too fast change of the temperature can cause damage to the fuel pump plungers and can cause leakages in the fuel pipes.

During the change−over procedure the temperature of the fuel must not change more than 2°C each minute. This prevents damage to the system, specially when you do the procedure frequently. The small change rate is also because of the large difference of viscosity between HFO and MDO/MGO.

You can do a change−over of the fuel only when the engine is running. While the engine has stopped, there is no fuel flow through the fuel rail. Change-over is thus not possible.

2. Automatic Fuel Change−over

WinGD recommends the installation and use of an automatic fuel change−over system to prevent problems during the change−over procedure.

If an automatic change−over system is installed, follow the instructions in the documentation of the manufacturer and the instructions for cylinder lubricating oil in paragraph 5.

3. Manual Fuel Change−over

When you do a manual change−over of the fuel, you must make sure that the change-over is safe, see the paragraphs that follow.

Specially make sure that during the procedures HFO never can flow into the MDO tank and pipe system.

Note: WinGD recommends to do a manual change−over only, if an automatic change−over system is not installed or if the automatic change−over system is unserviceable.

4. Recommended viscosity at inlet to fuel pumps

For the temperature necessary to make sure that the fuel upstream of the inlet to the fuel pumps is at the correct viscosity, see Fig. 1 Viscosity / Temperature Diagram in 0710−1. The viscosity for MDO must not be less than 2 cSt.

A viscosimeter measures the viscosity and thus controls the temperature of the fuel.

Make sure that you monitor the viscosity and the temperature of the fuel.

5. Cylinder Lubricating Oil

When you do a manual or automatic change−over of the fuel, you must make sure that you change to the correct cylinder lubricating oil at the same time. This prevents damage of the piston running system because of an incorrect BN. For more data refer to 0750−1, Lubricating oils.

WinGD recommends to monitor the change−over of the cylinder lubricating oil. Do a calculation of the cylinder lubricant quantity and make sure that you know the cylinder lubricating feed rate.

1) Make sure that you know the cylinder lubricant quantity that is between the change−over valve and the lubricating quills including the measurement tube.

2) Calculate the related lead time that the cylinder lubricating oil has to get to the lubricating quills.

Cylinder lubricant quantity in piping and measuring tank:

Volume piping: $\sum V = \sum \frac{d^2 * \pi}{4} * l$ $[V] = m^3$ $[d] = m$ $[l] = m$

Mass: $m = \rho * V$ $[m] = kg$ $[\rho] = \frac{kg}{m^3}$ $[V] = m^3$

The density of the cylinder lubricant can be found in the technical data sheet. If not available, an average value of 920 $\frac{kg}{m^3}$ is suitable for this purpose.

Total mass: *Mass of cylinder oil in measuring tank [kg]*
+
Mass of cylinder oil in piping [kg]

Lead time until new lubricant is in use:

$$consumption = \frac{effective\ feed\ rate * current\ power\ output}{1000}$$

$$lead\ time = \frac{total\ mass}{consumption} \qquad [lead\ time] = h \quad [m] = kg$$

$$[consumption] = \frac{kg}{h} \quad [effective\ feed\ rate] = \frac{g}{kWh} \quad [current\ power\ output] = kW$$

3) Use this lead time to have the correct timing for the change−over of the cylinder lubricating oil.

Note: When you change from MDO to HFO, WinGD recommends to start the change−over of the cylinder lubricating oil from low BN to high BN already inside the ECA zone. This prevents operation with high sulphur fuel and low BN cylinder lubricating oil.

6. Change−over from HFO to MDO

See 0720−1 Fuel Treatment and Fuel System, Fig. 1.

To change−over from HFO to MDO, do as follows:

1) Make a full time schedule for the change−over to obey the ECA rules.
2) If you operate the engine with MDO for a long period, you must change the cylinder lubricating oil to the applicable BN at the related time, refer to paragraph 5.
3) Set to OFF the trace heating of the fuel pipes and fuel rail approximately one hour before the change−over. The correct time is related to the pipe diameter and the waste heat in the system.
4) Set the viscosimeter to 17 cSt to decrease the temperature of the fuel.
5) Set to OFF all heating sources in the system (e.g. fuel heaters) some minutes before the change−over.
6) Decrease the load of the engine to max. 50% CMCR. The decrease of the engine power is related to the total quantity of fuel that flows in the system, e.g. the larger the mixing tank, the less decrease in load is necessary.
7) Follow the instructions of the plant to slowly change−over the fuel supply from HFO to MDO. Make sure that you decrease the fuel temperature a maximum of 2°C each minute.
8) If the temperature changes too much, wait until the fuel temperature is stable. Then you can continue the procedure. Try to decrease the temperature as linearly as possible.
9) When the temperature of the fuel is near the applicable value, you can start the cooler slowly to give a linear and smooth temperature change at minimum viscosity.
10) Do a check of the temperature, viscosity and pressure of the supplied fuel.
11) If the temperature, viscosity, or pressure is not correct, find the cause and repair the fault.
12) If you have to collect the MDO from the leakage and return pipes, do as follows:
    a) Wait until the system is completely flushed with MDO.

Note: This prevents contamination of the MDO with HFO.

    b) If also a MDO leakage tank is installed, move the 3−way valve in the pipe from the outlet of the fuel leakage fuel pump and injection control to the MDO leakage tank.
    c) If the fuel return of the pressure control valve goes into the HFO service tank, set the valve positions to have the fuel return go into the MDO service tank.

13) If you have to stop the engine, wait until the change−over procedure is fully completed.

Note: This prevents problems during the subsequent engine start because of a mixture of HFO and MDO in the system.

7. Change−over from MDO to HFO

See 0720−1 Fuel Treatment and Fuel System, Fig. 1.

To change−over from MDO to HFO, do as follows:

1) Make a full time schedule for the change−over to obey the ECA rules.
2) Make sure that you have changed the cylinder lubricating oil to the applicable BN, refer to paragraph 5.
3) Set to ON the trace heating of the fuel pipes and fuel rail.
4) If the engine room is cold, after a minimum of one hour make sure to get correct heating.
5) Make sure that HFO cannot flow into the MDO system.
   a) If also a MDO leakage tank is installed, move the 3−way valve in the pipe from the outlet of the fuel leakage fuel pump and injection control to the HFO leakage tank.
   b) If the fuel return of the pressure control valve goes into the MDO service tank, set the valve positions to have the fuel return go into the HFO service tank.
6) Close all covers on the rail unit.
7) Decrease the load of the engine to max. 75% CMCR. The decrease of the engine power is related to the total quantity of fuel that flows in the system, e.g. the larger the mixing tank, the less decrease in load is necessary.
8) Set the viscosimeter to 13 cSt to increase the temperature of the fuel.

The viscosimeter controls the end-heater, which keeps the fuel temperature at the necessary viscosity.

9) Follow the instructions of the plant to slowly change−over the fuel supply from MDO to HFO. Make sure that you increase the fuel temperature a maximum of 2°C each minute.

Note: Sudden temperature changes can stop the movement of the fuel pump plungers.

10) If the temperature changes too much, wait until the fuel temperature is stable. Then you can continue the procedure.
11) Do a check of the temperature, viscosity and pressure of the supplied fuel.
12) If the temperature, viscosity, or pressure is not correct, find the cause and repair the fault.
13) If you have to stop the engine, wait until the change−over procedure is fully completed.

Note: This prevents problems during the subsequent engine start because of a mixture of HFO and MDO in the system.

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).
- 0750−1 Operating Media, paragraph 3 Cylinder Lubricating Oil.
- 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 two injection valves per cylinder.

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 two injection valves in regular intervals.

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

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Operation

Operation at Overload

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.

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Shutting Down
General

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!

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Shutting Down

Measures to be Taken after Stopping

1. Procedures for short service breaks (some days to a some weeks)

1.1 Engine is maneuverable

If the engine must still be maneuvered after it has stopped, see the conditions that follow:

- The WECS−9520 engine control system must stay set to on.
- All the pumps for coolant water, lubricating oil and fuel must operate.
- Control air must be available and the starting air bottles must be full.
- Keep the cylinder cooling water at the correct temperature.
- Do not cool the lubricating oil.
- Keep the fuel at the necessary temperature in accordance with 0710−1 Viscosity-Temperature Diagram.

1.2 Engine is not maneuverable

If the engine is not maneuverable, see the conditions that follow:

- After the engine has stopped, the coolant water and lubricating oil pumps must operate for a minimum of 20 minutes to let the temperatures become stable. Do not let these media cool below their usual inlet temperatures. The sea-water pump can, thus, usually be stopped immediately.
- If the engine was shut down during operation with heavy fuel oil, then the supply must flow through the fuel pumps and the fuel rail. The fuel system must continue to operate.
- The fuel pipe heating system at the engine must be set to on. If this is not necessary, change the engine operation to diesel oil before shut-down (see 0270−1 Change-over from heavy fuel oil to diesel oil and 0620−1 Procedures before Putting Out of Service for Extended Period).
- The low pressure feed pump and booster pump can be stopped, if the engine was shut down during operation with diesel oil (see 0720−1 paragraph 4 Layout of the fuel system).
- Open the indicator valves in the cylinder covers.
- The turning gear can be engaged.
- WECS−9520 engine control system can be set to on.
- Where possible, keep the cooling water warm to keep the engine at a stable temperature. The cooling water pump thus, continues to operate unless it is necessary to stop the pump for maintenance.

⇒ At frequent intervals and with the indicator valves open, use the turning gear to turn the engine as necessary (daily in damp climates). Do this procedure while the lubricating oil pump and servo oil service pump operate and set to on the cylinder lubrication at the same time. After completion of this procedure, make sure that the piston stops in a different position each time.

Remark: Make sure that you know the safety precautions before you do repair work or overhauls (see Maintenance Manual 0011−1 and 0012−1). If necessary, release the pressure from the fuel system.

⇒ Repair all the defects found during operation (leaks, etc).

1.3 Starting air manifold – pressure release

Because of low air pressure after engine stop, the release of air in the starting air manifold 6 cannot be done correctly (see Fig. A). Thus, dirt and grease stay in the starting air manifold and can cause the piston rings of the starting air valve 7 to stick.

Use high-pressure air at regular periods to make sure that all dirt and grease is removed from the starting air manifold.

⇒ Do the steps that follow:

  ⇒ Engage the turning gear.

  ⇒ Open the drain and test valve 3 momentarily. If you can hear the starting air flow into the shut-off valve 1, close the drain and test valve 3. The starting air manifold 6 is pressurized with high-pressure starting air.

  ⇒ On the starting air bottles, close the shut-off valves.

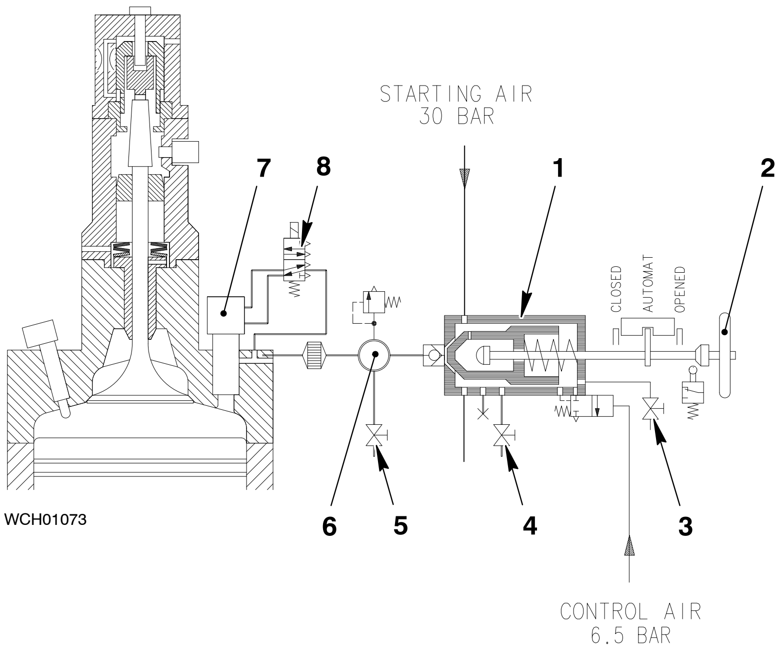
Remark: You can usually find the vent valve 5 installed at the free end of the starting air manifold. On some engines the vent valve is installed at the driving end.

⇒ Open the vent valve 5. The high-pressure air is released. Dirt and grease in the starting air manifold are removed.

⇒ Lift the lever then turn the handwheel 2 to the position CLOSED.

⇒ Open the vent valve 4 to drain the shut-off valve 1.

A



Key to Illustration: **Starting air system**

1 Shut-off valve for starting air
2 Handwheel
3 Drain and test valve 2.06
4 Vent valve 2.21
5 Vent valve 2.27
6 Starting air manifold
7 Starting air valve
8 5/2-way solenoid valve

1.4 Post-lubrication of the cylinders

Post-lubrication starts automatically during slow-down of the engine (speed less than 8%).

⇒ Close the shut-off valve on the control air supply (air supply from the board system).

Remark: Make sure that the lubricating oil pump is set to off before you bleed the air spring system.

2. Procedures for service breaks for a long period (weeks or months)

Refer to paragraph1.2 above and to 0620−1 Procedures before Putting Out of Service for a Long Period.

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Special Measures in Operation

Running-in of New Cylinder Liners and Piston Rings

1. General

After you have done an overhaul or you have installed new components of the piston running system, WinGD recommends to do a running–in procedure. This makes sure to build a correct film of lubricating oil on the piston running system. The procedure includes a temporary higher feed rate, refer to Fig. 1.

WinGD recommends an inspection of the cylinder liners and of the piston rings after 24 operation hours and after 72 operation hours (1, Fig. 1). For this running–in procedure it is not necessary to have a special loading up.

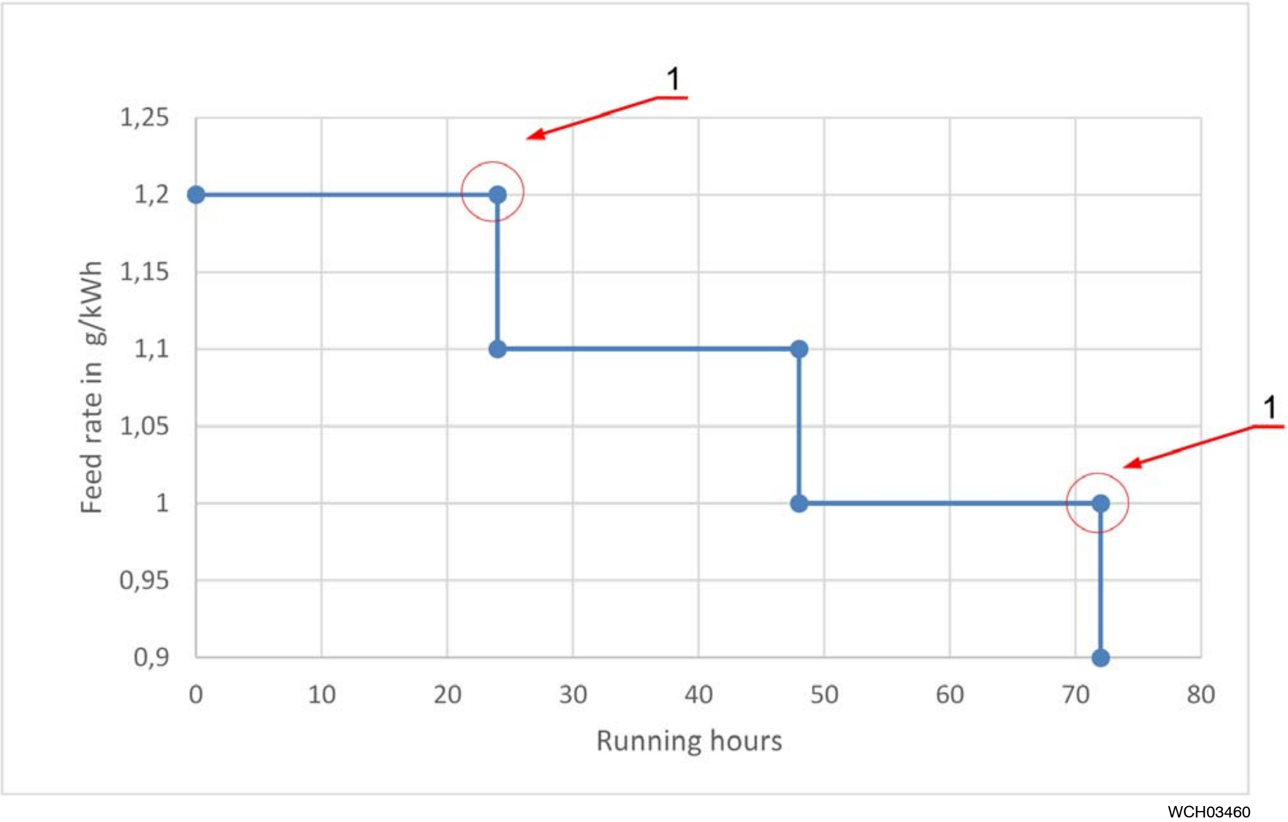


Fig. 1: Feed Rates for Running-in

2. Running−in Procedure

This procedure is only applicable, if you have done an overhaul or you have installed new components of the piston running system.

1) Set the cylinder lubricating feed rate for the applicable cylinders in the control system to 1.2 g/kWh.
2) Operate the engine for 24 hours.
3) Inspect the components for damage.
4) If damage occurs, find the cause and repair the fault.
5) If you have to replace parts of the piston running system, do step 2 and step 3 again.
6) Set the feed rate to 1.1 g/kWh.
7) Operate the engine for 24 hours.
8) Set the feed rate to 1.0 g/kWh.
9) Operate the engine for 24 hours.
10) Inspect the components for damage.
11) If damage occurs, find the cause and repair the fault.
12) If you have to replace parts of the piston running system, start with step 1 again.
13) Set the feed rate to 0.9 g/kWh.

After 72 hours you can set the feed rate to the usual settings. Refer to 0750−1/A1 Lubricating oils.

Special Measures in Operation

Indicator Diagrams

1. General

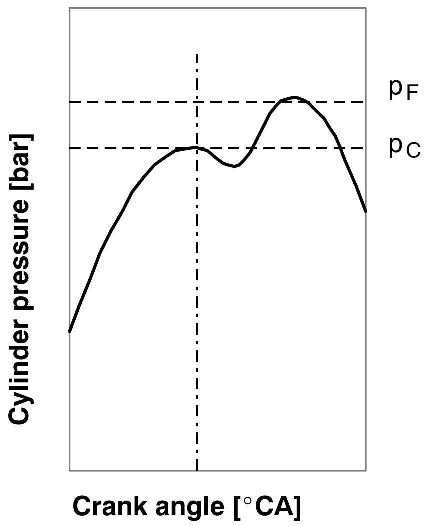
Indicator diagrams shall only be drawn with a suitable, well working indicator at constant power and speed, and in case of marine engines in calm sea and deep water.
For the interpretation of the indicator diagrams note the respective cylinder number, engine speed, the positions of the load indicator and VIT.

2. Definition of cylinder pressures

Higher compression ratio and fuel injection delay have been introduced to reduce the NO_x value for engines in compliance with the IMO rules.

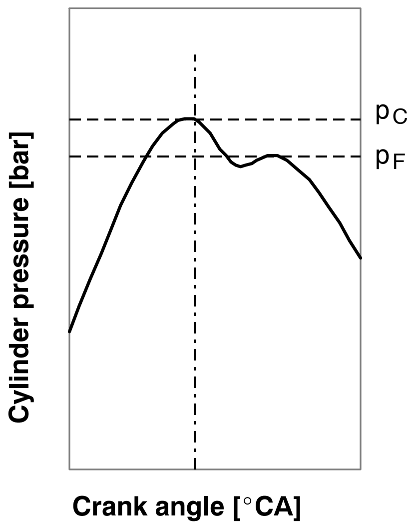
The ratio of the maximum firing pressure to the compression pressure is within the range of 0.90 to 1.25 at 100% load.
Depending on the engine rating and the corresponding IMO tuning, the diagram curves can **vary within the two following cases**:

Case A



P_C = Compression pressure at TDC

Case B

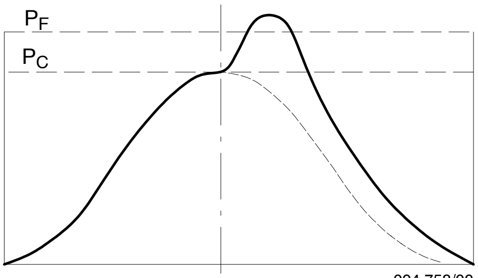


P_F = maximum firing pressure

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



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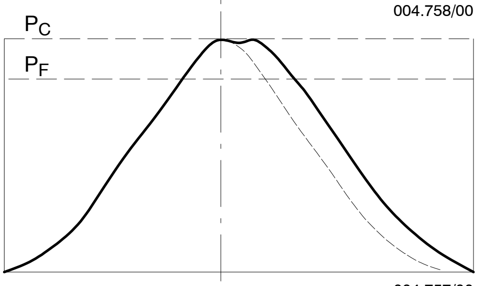
Case A



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Case B

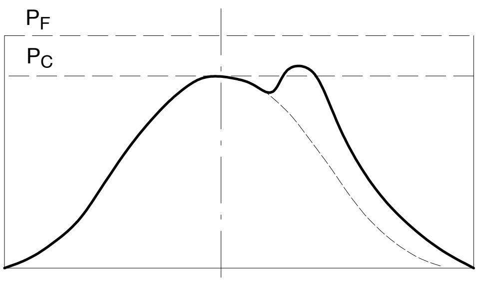
3.1 Maximum firing pressure too high at correct compression pressure

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.



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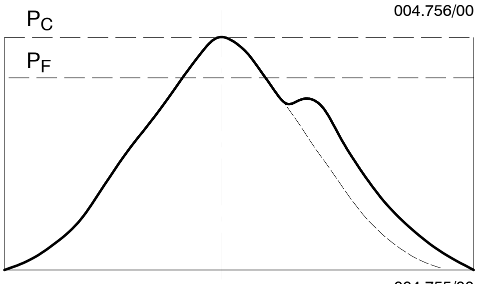
Case A



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Case B

3.2 Maximum firing pressure too low at correct compression pressure

Possible causes:

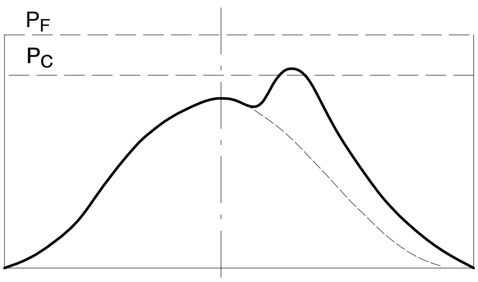
- Poor combustion: Nozzle tip with trumpets or worn out.

⇒ 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.



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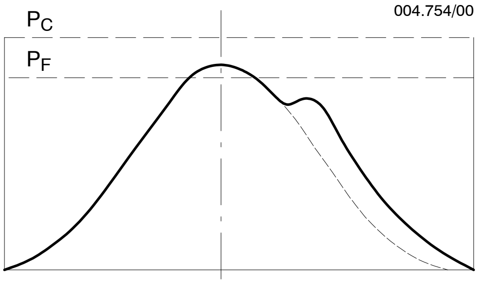
Case A



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Case B

3.3 Compression and maximum firing pressure too low

Possible causes:

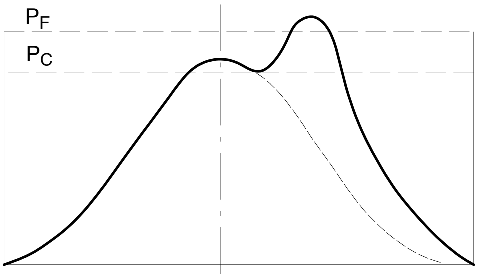
- Actual load lower than assumed.
- Exhaust valve leaking.

⇒ 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).



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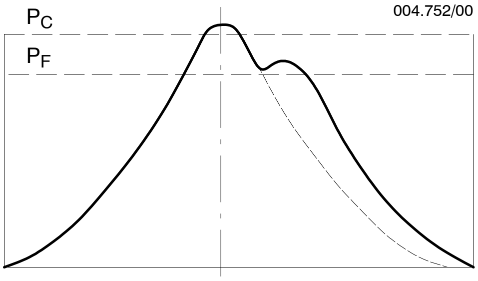
Case A



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Case B

3.4 Compression pressure and maximum firing pressure too high

Possible cause:

- Engine overloaded.
- VEC timing wrong.

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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 block (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 bottoms of the cylinder block and scavenge air receiver and if necessary clean them.

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 injection of cylinder concerned with user parameter Inj. CUTOFF 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_2) 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_2 gas.

Remark: Pay attention to paragraph 11 in 0210−1 'Entering the engine after the use of CO_2'.

- 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.

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.

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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.

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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.

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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.

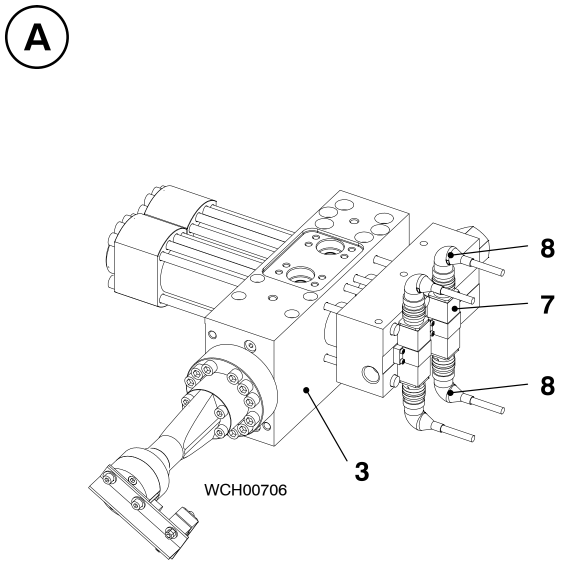
⇒ Reopen heating pipes.

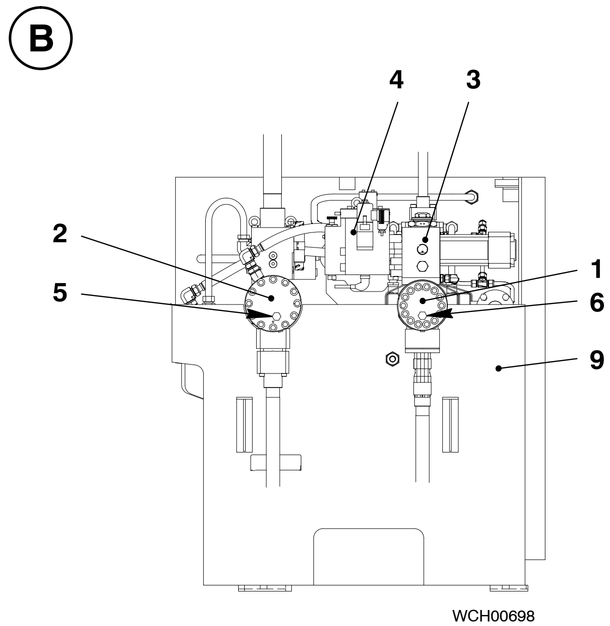
⇒ Adjust the lubricating oil feed rate for the respective cylinder to the previous settings (see 7218–1 'Adjusting the feed rate of lubricating oil').

⇒ 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)





DRIVING END

Key to Illustrations: 'A' Injection control unit
'B' Rail unit at driving end

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

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

1.1 Identification

- Higher regulating linkage 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 Supply Unit 5552−2 in the Maintenance Manual).

2. Defective actuator

2.1 Identification

- If an actuator fails, its regulating output remains in position or turns slowly to zero delivery. The toothed rack does not react to load changes.
- ***5 to 7 cylinder engines:*** At higher fuel consumption, the intact actuator takes over the control of fuel quantity regulation.
- ***8 cylinder engine:*** 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 or turn slowly to zero delivery. 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.

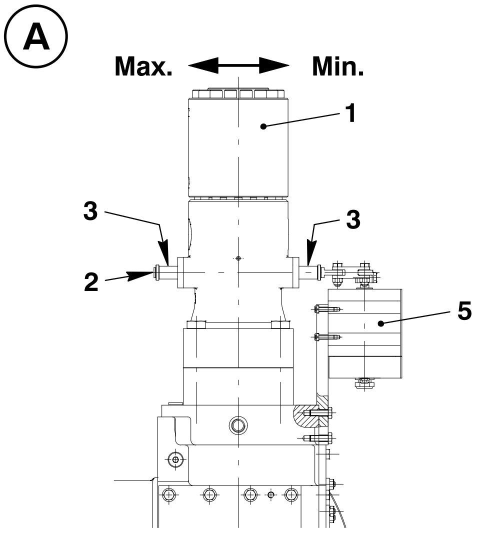
Operation with this regulating functions should be avoided if possible or be maintained only few hours, reduce rail pressure (see 2.3 ’Measures’ and 5562−1 ’Fuel pressure control valve 3.06’).

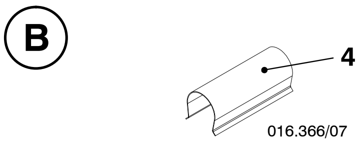
At an overpressure in the fuel rail (failure or malfunction of fuel pressure control valve 3.06), fuel overpressure safety valve 3.52 opens and an alarm is triggered by level switch LS3446A.

2.2 Causes

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

2.3 Measures





Failure of one actuator:

⇒ Fit spacers 3 (tool 94555a) on toothed rack 2 in position 'Center line' to fuel pump with regard to the faulty actuator.

⇒ Replace defective actuator at the first opportunity (see Regulating Linkage 5801–1 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 4 (tool 94555) can also be fitted in position 'Max.' or 'Min.' depending on preferential output (see following tables).

⇒ Turn knurled screw at fuel pressure control valve 3.06 (see 5562–1) counter-clockwise till the stop.

Key to Illustrations: **'A' Spacers in position 'Center line'**
'B' Spacer for position 'Min.' and 'Max.'

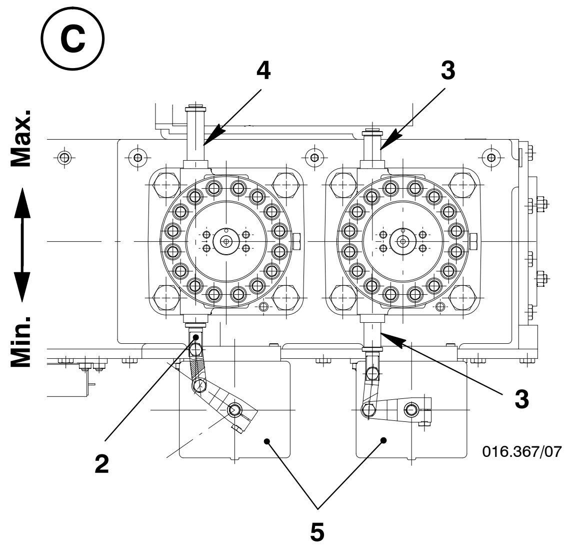
1 Fuel pump 3.14
2 Toothed rack
3 Spacer (tool 94555a)
4 Spacer (tool 94555)
5 Actuator 3.21

Engine with <u>two</u> fuel pumps (5 to 7 cylinders), <u>one</u> pump fixed:

Tool	Position of toothed rack	Range of engine output
94555a	Center line	approx. 20–80 %
94555	Min.	approx. 0–40 %
94555	Max.	approx. 40–100 %

Engines with <u>three</u> fuel pumps (8 cylinder), <u>one</u> pump fixed:

Tool	Position of toothed rack	Range of engine output
94555a	Center line	approx. 10–90 %
94555	Min.	approx. 0–70 %
94555	Max.	approx. 30–100 %



DRAWN FOR 5 to 7 CYLINDERS
WITH HEINZMANN ACTUATORS

Failure of all actuators:

⇒ Fit spacers 3 and 4 (tools 94555a and 94555) on toothed racks 2 in position 'Center line' and 'Max.' to all fuel pumps.

- Spacers 3 and 4 can also be fitted depending on preferential output (see following tables).

⇒ Turn knurled screw at fuel pressure control valve 3.06 (see 5562–1) counter-clockwise till the stop.

Key to Illustration: 'C' Spacer for position 'Min.' and 'Max.'

1 Fuel pump 3.14
2 Toothed rack
3 Spacer (tool 94555a)
4 Spacer (tool 94555)
5 Actuator 3.21

Fixing possibilities of toothed racks and their effect.

Engine with <u>two</u> fuel pumps (5 to 7 cylinders), <u>both</u> pump fixed:

Tool	Position of toothed rack	Range of engine output
94555a and 94555	Center line and Max.	approx. 80 %
94555a and 94555	Center line and Min.	approx. 30 %

Engine with <u>three</u> fuel pumps (8 cylinder), <u>all</u> pumps fixed:

Tool	Position of toothed rack	Range of engine output
94555a and 94555	2x Center line and 1x Max.	approx. 70 %
94555a and 94555	1x Center line and 2x Max.	approx. 90 %
94555a and 94555	1x Max. and 2x Min.	approx. 40 %

Remark: With this emergency operation, 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.

Emergency operation with this regulating functions should be maintained only few hours.

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.

3. Defective injection control unit

3.1 Identification

- Alarm indication in WECS−9520 (remote control).
- The fuel injection is cut out 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 of 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 defective.
- Fuel quantity piston seized.
- Breakage of an 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!

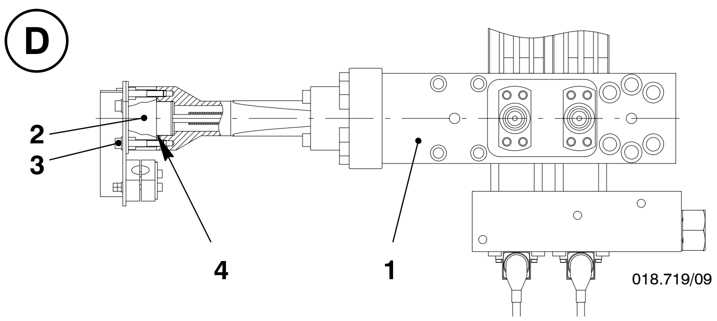
⇒ Loosen and remove screws 3.

⇒ 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!**



Key to Illustration: 'D'

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

Fuel quantity piston:

⇒ If the fuel quantity piston is at the stop, manually relieve fuel rail pressure shortly at fuel shut-down pilot valve 3.08 (EM. STOP ZV7061S).
This valve is arranged on fuel pressure control valve 3.06 (see 5562−1).

- 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):

- Replace defective pre-control valve at the first opportunity.

⇒ Stop the engine.

⇒ Switch off bearing oil pump.

⇒ Carefully loosen drain screw 7 by approx. two turns for pressure relief of servo oil rail 2 (see Fig. 'E').

⇒ Remove cable 6.

⇒ Loosen screws 5 and remove them together with pre-control valve 4.

⇒ It is to be ensured that the three O-rings are put in the new pre-control valve and the surfaces are clean.

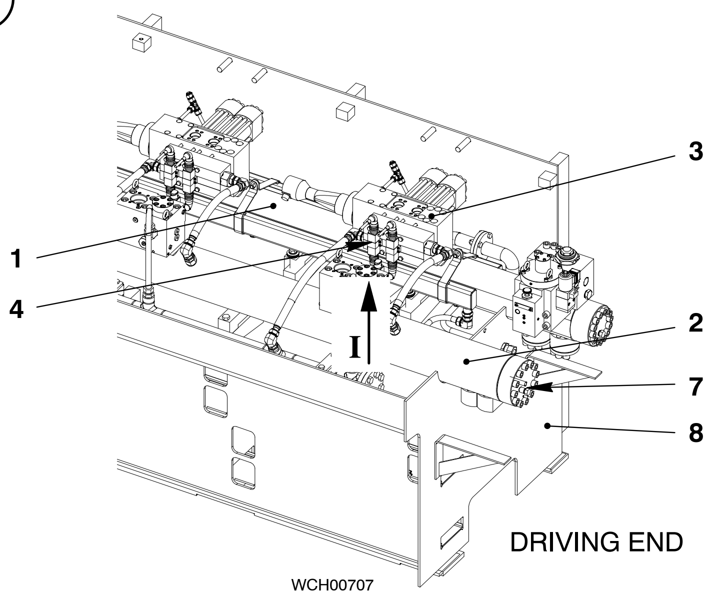
⇒ Fit the pre-control valve, apply Never-Seez NSBT-8 to the four screws 5 and tighten them with a torque of 2.5 Nm (see Fig. 'E' and Injection Control Unit 5564−1 in the Maintenance Manual).

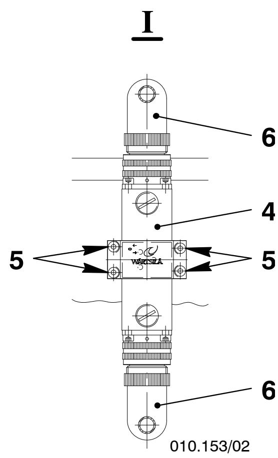
CHECK ***Important!*** Pay attention that the bore positions correspond.

⇒ Close drain screw 7 and tighten it with a torque of 200 Nm.

⇒ Reconnect cable 6. ***Important:*** **Plug must be tight!**

E





Key to Illustration: ’E’ Servo oil and fuel rail

1	Fuel rail 3.05	5	Screw
2	Servo oil rail 4.11	6	Cable
3	Injection control unit 3.02	7	Drain screw 4.82
4	Pre-control valve (rail valve) 3.76	8	Rail unit

Injection control unit:

The fuel injection must be cut out 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 out (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 at a breakage of an injection pipe (see 0510–1 ’Measures’).

⇒ Replace defective injection pipe at the first opportunity (see 0510–1 ’Exchange of defective injection pipe’ and 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).

4. Defective fuel pressure control valve 3.06

4.1 Identification

- Engine load drops or engine stops.
- Fuel oil system pressure too low (alarm).
- Regulating linkage position higher then 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.

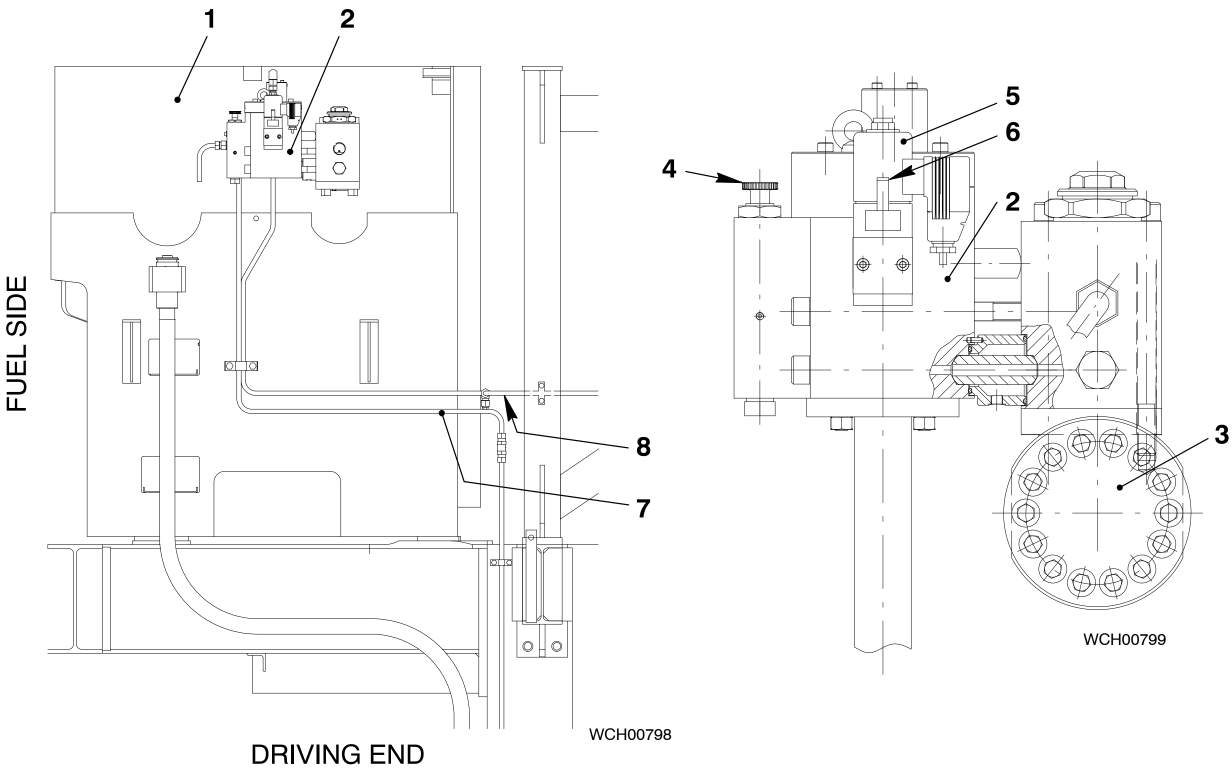
⇒ Check oil supply to fuel pressure control valve, clean filter in the inlet.

Attention! Replacing of the fuel pressure control valve can only be carried out at engine standstill!
The oil supply 7 from bearing oil system 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.

F



Key to Illustration: ’F’

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 Bearing oil supply
8 Non-return valve 3.67

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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 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.

⇒ Carefully loosen drain screw 2 by approx. two turns for pressure relief of servo oil rail 1 (see Fig. 'A').

⇒ Loosen screws 7 on flange 6 of actuator pipe 4 in order to drain the latter via check bore 'KC' in housing 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.

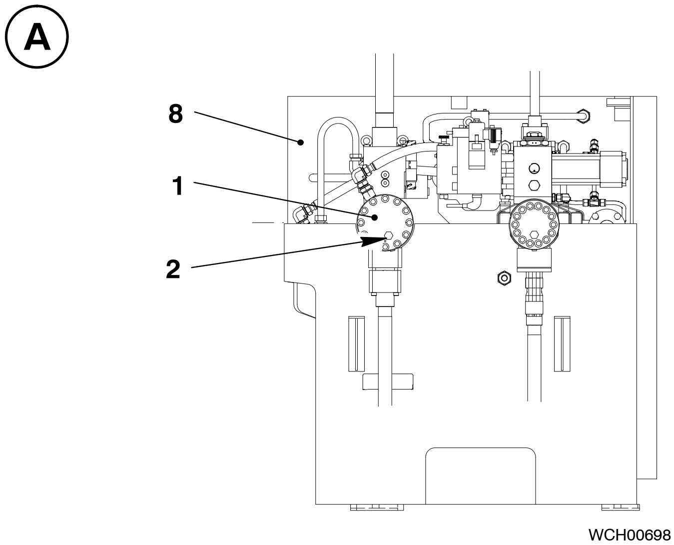
⇒ Cut in the injection (see 0510–1).

⇒ Set the exhaust valve control unit for the cylinder concerned to AUTO with user parameter EXH. VALVE AUTO / MAN. in remote control.

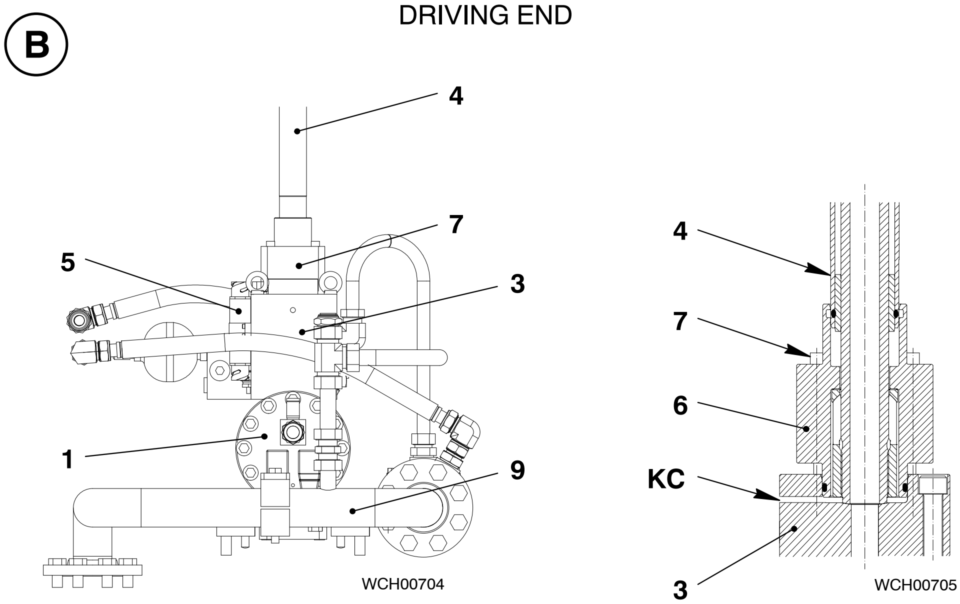
⇒ Reconnect plugs to pre-control valve (rail valve) 5.

CHECK Carry out a visual leakage test.

Operation with Exhaust Valve Control Unit Cut Out



DRIVING END



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

1	Servo oil rail 4.11	7	Screw
2	Drain screw 4.82	8	Rail unit
3	Exhaust valve control unit 4.10	9	Servo oil return piping 4.63
4	Actuator pipe 4.66		
5	Pre-control valve (rail valve) 4.76		
6	Flange	KC	Check bore

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 pressure element 4 (tool 94259a) with oiled thread (see Fig. 'D').

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

For safety reasons the pressure element 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 sping venting 4.08 to operating position after fitting the pressure element.

⇒ 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 pressure element 4 (tool 94259a). 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).

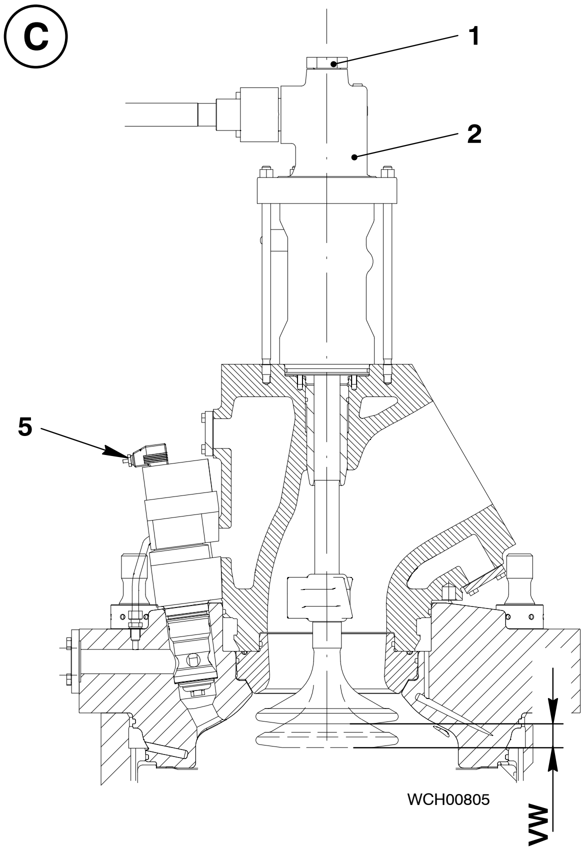
⇒ Turn venting cock 4.08 back to operating position.

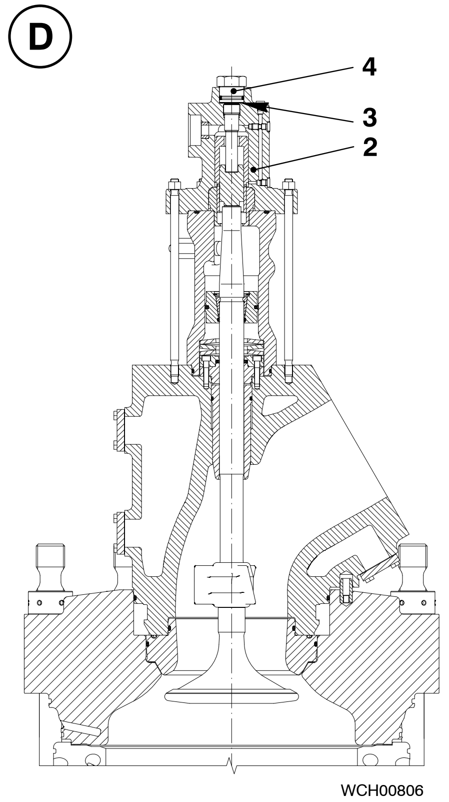
⇒ Switch on again bearing oil pump.

⇒ 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





Key to Illustrations: 'C' Exhaust valve
'D' Pressure element fitted

1 Damper
2 Upper housing
3 Shim ring
4 Pressure element (tool 94259a)
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 the 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 oil parameters').
- Cold lubricating oil.

1.3 Measures

⇒ If the automatic filter is clogged, switch over to bypass, the engine remains in operation.

⇒ Clean clogged filter elements manually or replace them.

⇒ 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 – FS2062A indicate a pump failure, i.e. an alarm is triggered in alarm and monitoring system ('Servo oil pump 1 / 2 flow').

2.2 Causes

- Servo oil pump blocked, shaft at shearable overload protection broken (see Servo Oil Pump 5551–1).
- Failure of the actuators CV7221C – CV7222C.
- 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 pressure relief of servo oil rail' and Supply Unit 5552–1 in the Maintenance Manual).

Attention! The operating mode with a pump out of order must not be considered as permanent, and if the 2nd pump fails the engine will no longer be operative!

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 out automatically (Inj. CUT OFF) on the corresponding cylinder, and a SLOW DOWN will be released.
- Alarm indication by level switch LS3444A 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.

⇒ Carefully loosen drain screw 1 by approx. two turns for pressure relief of servo oil rail 2 (see Fig. ’A’).

⇒ Remove cable 7.

⇒ Loosen screws 6 and remove them together with the 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 and tighten the latter with a torque of 2.5 Nm (see Fig. ’A’ and Exhaust Valve Control Unit 5612−1 in the Maintenance Manual).

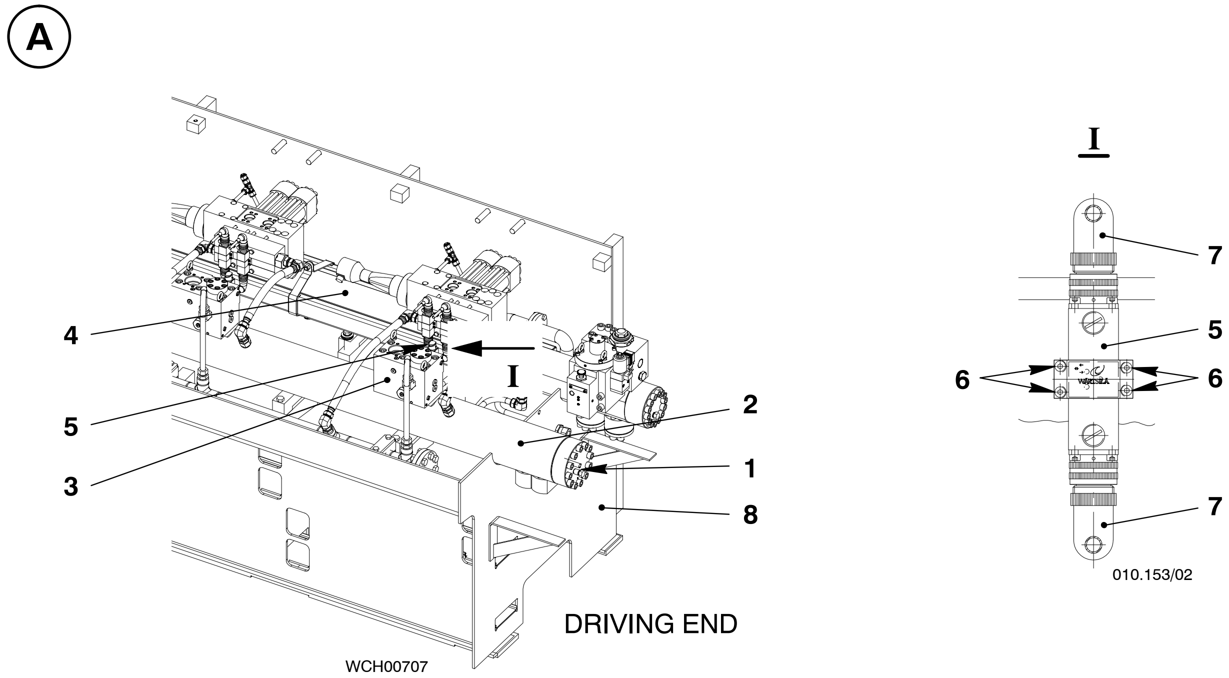
CHECK

Important! Pay attention that the bore positions correspond.

⇒ Close drain screw 1 and tighten it with a torque of 200 Nm.

⇒ Reconnect cable 7. ***Important:*** **Plug must be tight!**

Faults in Servo Oil System



Key to Illustration: 'A' Servo oil rail at driving end

1	Drain screw 4.82	5	Pre-control valve (rail valve) 4.76
2	Servo oil rail 4.11	6	Screw
3	Exhaust valve control unit 4.10	7	Cable
4	Fuel rail 3.05	8	Rail unit

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 defective exhaust valve control unit or hydraulic piping' and 8460−1 in Maintenance Manual).

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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 bend 6 from starting air pipe 5 and fit blank flange 7 (tool 94831) as shown in Fig. 'A'.

⇒ Remove control signal plug 10 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) 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 the connecting rod

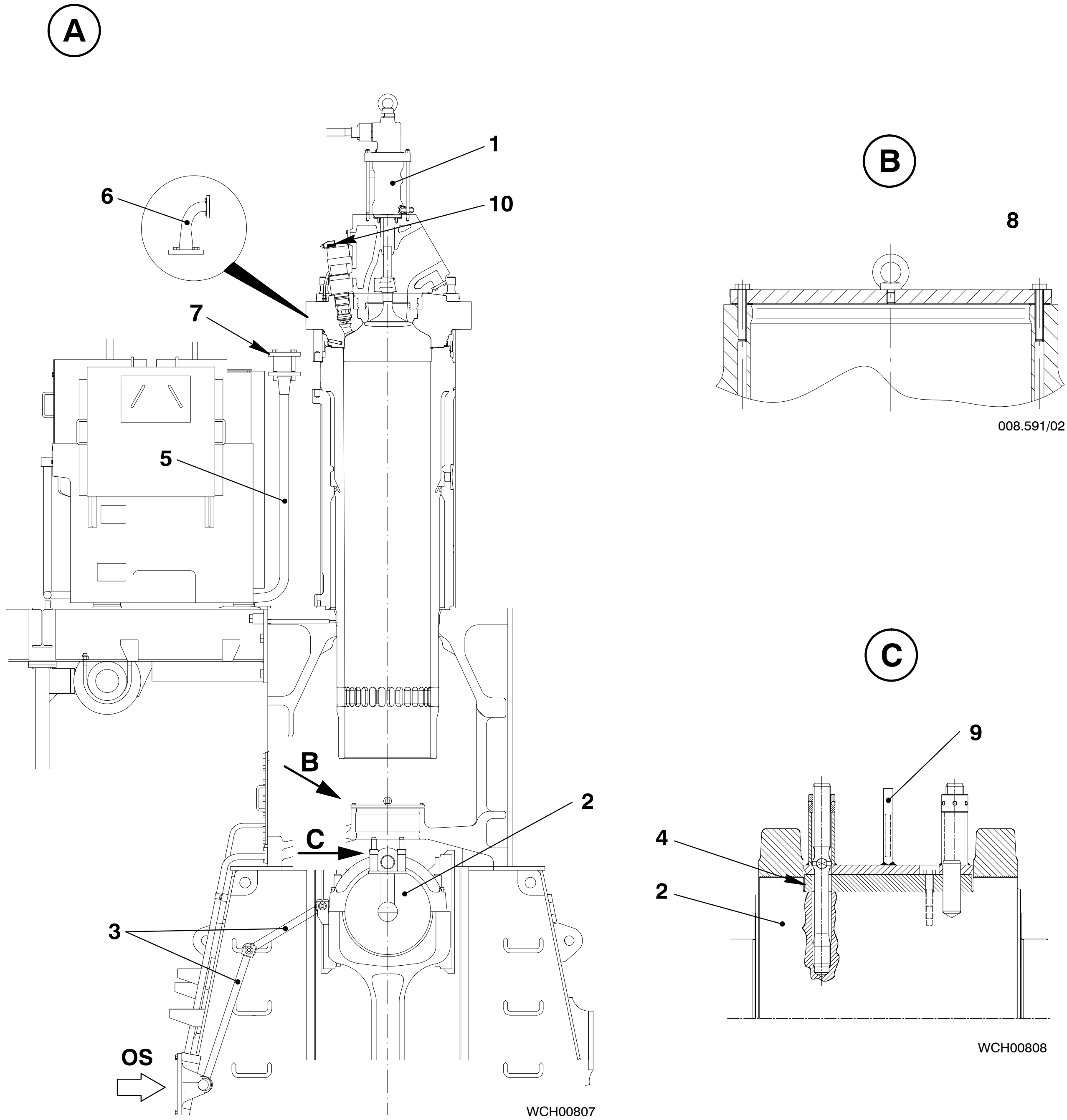
3.1 Measures

⇒ With the exception of mounting cover and lifting plate 9 (tool 94324) onto the crosshead pin, all measures under section 2.1 must be carried out.

⇒ Furthermore blank off the oil supply for piston cooling at 'OS' and for the crosshead lubrication outside the engine.

⇒ Remove toggle lever 3.

Operation with Running Gear Partially or Totally Removed



Key to Illustrations: **'A' Sealing off the cylinder**
'B' Covering for the gland bore
'C' Sealing off the crosshead

1	Exhaust valve	7	Blank flange (tool 94831)
2	Crosshead	8	Cover plate (tool 94345d)
3	Toggle lever	9	Cover and lifting plate (tool 94324)
4	Compression shim	10	Control signal plug
5	Starting air pipe		
6	Bend (starting air inlet)	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).

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Operation under Abnormal Conditions

Overpressure in the Combustion Chamber

1. General

It is possible that overpressure can occur in the combustion chamber. Overpressure in the combustion chamber (i.e. too much fuel, oil, water or a permanently closed exhaust valve etc.) can cause the relief (safety) valve to open and / or the cylinder cover to lift.

***Attention!* Investigate the cause(s) of the overpressure immediately.**

2. Measures

Remove the cylinder cover and the water guide jacket for a visual inspection of the combustion chamber (see 2708–1 in the Maintenance Manual).

Do the checks that follow:

⇒ Use the correct round bar to make sure that the nuts of the elastic studs 5 are tight.

⇒ Put the hydraulic tensioning device 94215 in position as given in 2708–2 Maintenance Manual.

⇒ Carefully operate the hydraulic tensioning device. Increase the pressure until the nuts become loose.

- If the pressure is almost the same as the nominal tightening pressure, the elastic studs are not overstressed and can be used again.
- If the nuts become loose at a pressure of less than 20% of the nominal tightening pressure, replace the elastic studs as given in the Maintenance Manual 2751–1.

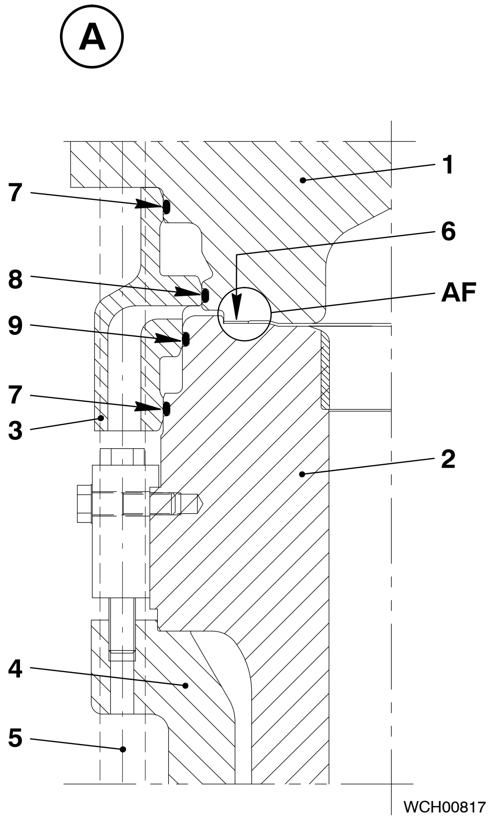
⇒ Make sure that:

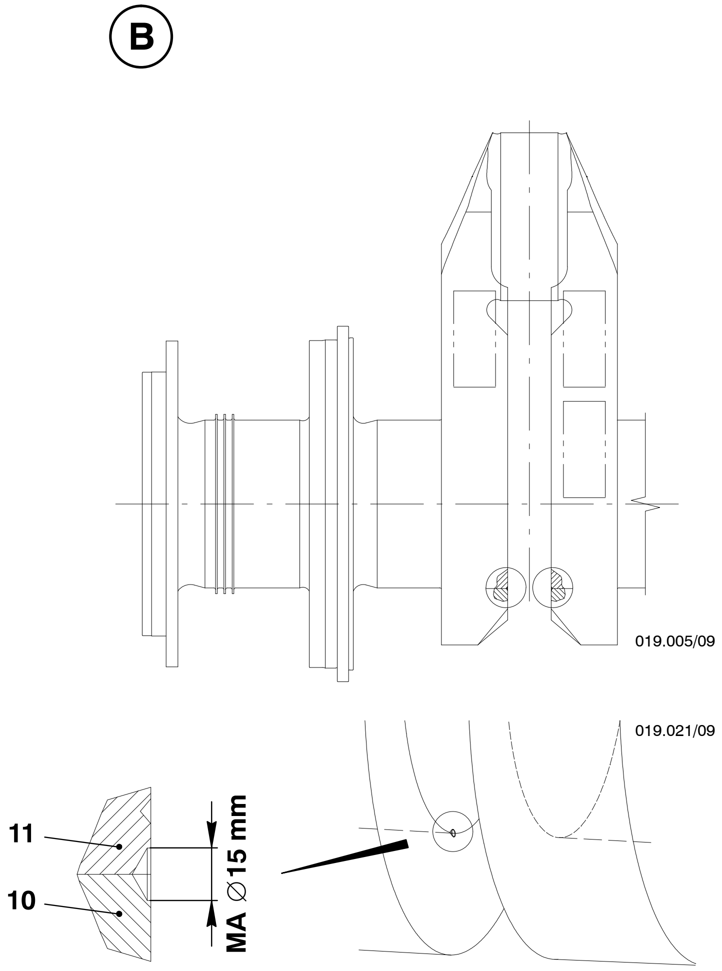
- The gasket 6 is serviceable.
- The surfaces ’AF’ on the cylinder cover 1 and liner 2 are in perfect condition.
- The O-rings 7, 8, 9 and 10 are replaced with new items.
- If a relief valve is fitted (depending on Class requirements), do a check in accordance with 2745–1 in the Maintenance Manual.
- On the crankshaft, the two marks ’MA’ on all cylinders are in line. If the marks are not in line, the crank 10 has turned.

***Attention!* If the crank has turned, contact WinGD immediately.**

Remark: If the engine must be operational as soon as possible and the problem cannot be rectified within reasonable time, see the instructions give in:

- Operation with Running Gear Partially or Totally Removed 0540–1
- Operation with Injection Cut Out (One or More Cylinders) 0510–1 or other related instructions.





Key to Illustrations:

1	Cylinder cover	8	O-ring
2	Cylinder liner	9	O-ring
3	Water guide jacket	10	Crank
4	Supporting ring	11	Shaft journal
5	Elastic stud		
6	Gasket	AF	Seating surface
7	O-ring	MA	Mark (recess)

3. Fitting of cylinder cover

See Maintenance Manual:

- Removal and Fitting of Cylinder Cover and Water Guide Jacket 2708−1
- Loosening and Tensioning of Cylinder Cover Elastic Studs 2708−2

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 drain pipe into the float / solenoid switch unit of the scavenge air cooler drain. An alarm is triggered by the corresponding level switch.

Since also sea-water is used to cool the scavenge air, there is the risk that any leakage could cause serious corrosion of the air flaps, etc. in the receiver.

Remark: Should a flow of water be observed through the sight glass of the scavenge air cooler drain **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.

⇒ 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 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 low load.

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.

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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.

Intentionally blank

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.

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Operation under Abnormal Conditions

Turbocharger Out of Service

1. General

If a turbocharger fails, the engine must be shut down as quickly as possible to prevent more damage.

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

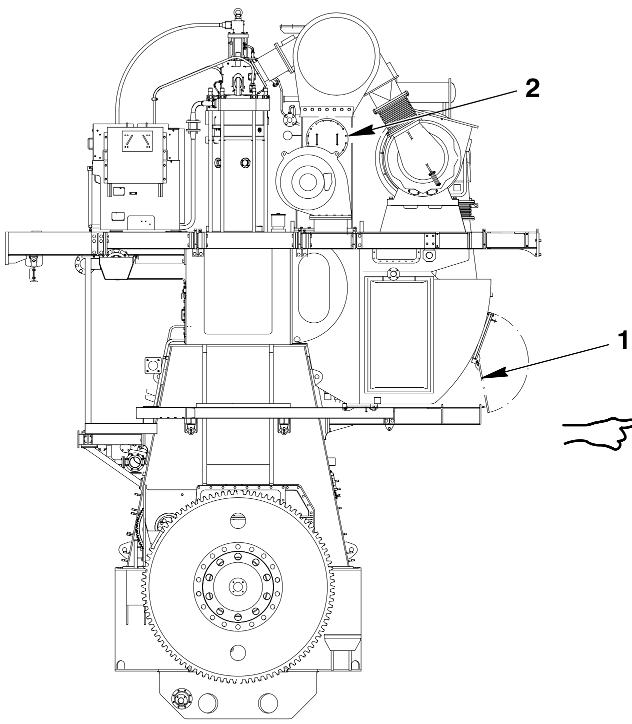
In 'Emergency Operation', the engine must only operate as long as is absolutely necessary. (For more instructions, see 0500−1).

The loads (outputs) given are guidance values. These values can be further reduced depending on the condition of the engine.

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

2. Breakdown case 1 (standard procedure)

Failure of the turbocharger on engines with one turbocharger without exhaust bypass piping.



Operable output relative to CMCR:

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

Measures:

⇒ Lock the rotor of the defective turbocharger as described in the turbocharger manual.

⇒ Open the cover 1 on the air duct.

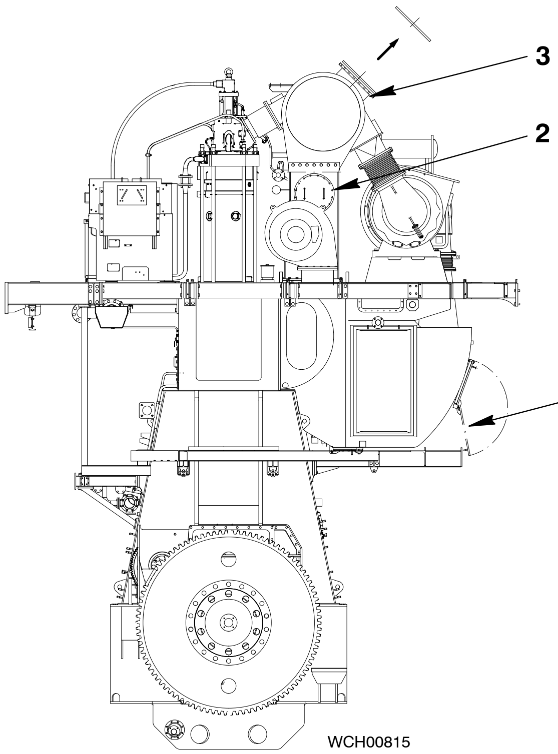
⇒ Switch on the auxiliary blowers.

⇒ If an auxiliary blower fails, do not remove the cover 2 on the defective blower side.

Remark: The exhaust gas temperature before turbocharger must not be higher than at normal operation. Thick, black exhaust smoke must be prevented.

3. Breakdown case 2 (optional procedure)

Failure of the turbocharger on engines with one turbocharger and exhaust bypass piping.



Operable output relative to CMCR:

Operable output relative to CMCR: **Approximately 25% to 30%** depending on the output of the auxiliary blowers.

Measures:

⇒ Lock the rotor of the defective turbocharger as described in the turbocharger manual.

⇒ Open the cover 1 on the air duct.

⇒ Open the bypass pipe on the exhaust pipe 3.

⇒ Switch on the auxiliary blowers.

⇒ If an auxiliary blower fails, do not remove the cover 2 on the defective blower side.

Remark: The exhaust gas temperature before turbocharger must not be higher than at normal operation. Thick, black exhaust smoke must be prevented.

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 33 (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 pressure relief 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).

Intentionally blank

Special Measures before and after Operation

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

1. General

In the event of the engine being put out of service for an extended period, proper precautions have to be taken in order to protect the engine against corrosion and rust formation. There are two cases to be considered:

Case 1:

- Period of several weeks with (reduced) ship's crew on board.

Case 2:

- Period of several months without ship's crew on board.

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 WinGD).

2. Case 1

2.1 Measures and checks

Remark: It is recommended to run the engine on diesel oil instead of heavy fuel oil for some time before shutting it down (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 the shut-off valve for starting air 2.03 to position CLOSED (closed by hand) and open venting valves 2.21 and 2.27 (see Control Diagram 4003–2).

⇒ Check on the pressure gauges whether no pressure is indicated.

⇒ Engage turning gear.

- 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.

⇒ Open the indicator valves on the cylinder covers.

- Post-lubrication starts automatically during slow-down of the engine (speed below 8%).

⇒ Cut out fuel pump by means of tool 94430 (see 5556–2).

⇒ Close the stop valves on the fuel tanks.

⇒ Open the drain valves of the exhaust gas manifold and on the exhaust gas pipe, draining condensate and subsequently close the drain valves again.

⇒ Cover the exhaust gas manifold and the silencer of the turbocharger airtight with a tarpaulin in order to prevent air circulation through the engine (risk of condensed water formation).

- 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).

⇒ 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).

- Where the auxiliary engines and boilers are also put out of operation and there is risk of frost, all the cooling systems have to be drained off completely (in such cases the empty cooling spaces have to be protected against corrosion).
- Switch off WECS−9520 by breaker in the power supply box E85.
- Switch off the control box for the automatic filter.

CHECK

Within 48 hours after putting the engine out of service the following checks have to be carried out:

⇒ Open cover of rail unit and check for condensate and corrosion traces.

⇒ Remove inspection cover from supply unit and check housing internal for condensate and camshaft, cams and roller for corrosion traces.

2.2 Measures and checks to be repeated

Weekly:

⇒ With the indicator valves open, turn the engine by means of the turning gear till the piston has reached 60° before or after TDC (check on flywheel) so that cylinder lubricating oil can be fed directly into the piston ring packet. Select corresponding cylinder number in field MANUAL LUBRICATION ON CYL. in the operator interface.
Thereby the lubricating oil pump and the servo oil service pump must be in operation (see Prepare the Cylinder Lubricating System 0140−1).

⇒ Subsequently turn the engine two full turns with the turning gear in order to distribute the cylinder lubricating oil on the cylinder liner wall. The recommended intervals are weekly in dry and daily in damp climates. Stop the engine each time in another position.

⇒ Open cover of rail unit and check for condensate and corrosion traces.

⇒ Remove inspection cover from supply unit and check housing internal for condensate and camshaft, cams and rollers for corrosion traces.

Remark: If there are signs of corrosion, the affected parts must be carefully cleaned and subsequently protected with an anticorrosive oil providing an anti-rust finish.
Reduce intervals of post-lubrication and apply (spraying) oil to the dry parts.

Operating Media
Diesel Engine Fuels

Overview

1. General

Almost all mineral residual and distillate and some renewable fuels can be burned in a diesel engine if applicable procedures are done. But, the quality of the fuel will have an effect on the frequency of overhauls and the work necessary to prepare the fuel. It is the primary economic considerations that according to the type, size and speed of the engine, and its application gives the fuel quality margins.

Gas oils and diesel oils (distillates) can be used in all WinGD engines with some limits. WinGD 2-stroke diesel engines are designed to operate on up to 700 mm^2/s (cSt) at 50°viscosity heavy fuel oil (ISO 8217:2017 RMK 700 grade) if sufficient fuel heating and treatment is done. When fuels with a very low sulphur content are used, operators must be careful when running-in new piston rings and cylinder liners.

Heavy fuel oil must have treatment in an applicable fuel treatment plant.

When bunkering, it is possible that the fuel suppliers will report only some of the values given in the Quality Specifications. Frequently, only the density and maximum viscosity is given. This makes the analysis of a fuel difficult, thus it is important to get a full certificate of analysis with each bunker.

The supplier must guarantee the stability of the fuel, i.e. resistance to the formation of sludge. Also, the fuel must not have a corrosive effect on the injection equipment and must not contain used lubricating oil or chemical waste.

If possible, oils from different bunkers must not be mixed because there is a risk that the fuels will have different compositions (e.g. this can cause fouling of filters or too much sludge, which will overload the fuel preparation equipment). Fresh bunkers must always be put into empty tanks and not on top of old bunkers.

2. Heavy fuel oil

Diesel engine fuels include many different petroleum products from gas oil to Heavy Fuel Oil (HFO). Gas oil is made from crude oil by distillation and processing. HFO is the remaining material after distillation of the crude oil. To get the necessary viscosity, the material is mixed with lighter, less viscous components. Modern refineries also apply a secondary conversion process, such as viscosity breaking (visbreaking) and catalytic cracking to get a higher yield of lighter products. The remaining products are mixed to get HFO.

Viscosity is usually used to identify diesel engine fuels. The viscosity is shown in mm^2/s, referred to as centistokes (cSt) and measured at 50°C. The fuels are classified in accordance with ISO 8217 and the latest revision is the sixth edition dated March 2017.

Viscosity itself is not a quality criterion. To make an analysis of the fuel quality (to make sure that the fuel is applicable for use in a diesel engine), refer to the properties such as those given in the Table 1.

To make an estimate of the ignition properties of a distillate diesel fuel, the CETANE number (standardized engine test) or the CETANE index (calculation) were used. The ignition and combustion properties are very important for medium and high-speed engines. For low-speed diesel engines, the ignition properties are not very important.

Note: Some very poor fuels that are not frequently found can have important ignition properties.

Very good supervision, engine maintenance and fuel treatment equipment is necessary when fuel with properties near the maximum limits are used. Fuel preparation that is not sufficient and poor quality fuels cause overhauls to be more frequent and thus, an increase in the cost of maintenance.

The values in the column Bunker limit (ISO 8217:2017 RMK700) show the minimum quality of heavy fuel as bunkered, i.e. as supplied to the ship/installation. Good operation results come from commercially available fuels that are in the ISO 8217 limits. But the use of fuel with metal, ash and carbon contents and a lower density can have a positive effect on overhaul periods. These effects can improve combustion and exhaust gas composition as well as a decrease in wear.

The fuel as bunkered must be processed before it goes into the engine. It is recommended that you refer to the related specifications of Winterthur Gas & Diesel Ltd. for the design of the fuel treatment plant. The minimum centrifuge capacity is 1.2 x CMCR x BSFC / 1000 (litres/hour), which is has a relation to 0.21 l/kW. The fuel treatment must remove sludge and decrease catalyst fines and water to the recommended engine inlet limits.

In ISO 8217, foreign substances such as used oil or chemical waste must not be added to the fuel. This is because of the hazards to the crew, machines and the environment. Tests that are done for unwanted substances as acids, solvents and monomers with titrimetric, infrared and chromatographic methods, are recommended. This is because of the damage these substances can cause to fuel treatment, fuel injection equipment, pistons, rings, liners, and exhaust valves and seats. Turbocharger, exhaust system and boiler contamination can also occur because of poor fuel quality.

It is very important that the fuel is fit for purpose in the related engine application.

Table 1: Specifications for HFO

Parameter	**Unit**	**Bunker Limit**	**Test Method**	**Fuel Quality at Engine Inlet**
Kinematic viscosity at 50°C	mm^2/s [cSt]	Maximum 700	ISO 3104	13 to 17 (not related to temperature) 2)
Density at 15°C	kg/m^3	Maximum 1010 3)	ISO 3675/12185	Maximum 1010
CCAI	–	Maximum 870	Calculated	Maximum 870
Sulphur 4)	m/m [%]	Statutory specifications	ISO 8754/14596	Maximum 3.5
Flash point	°C	Minimum 60.0	ISO 2719	Minimum 60.0
Hydrogen sulphide 5)	mg/kg	Maximum 2.00	IP 570	Maximum 2.00
Acid number	mg KOH/g	Maximum 2.5	ASTM D 664	Maximum 2.5
Total sediment aged	m/m [%]	Maximum 0.10	ISO 10307–2	Maximum 0.10
Carbon residue: micro	m/m [%]	Maximum 20.00	ISO 10370	Maximum 20.00
Pour point (upper) 6)	°C	Maximum 30	ISO 3016	Maximum 30
Water	v/v [%]	Maximum 0.50	ISO 3733	Maximum 0.20
Ash	m/m [%]	Maximum 0.15	ISO 6245	Maximum 0.15
Vanadium	mg/kg [ppm]	Maximum 450	ISO 14597/ IP501/470	Maximum 450
Sodium	mg/kg [ppm]	Maximum 100	IP501/IP470	Maximum 30
Aluminum plus Silicon	mg/kg [ppm]	Maximum 60	ISO 10478/ IP501/470	Maximum 15
Used lubricating oils (ULO) must not be present: Calcium and zinc or Calcium and phosphorous	mg/kg	ULO shows if: Ca>30 and Zn>15 or Ca>30 and P>15	IP501 or IP470 IP500	Do not use if: Ca>30 and Zn>15 or Ca>30 and P>15
Winterthur Gas & Diesel Ltd. fuel specifications and quality limits at the engine inlet related to ISO 8217:2017 1)				

The notes that follow are related to the data in Table 1:

$1 mm^2/s = 1 cSt$ (Centistoke)

1) You can get ISO standards from the ISO Central Secretariat, Geneva, Switzerland (www.iso.ch).

2) For W–X engines the fuel viscosity at the fuel pump inlet can be in the range of between 10 mm^2/s (cSt) and 20 mm^2/s (cSt). When the engine operates on HFO, Winterthur Gas & Diesel Ltd. recommends a fuel viscosity at the fuel pump inlet in the range of between 13 mm^2/s (cSt) and 17 mm^2/s (cSt).

3) The maximum limit is 991kg/m^3 if the fuel treatment plant cannot remove water from high-density fuel.

4) Note that lower sulphur limits can apply and are related to statutory specifications and sulphur limits not given in ISO 8217:2017.

5) The hydrogen sulphide limit is applicable from 1 July 2012.

6) Purchasers must make sure that the pour point is sufficient for the equipment on board, specially for operation in cold climates.

Note: For data about the parameters given in the table above, see paragraph 3.1 to paragraph 3.12.

CAUTION

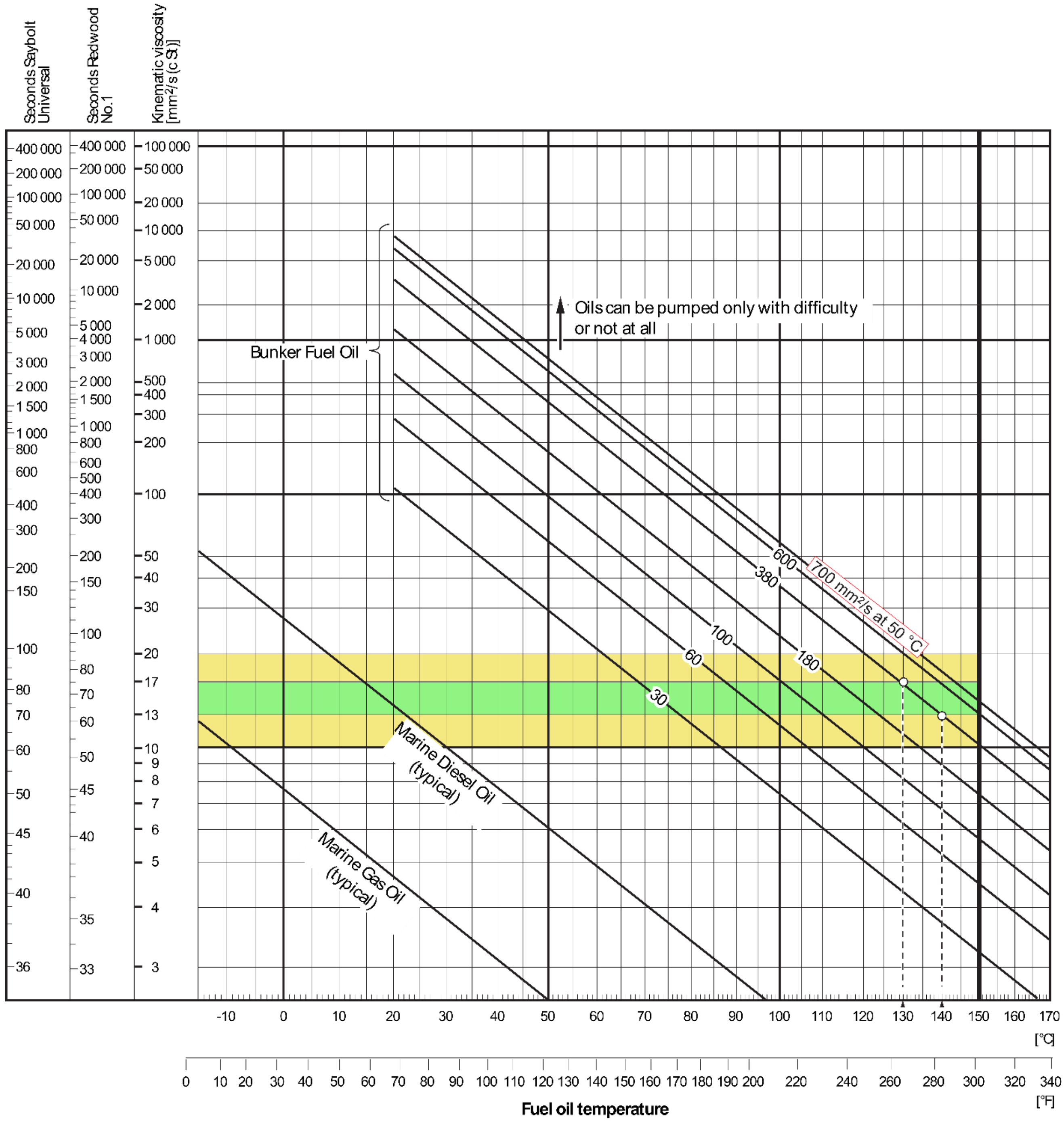
Damage Hazard: For WinGD 2-stroke engines, the maximum permitted fuel temperature at the engine inlet is 150°C. Always make sure to obey this limit. Damage to the engine can occur. For more data, see also 250–1 Operation Data Sheet.

***Damage Hazard:* Hydrogen Sulphide (H_2S) is a very toxic gas and exposure to high concentrations is dangerous and can kill you. Be careful when tanks or fuel lines are opened because there can be H_2S vapor. At low concentrations H_2S smells almost the same as bad eggs. You cannot sense H_2S at moderate concentrations. H_2S will cause nausea and dizziness.**

3. Data about Heave Fuel Oil Specifications

3.1 Viscosity

The recommended viscosity range upstream of the engine is between 13 mm²/s (cSt) and 17 mm²/s (cSt). You get the necessary temperature for a given nominal viscosity from the data in Fig. 1 below:



1. Required viscosity range for RTA and older engines
2. Recommended viscosity range for RT-flex and W-X engines

Required viscosity range for RT-flex and W-X engines

Example:

To get the recommended viscosity upstream of the fuel pumps, the fuel of 380 mm²/s [cSt] at 50°C must be heated to between 130°C and 140°C.

WCH03126

The maximum permitted viscosity of the fuel that can be used in an installation is related to the heating and fuel preparation facilities available. The flow rate and the temperature of the fuel that flows through the centrifuges must be adjusted in relation to the viscosity to get good separation. Do not heat the fuel to more than 150°C to get the recommended viscosity at the engine inlet. This is because the fuel can start to decompose, get contamination and be dangerous as it is possible that the temperature will be higher than the flash point.

3.2 Density

The composition of the fuel gives the density. A high density shows a high aromatic content. It is not always possible to use conventional methods to measure the density at 15°C. Thus, the measurement is made at a higher temperature and then converted and adjusted to the reference temperature. Most bunkers are to the ISO 8217:2017 RMG specification, which has a maximum density of 991.0 kg/m^3. Applicable fuel preparation equipment, which can be adjusted for a fuel density greater than 991.0 kg/m^3, must be available on board if high density fuels are used.

3.3 CCAI (Calculated Carbon Aromaticity Index)

The ignition and combustion properties of the fuel in a diesel engine are related to the specific engine design, load profile and fuel properties.

The CCAI is a calculated quantity of the ignition properties or ignition interval of the fuel related to the viscosity and density. The CCAI has no effect on the combustion properties. The CCAI limit is useful to measure fuels with unusual density-viscosity relations.

More tests are available to find ignition and combustion properties and these can be helpful to examine the performance of fuels.

3.4 Sulphur

Sulphur limits are not specified in ISO 8217:2017 because statutory specifications put a limit on this value. The maximum sulphur level that can be used in WinGD 2-stroke engines is 4.5% m/m.

The alkalinity (base number (BN)) of the cylinder lubricating oil must be selected in relation to the sulphur level of the fuel in use. The engine can operate for short periods (some hours) with a cylinder lubricating oil that has an incorrect BN, but a longer operation time must be prevented.

Indications for the selection of the BN of the lubricating oil in relation to the sulphur content of the fuel are found in:

- 0410–1 Running-in of New Cylinder Liners and Piston Rings
- 0750–1 Lubricating Oils, paragraph 3.

3.5 Flash point

The flash point is an important safety and fire hazard parameter for diesel fuels. Fuel is always a fire hazard. There can be flammable vapors above the remaining fuel in the tanks. There must be caution on ships when the temperature of the remaining fuel is increased above the flash point to help with the filter process and injection.

3.6 Hydrogen sulphide

Danger: **Hydrogen Sulphide (H_2S) is a very toxic gas and exposure to high concentrations is dangerous and can kill you. Be careful when tanks or fuel lines are opened because there can be H_2S vapor. At low concentrations H_2S smells almost the same as bad eggs. You cannot sense H_2S at moderate concentrations. H_2S will cause nausea and dizziness.**

3.7 Acid number

Fuels with high acid numbers have caused damage to fuel injection systems. Most fuels have a low acid number, which is not dangerous, but an acid number above 2.5 mg KOH/g, can cause problems. Some naphthenic fuels can have an acid number of more than 2.5 mg KOH/g, but still be permitted. Only a full laboratory analysis can find the strong acid number.

3.8 Sediment, carbon residue, asphaltenes

High quantities of sediment, carbon and asphaltenes decrease the ignition and combustion quality of the fuel and increase wear and damage to engine components. Asphaltenes also have an effect on the stability of mixed fuels and can cause too much sludge in the separators and filters. If the mixed fuel is not stable, particles can collect on the bottom of the tank.

To keep risks to a minimum, make sure that bunkers from different suppliers and sources are not mixed in the storage tanks on board. Also be careful when HFO is mixed on board to decrease the viscosity. Paraffinic distillate, when added to an HFO of low stability reserve, can cause the asphaltenes to collect, which causes heavy sludge.

HFO can contain up to 14% asphaltenes and will not cause ignition and combustion problems in 2-stroke engines if the fuel preparation equipment is adjusted correctly.

3.9 Pour point

The operation temperature of the fuel must be kept between approximately 5°C and 10°C above the pour point to make sure that the fuel can flow easily.

3.10 Water

The separator and the correct configuration of drains in the settling and service tanks is used to decrease the water quantity in the fuel. A complete removal of water is highly recommended to decrease the quantity of hydrophilic cat fines and sodium in the fuel. Sodium is not a natural oil component, but diesel engine fuel often has sea water contamination, which has sodium. 1.0% sea water in the fuel is related to 100 ppm sodium.

To get a good separation effect, the flow rate and temperature of the fuel must be adjusted in relation to the viscosity. For high-viscosity fuels the separation temperature must be increased, although the flow rate must be decreased in relation to the nominal capacity of the separator. For the recommended data to operate the separator, refer to the instruction manual.

3.11 Ash and trace metals

Fuels with a low content of ash, vanadium, sodium, aluminium, silicon, calcium, phosphorous and zinc are recommended. These materials can increase mechanical wear, high-temperature corrosion and particles in the turbocharger, exhaust system and boilers.

3.11.1 Vanadium and sodium

Sodium compounds decrease the melting point of vanadium oxide and sulphate salts, specially when the vanadium to sodium ratio is 3:1. High sodium quantities (as well as lithium and potassium) at the engine inlet can cause damage to the turbocharger, exhaust system and boilers. Ash modifiers can correct the effect of high-temperature corrosion and particles.

3.11.2 Aluminium and silicon

Aluminum (Al) and silicon (Si) in the fuel are an indication of catalytic fines (cat fines). These are particles of hard oxides (round particles of material almost the same as porcelain) which cause high abrasive wear to pistons, piston rings and cylinder liners. Cat fines are used as a catalyst in some processes in petroleum refining and can be found in diesel engine fuels. The most dangerous cat fines are between 10 microns and 20 microns.

Cat fines are attracted to water droplets and are very difficult to remove from the fuel. With correct treatment in the fuel separator, the aluminium and silicon content of 60 ppm (mg/kg) can be decreased to 15 ppm (mg/kg), which is thought to be satisfactory. For satisfactory separation, a fuel temperature as close as possible to 98°C is recommended. If there are more than 40 ppm cat fines in the bunkered fuel, a decreased flow rate in the separator is recommended. Also, the instructions of the equipment manufacturer must be obeyed.

Cat fines can collect in the sediment of the fuel tank from other bunkers. During bad weather conditions, the movement of the ship mixes the sediment into the fuel. Thus, it is better to think that all fuels contain cat fines, although it is possible that a fuel analysis can show a different result. This makes continuous and satisfactory separation very important.

Note: The Al+Si limit in the new ISO 8217:2017 specification is decreased to 60 mg/kg for the RMG and RMK grades.

3.12 Used lubricating oil and chemical waste

Used lubricating oils and chemical waste must not be mixed into the fuel pool. If used lubricating oil is mixed in, fuel is not stable because the base oil is very paraffinic and can cause too much sludge. Most used lubricating oil is from the crankcase, thus sufficiently large quantities of calcium, zinc, phosphorous and other additives and wear metals can cause contamination. The limits in ISO 8217: 2017 and the Winterthur Gas & Diesel Ltd. specification make sure that no used lubricating oil is in the fuel. This is related to the limits of the test methods used to find the levels of these metals, which can occur naturally in the fuel.

Chemical waste must not be added to the fuel. There were some examples of polymers, styrene and other chemical substances found in fuel. These materials can cause the fuel to become too thick, to become almost solid and block filters. They can also cause damage to fuel injection systems and cause fuel pump plungers and injectors to stop.

4. Distillate fuel requirements

Remark: **For data about the parameters given in the table above, see paragraph 5.1 to paragraph 5.12.**

Table 2: Specifications for Distillate Fuels

Parameter	**Unit**	**Bunker Limit**	**Test Method**	**Fuel Quality at Engine Inlet**
Kinematic viscosity at 40°C	mm^2/s [cSt]	Maximum 11.0 Minimum 2.0	ISO 3104	Minimum 2.0 (not related to temperature)
Density at 15°C	kg/m3	Maximum 900	ISO 3675/12185	Maximum 900
Cetane index	–	Minimum 35	ISO 4264	Minimum 35
Sulphur [1)]	m/m [%]	Maximum 1.5	ISO 8754/14596	Maximum 1.5
Flash point	°C	Minimum 60.0	ISO 2719	Minimum 60.0
Hydrogen sulphide [2)]	mg/kg	Maximum 2.0	IP 570	Maximum 2.0
Acid number	mg KOH/g	Maximum 0.5	ASTM D 664	Maximum 0.5
Total sediment by hot filtration	m/m [%]	Maximum 0.1	ISO 10307–1	Maximum 0.1
Oxidation stability	g/m^3	Maximum 25	ISO 12205	Maximum 25
Fatty acid methyl ester (FAME)	m/m %	–	ASTM D 7963 or IP 579	–
Carbon residue: micro method on 10% volume distillation residue	m/m %	Maximum 0.3	ISO 10370	–
Carbon residue: micro method	m/m %	Maximum 0.3	ISO 10370	Maximum 0.3
Pour point (upper) winter [3)]	°C	Maximum 0	ISO 3016	Maximum 0
Pour point (upper) summer	°C	Maximum 6	ISO 3016	Maximum 6
Cloud point winter	°C	–	ISO 3015	–
Cloud point summer	°C	–	ISO 3015	–
Cold filter plugging point winter	°C	–	IP 309 or IP 612	–
Cold filter plugging point summer	°C	–	IP 309 or IP 612	–
Water	v/v [%]	Maximum 0.3	ISO 3733	Maximum 0.2
Ash	m/m [%]	Maximum 0.01	ISO 6245	Maximum 0.01
Lubricity, corrected wear scar diameter (wsd) at 60°C	µm	Maximum 520	–	Maximum 520
Winterthur Gas & Diesel Ltd. distillate fuel specifications and quality limits at the engine inlet related to ISO 8217:2017				

The notes that follow relate to data in Table 2:

$1 mm^2/s = 1 cSt$ (Centistoke)

1) The purchaser must specify the maximum sulphur content in accordance with the usual statutory specifications.
2) The hydrogen sulphide limit is applicable from 1 July 2012.
3) Purchasers must make sure that the pour point is sufficient for the equipment on board, specially for operation in cold climates.

Distillate fuels are used more in 2-stroke engines to meet area specified emission standards. They are easier to operate than residual fuel, but caution is necessary for some problems. See Service Bulletin RT−82: Distillate Fuel Use.

ISO 8217: 2017 specifies DMX, DMA, DMZ and DMB categories. The WinGD engine inlet specification is based on the DMB grade which is the highest viscosity grade. The DMX grade must not be bunkered as the viscosity could be below 2.0 mm^2/s and the flash point could be below 60°C.

5. Data about Distillate Fuel Specifications

5.1 Viscosity

The recommended viscosity range on residual fuel upstream of the engine inlet is 13 mm^2/s (cSt) to 17 mm^2/s (cSt). But, because distillate fuel does not have such a high viscosity, a minimum viscosity of 2.0 mm^2/s (cSt) at the fuel pump inlet is necessary.

Operators must be careful during the change-over procedure from distillate to residual fuel and back to make sure of problem free operation. See the Service document: Engine operation on MDO/MGO, change-over from HFO to MDO/MGO and the Service Bulletin RT−82: Distillate Fuel Use.

In some conditions, it is possible that you cannot get the minimum viscosity of 2.0 mm^2/s (cSt) at the fuel pump inlet. In such conditions, a fuel cooling system will be necessary to make sure that the inlet to the fuel pumps has the minimum viscosity.

5.2 Density

The composition of the fuel gives the distillate density and a high density indicates a high aromatic quantity.

5.3 Cetane Index

The ignition and combustion properties of a distillate fuel in a diesel engine is related to the specific engine design, load profile and fuel properties. The Cetane Index is a calculated quantity of the ignition properties or ignition interval of the fuel related to the distillation and density. The density and the temperature when 10%, 50% and 90% of the fuel is distilled, gives the Cetane Index. This has no effect on the fuel combustion properties.

5.4 Sulphur

Sulphur limits are specified in ISO 8217:2017 for distillate fuels, but statutory specifications must be obeyed. The alkalinity (BN) of the cylinder lubricating oil must be selected in relation to the sulphur content of the fuel in use.

The engine can operate for short periods (some hours) with a cylinder lubricating oil that has an incorrect BN, but a longer operation time must be prevented.

Indications for the selection of the BN of lubricating oil in relation to the sulphur content of the fuel are found in:

- 0410−1 Running-in New Cylinder Liners and Piston Rings
- 0750−1 Lubricating Oils, paragraph 3.

5.5 Flash point

The flash point is an important safety and fire hazard parameter for diesel fuels. Fuel is always a fire hazard because there can be flammable vapors above the remaining fuel in the tanks.

5.6 Hydrogen sulphide

***Injury Hazard:* Hydrogen Sulphide (H_2S) is a very toxic gas and exposure to high concentrations is dangerous and can kill you. Be careful when tanks or fuel lines are opened because there can be H_2S vapor. At low concentrations H_2S smells almost the same as bad eggs. You cannot sense H_2S at moderate concentrations. H_2S will cause nausea and dizziness.**

5.7 Acid number

Fuels with high acid numbers have caused damage to fuel injection systems. Most fuels have a low acid number, which is not dangerous, but an acid number above 2.5 mg KOH/g, can cause problems.

5.8 Sediment

High quantities of sediment decrease the ignition and combustion quality of the fuel and increase wear and damage to engine components. High sediment quantities can cause filters to block, or frequent discharge from filter systems that have automatic cleaning. For more data about mixtures, see paragraph 3.8 in the HFO section.

5.9 Pour point

The operation temperature of the fuel must be kept between approximately 5°C and 10°C above the pour point to make sure that the fuel flows easily. It is possible that in very cold conditions, there could be problems for distillate fuel.

5.10 Water

The quantity of water in distillate fuel can be decreased as follows:

- Let the fuel settle in the service tanks
- Use the centrifuge to remove water from the fuel.

5.11 Ash and trace metals

Distillates must have low quantities of ash, vanadium, sodium, aluminium, silicon, calcium, phosphorous and zinc related to residual fuels. High quantities of these materials increase mechanical wear, high-temperature corrosion and particles in the turbocharger, exhaust system and the boilers.

5.12 Used lubricating oil and other contaminants

Lubricating oils and chemical waste must not be mixed into the distillate fuel pool. Lubricating oil can cause water to stay because of the large quantity of detergent. Additive materials such as calcium, magnesium, zinc and phosphorous could increase the ash content to more than that given in the specification.

Chemical waste must not be added to distillate fuel. There were some examples of chemical waste substances found in fuel. These materials can cause the fuel to become too thick, to become almost solid and block filters. They can also cause damage to fuel injection systems and cause fuel pump plungers and injectors to stop.

6. Bio-derived products and Fatty Acid Methyl Esters (FAME)

Such components can be found in diesel engine fuels and can cause a decrease of greenhouse gases and SOx emissions. Most bio-fuel components in the diesel pool are Fatty Acid Methyl Esters (FAME), which come from a special chemical treatment of natural plant oils. These components are mandatory in automotive and agricultural diesel in some countries. FAME is specified in ISO 14214 and ASTM D 6751.

FAME has good ignition properties and very good lubrication and environmental properties, but the other properties that follow about FAME are well known:

- Possible oxidation and thus long term storage problems.
- A chemical force that causes fuel and water to combine
- Microbial growth can appear in the fuel.
- Unsatisfactory low temperature properties.
- FAME material particles can appear on exposed surfaces and filter elements.

7. Fuel Additives

WinGD does not recommend the use of fuel additives. Additives are not necessary for fuels that obey the ISO 8217 standard or for fuels that WinGD has recommended.

If you think, that it is necessary to use additives, WinGD recommends to speak to the fuel supplier and to the additive supplier. They can give you the related results of the use of additives. If you use additives for some causes, you get the full responsability.

Note: WinGD does not accept liability or responsibility for the performance or potential damage caused by the use of such additives.

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Operating Media

Fuel Treatment, Fuel Oil System

1. General

Heavy fuel oils (HFO), as they are supplied today for use in diesel engines must have careful treatment, which makes the installation of applicable plant necessary. The best procedure to remove solid particles and water from fuel is to use centrifugal separators.

2. Treatment of heavy fuel oils and treatment plant

HFO are contaminated with solid particles and water. If HFO that is dirty or not sufficiently treated goes into the engine, wear on engine components can occur (e.g. piston rings, cylinder liners, injection pumps, valves etc). Also, too much sediment can collect in the combustion spaces.

Sodium in the fuel (which comes from seawater) causes contamination on the pistons and in the turbocharger. The water must be carefully removed from the fuel.

Settling tanks are used for the first steps of treatment, but their effect is only a coarse separation to release water from the HFO. The settling tanks must have the sludge and water, that collects in the bottom of the tank, drained at intervals.

Correctly operated centrifuges that are of the best size and adjustment are used to get good results during the procedure to clean the fuel. Modern designs mean that is not necessary to adapt the gravity discs for fuels of different densities.

Modern machines automatically remove the sludge from the centrifuge. For modern engines designed to burn HFO of the lowest grade, such centrifuges are necessary. This is applicable when HFO with densities of 991 kg/m^3 and higher and with viscosities of 700 cSt/50°C are used. For more data, see 0710−1 Diesel Engine Fuels.

Homogenizers can improve combustion properties, but cannot remove solid particles from the fuel. Homogenizers thus, are only auxiliaries in the treatment plant.

Filters hold solid particles of a specified size and shape, but cannot hold back water. Water will cause the filters to block quickly.

3. Heavy fuel oil and diesel fuel oil separation

It is recommended that modern centrifuges are used for the treatment of heavy fuels.

The separation effect, i.e. the cleaning effect, is related to the flow rate and viscosity of the HFO. Usually, the smaller the volume (m^3/h or ltr/h) and the lower the viscosity of the HFO, the better the separation. If the flow rate is too high and/or the separation temperature is too low, the effect of the separator will be decreased.

If the HFO separators do not operate satisfactorily, it is possible that impurities (e.g. cat fines) in the bunkers will not be sufficiently removed. This can cause damage to the engine (e.g. increased wear of piston ring, cylinder liner and fuel injection equipment).

The HFO must be heated before it goes into the centrifuge to keep the temperature constant to a tolerance of ± 2° C. The separation temperature must be as near as possible to 98° C. The instructions of the centrifuge manufacturer must be obeyed during the separation procedure.

The sludge that comes from the separation process must be removed regularly from the separator drum. For self-cleaning centrifuges, the sequence of the procedure can be controlled automatically. But in such a plant, personnel must keep control of the correct function and frequency of procedures. You must do regular checks to make sure that the sludge from the separator drum can drain freely. This prevents back pressure, which makes sure that the centrifuge operates correctly to clean the HFO.

4. Layout of fuel oil system

In the recommended standard plant, pressure is kept in the full fuel system to prevent the evaporation of water in the fuel at the temperature necessary for the heavy fuel oil (HFO). Refer to Fig. 'A'.

At the applicable position of the three-way valve (10), the low pressure pumps (19) supply heavy fuel oil from the daily tank (3, 4) to the mixing unit (21). The booster pumps (22) supplies the fuel from the mixing unit (21) through the end-heaters (23) and fuel filter (24) to the fuel pumps in the supply unit (28). The rated capacity of the booster pump (22) is more than that necessary for the engine. The fuel that the engine does not use flows back to the mixing unit (21). Fuel oil leakage from the mixing unit (21) flows into the clean fuel oil leakage tank (33) or the fuel oil overflow tank (33). You can use the clean fuel oil leakage tank (33) to isolate marine diesel oil (MDO) or marine gas oil (MGO) leakage from HFO leakage.

The pressure regulating valve (17) sets the applicable system pressure. The pressure retaining valve (27) sets the pressure at the inlet to the fuel pumps (for the adjustment value, see 0250−1 Operating Data Sheet).

The pump (19) supplies only as much heavy fuel oil from the HFO daily tank (3) as necessary for the engine. If necessary, the temperature of the heavy fuel oil in the HFO daily tank (3) must be increased.

Remark: The official safety regulations give a maximum temperature limit of the heavy fuel oil (HFO).

The temperature of the fuel between the mixing unit (21) and the fuel system on the engine must be increased to the applicable injection temperature. The end-heater (23) increases the temperature of this fuel. If necessary during the temperature increase, the heating systems of the mixing unit (21) and the return pipe can be set to on.

HFO must not go into the marine diesel oil (MDO) daily tank (6).

Key to Illustrations: 'A' Schematic Diagram – Fuel System

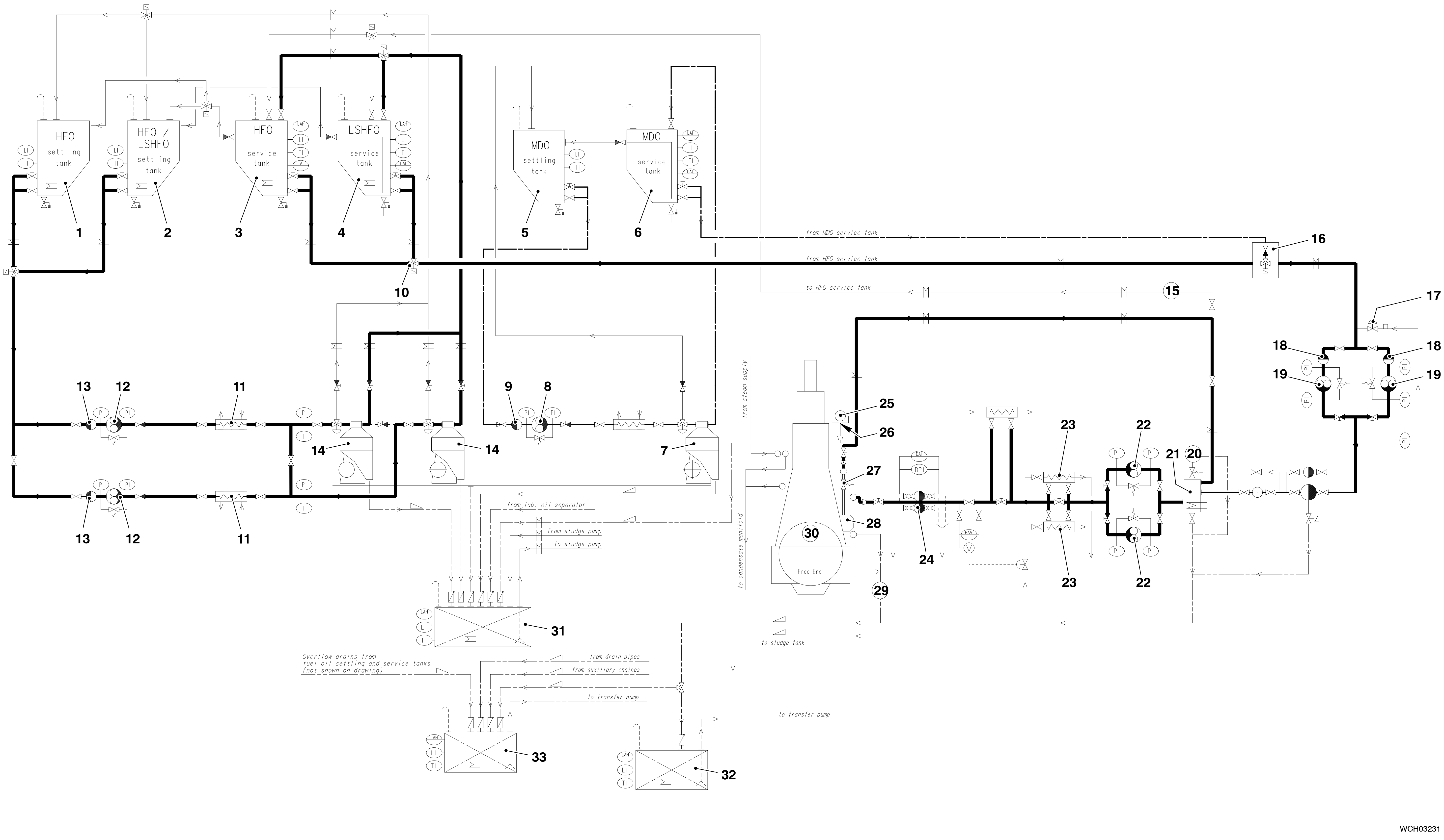
1 HFO settling tank
2 HFO/LSHFO settling tank
3 HFO daily tank
4 LSHFO daily tank
5 MDO settling tank
6 MDO daily tank
7 Self-cleaning MDO separator
8 MDO separator supply pump
9 MDO suction filter
10 Three-way valve
11 HFO/LSHFO preheater
12 HFO/LSHFO separator supply pump
13 Suction filter
14 Self-cleaning HFO/LSHFO separator
15 Bypass pipe
16 Automatic fuel change-over unit
17 Pressure regulating valve
18 Suction filter
19 Low pressure supply pump
20 Air overflow pipe
21 Mixing unit, heatable and insulated
22 Booster pump
23 End heater
24 Fuel filter
25 Fuel rail
26 Fuel leakage rail unit
27 Pressure retaining valve
28 Supply unit (fuel pump)
29 Fuel leakage pipe injection valve
30 Main engine
31 Sludge tank
32 Clean fuel oil leakage tank
33 Fuel oil overflow tank

DAH Differential pressure alarm high
DPI Differential pressure indication
LAH Fluid level alarm high
LAL Fluid level alarm, low
PI Pressure indicator
TI Temperature indicator
VAH Viscosity alarm high

(F) Flow indicator
Heated & insulated pipes
Insulated pipes
Pressure regulating valve
Sight glass
(V) Viscosimeter

Operating Media

Fuel Treatment, Fuel Oil System



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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 (see Control Diagram 4003–2).

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Operating Media
Lubricating Oils

Overview

1. General

The engine has different oils for system oil and cylinder lubrication.

2. System Oils

System oil has the functions that follow:

- System oil lubricates the bearings, the running parts of the engine and the crosshead assemblies.
- System oil decreases the temperature of the pistons and the vibration dampers.
- System oil is used as hydraulic fluid in the servo oil system.

2.1 Requirements for System Oil

The system oil must have the basic properties that follow:

- An additive−type crankcase oil of SAE 30 viscosity
- Minimum Base Number (BN) of 5 mg KOH/g
- Minimum failure load stage of 11 ± 1 related to the FZG gear oil test method A/8.3/90 (ISO 14635−1)
- Detergency properties
- Thermal stability
- Anti−corrosion properties
- Anti−foam properties
- Demulsifying performance

You find a list of applicable and validated system oils in paragraph 8.

2.2 Recommended Procedure for System Oil Maintenance

WinGD recommends to install a self−cleaning centrifugal separator in the plant oil system. Thus you can keep the system oil in good condition for a long period.

- There is always a risk that water, specially sea water, can enter the system oil and cause corrosion on engine parts. Water contamination can also cause bacterial contamination of the system oil, which gives a decrease in lubrication performance and gives heavy corrosion of the engine parts. Thus solid contaminants (dirt) and water must be removed from the system oil as completely as possible.
- The self−cleaning centrifugal separator is used as a purifier in bypass mode. The oil flows from the oil tank through the centrifugal separator. Set the oil flow through the centrifugal separator related to the manufacturer of the centrifugal separator. WinGD recommends an oil temperature for this treatment of 95°C unless the manufacturer of the centrifugal separator recommends differently.

2.3 Alert and Condemnation Limits for System Oil

Table 1 shows the WinGD recommendations for alert and condemnation limits for system oil.

Table 1: Alert Limits of System Oil Parameters

Parameter	Alert Limit	Condemnation Limit	Unit	Test Method
Viscosity at 40°C	Maximum 140	Maximum 150	mm^2/s [cSt]	ASTM D 445
Flash point	Minimum 200	Minimum 180	°C	ASTM D 92/93
Total insoluble materials	Maximum 0.7	Maximum 1.0	% m/m 1)	ASTM D 893b
Base Number (BN)	Maximum 12	Maximum 15	mg KOH/g	ASTM D 2896
Water content	Maximum 0.20	Maximum 0.30	% m/m	ASTM D 95 or ASTM D 1744
Strong Acid Number (SAN)	0.0	0.0	mg KOH/g	ASTM D 664
Calcium	–	Maximum 6000	mg/kg [ppm]	ICP
Zinc	–	Maximum 100	mg/kg [ppm]	ICP
Phosphorus	–	Maximum 100	mg/kg [ppm]	ICP
FZG gear oil test	Minimum failure load stage (FLS) 9	Minimum failure load stage (FLS) 8	–	A/8.3/90 (ISO 14635-1)

1) % m/m means by mass, e.g. a water content of 0.20% m/m means that the water content is 0.20% of the mass of the total solution.

2) To do the FZG gear oil test is recommended one time each year.

Note: Use these limits as a guide. You cannot make an estimate of the system oil by one parameter. Get also other oil parameters to find the causes of problems.

2.4 Particle Count and Size Classes

The requirements for particle size analysis applies only for hydraulic systems. These systems operate the exhaust valves, the cylinder oil system and the fuel injection system (if applicable). Abrasive particles in the oil can cause wear on different parts of the engine. Some types of WinGD engines have a filter for servo oil.

2.4.1 Specifications

There are two different specifications for particle classes:

- ISO 4406
- NAS 1638 and SAE AS 4059

The (newer) ISO 4406 particle count and size classes for oils are given in Table 2.

Table 2: ISO 4406 Particle Count and Size Classes

WinGD recom-mendations	Number of particles per 100 ml		
	More Than	**Up To and Includes**	**Class**
	250 000 000	–	Less than 28
	130 000 000	250 000 000	28
	64 000 000	130 000 000	27
	32 000 000	64 000 000	26
	16 000 000	32 000 000	25
	8 000 000	16 000 000	24
	4 000 000	8 000 000	23
	2 000 000	4 000 000	22
	1 000 000	2 000 000	21
> 6 µm maximum	**500 000**	**1 000 000**	**20**
	250 000	500 000	19
	130 000	250 000	18
> 14 µm maximum	**64 000**	**130 000**	**17**
	32 000	64 000	16
	16 000	32 000	15
	8 000	16 000	14
	4 000	8 000	13
	2 000	4 000	12
	1 000	2 000	11
	500	1 000	10
	250	500	9
	130	250	8
	64	130	7
	32	64	6
	16	32	5
	8	16	4
	4	8	3
	2	4	2
	1	2	1
	0	1	0

The ISO 4406 particle count system has specified three size classes related to a 100 ml oil sample as follows:

- R_4 = number of particles equal to or larger than 4 µm
- R_6 = number of particles equal to or larger than 6 µm
- R_{14} = number of particles equal to or larger than 14 µm.

The (older) NAS 1638 and SAE AS 4059 cleanliness classes for oils are given in Table 3.

Table 3: NAS 1638 and SAE AS 4059 Cleanliness Classes

	Number of particles per 100 ml for particle size ranges (μm)				
Clean-liness Class	**5 to 15**	**15 to 25**	**25 to 50**	**50 to 100**	**100 to 150**
(14)	4 096 000	729 600	129 600	23 040	4 096
(13)	2 048 000	364 800	64 800	11 520	2 048
12	1 024 000	182 400	32 400	5 760	1 024
11	512 000	91 200	16 200	2 880	512
10	256 000	45 600	8 100	1 440	256
9	128 000	22 800	4 050	720	128
8	64 000	11 400	2 025	360	64
7	32 000	5 700	1 012	180	32
6	16 000	2 850	506	90	16
5	8 000	1 425	253	45	8
4	4 000	712	126	22	4
3	2 000	356	63	11	2
2	1 000	178	32	6	1
1	500	89	16	3	1
0	250	44	8	2	0
00	125	22	4	1	0

2.4.2 Recommended Limits

For particles up to 21 μm, WinGD recommends the specification for a 100 ml oil sample in the system oil as follows:

- ISO 4406 ––/20/17 maximum

This has the meaning that follows:

- It is not necessary to count particles of a size of smaller than 6 μm (R_4 count).
- A maximum of 1 000 000 particles of a size equal to or larger than 6 μm (R_6 count) is permitted.
- A maximum of 130 000 particles of a size equal to or larger than 14 μm (R_{14} count) is permitted.

For particles larger than 21 μm, you must obey the NAS and SAE AS specification as in Table 4 and in Table 5.

Table 4: Recommended NAS limits for an engine with servo oil filter

	Particle size ranges (μm)				
	5 to 15	**15 to 25**	**25 to 50**	**50 to 100**	**100 to 150**
System Oil					
– Cleanliness class	12	11	10	8	5
– Particles per 100 ml	1 024 000	91 200	8 100	360	8
Servo Oil					
– Cleanliness class	12	11	8	5	0
– Particles per 100 ml	1 024 000	91 200	2 025	45	0

Table 5: Recommended NAS limits for an engine without servo oil filter

	Particle size ranges (μm)				
	5 to 15	**15 to 25**	**25 to 50**	**50 to 100**	**100 to 150**
System Oil					
– Cleanliness class	12	11	9	7	5
– Particles per 100 ml	1 024 000	91 200	4 050	180	8

Note: Obey the data that follows:

- Particle counting has poor repeatability and reproducibility.
- The method does not determine the nature, hardness or shape of the particles.
- Use the used oil analysis and particle count data to form a full picture.

2.5 Recommended Procedure for Samples

WinGD recommends to get a sample of the system oil each 3000 operating hours for regular oil analysis and each 6000 operating hours for additional FZG and particle count (ISO 4406 and NAS 1638) analysis. Get the oil samples at the related oil sample points:

- For an engine with servo oil filter, get the samples as follows:
  - Get a sample from the sample point at the engine inlet.
  - If the analysis shows unusual values, get a sample from the sample point after the servo oil filter.
- For an engine without servo oil filter, get the sample from the sample point at the engine inlet.

CAUTION

Damage Hazard: The system oil is hot. Put on gloves and safety goggles to prevent injuries. Do the work carefully.

Do this procedure only, if the oil pump is running and the system oil has operating temperature.

1) Flush the sample pipe.
   a) Put an applicable container under the sample valve.
   b) Slowly open the sample valve to flush out oil and possible dirt.
   c) Close the sample valve.
   d) Discard the oil correctly.
2) Get an oil sample.
   a) Put the sample bottle under the sample valve.
   b) Slowly open the sample valve to fully fill the sample bottle.

   Note: The necessary quantity of oil is as follows:
   - 100 ml for regular oil analysis
   - 5 l for FZG and particle count analysis.

   c) Close the sample valve.
   d) Close the sample bottle tight.
3) Write the data that follows on the bottle:
   - Name of the ship
   - Type and serial number of the engine
   - Date of sampling
   - Location of the sample point
   - Operating hours of the oil and of the engine
   - Brand and type of the oil.
4) If applicable, do step 1 to step 3 again for the other sample point.
5) Send the sample bottles in an applicable package to a laboratory for analysis.
6) Do the procedures related to the results, refer to paragraph 2.6.

With these regular checks you can find deterioration in time. Thus you can do procedures to correct the problems.

2.6 Recommended Procedures related to the Results

If one or more of the alert values in Table 1 are given, you must do applicable procedures to correct the problem. WinGD recommends that you speak to the system oil supplier in such a condition. Applicable procedures are as follows:

- Increase the purification in the separator (decrease the flow rate and/or adjust the temperature).
- Treat the oil in a renovating or settling tank.
- Replace a part of the system oil.

If an alert value is given, do not run the engine for a longer period.

If a condemnation value is given, immediately replace a part of the system oil until the values are satisfactory. If you cannot change a part of the system oil immediately, stop the engine until you could change a part of the system oil. This prevents damage to the engine.

2.6.1 Base Number (BN) increases suddenly

If the Base Number (BN) of the system oil increases suddenly, do a check of all piston rod gland boxes and of the piston rod conditions. If necessary, replace the sealing rings of the related gland box or repair the gland box.

Note: If the BN increases a small quantity, this is usually an indication that the system oil consumption is low. A usual consumption and replenishment of system oil is necessary to keep the system oil in good condition.

2.6.2 Flash point decreases

If the flash point of the system oil decreases below the values given in Table 1, do a replenishment of the system oil. This prevents an increase of the BN of the system oil.

2.6.3 Particle number increases

If the particle number of the particle count increases above the limits given in paragraph 2.4.2, do the procedures that follow in the given sequence:

- For an engine with a servo oil filter:
  - Do a check of the servo oil filter. If necessary, replace the filter element or repair the filter.
- For all engines:
  - Do a check of the centrifugal separator. If necessary, adjust the flow rate or the temperature to increase the performance of the centrifugal separator. Refer to the manufacturers recommendations.
  - Do a check of all piston rod gland boxes. If necessary, replace the sealing rings of the related gland box or repair the gland box.
  - Make an element analysis of the particles. This gives data about worn components in the engine. Repair the related components.
  - Make a replenishment of the system oil. This can include a change of some of the oil or of all of the oil in the oil system.

This prevents that abrasive particles can cause damage of the related engine parts.

2.7 Recommended Procedures for Gear Wheels

If you install a new gear wheel or if you have polished a gear wheel, the FZG load stage of the system oil must be at a satisfactory value. This prevents scuffing of the gear wheels during the running−in of the gear wheels.

If you have used the system oil for more than one year, make the FZG gear oil test (test method A/8.3/90, ISO 14635−1). If the related alert or condemnation value is given (refer to Table 1), do a replenishment of the system oil before you do the running−in.

3. Cylinder Oils

Cylinder oil is used for the functions that follow:

- Neutralize the sulphuric acids that occur during combustion to prevent corrosion on piston rings and cylinder liners
- Build an oil film between the cylinder liner and the piston rings and thus decrease the friction
- Keep the piston, the piston rings and the cylinder liners free from deposits.

The correct feed rate range for cylinder oil is between 0.6 g/kWh and 1.2 g/kWh.

3.1 Requirements for Cylinder Oil

The cylinder oil must have the basic properties that follow:

- A high−alkaline cylinder oil of SAE 50 viscosity (minimum kinematic viscosity of 18.5 cSt at 100°C)
- The Base Number (BN) of the cylinder oil must be related to the items that follow:
    - Engine operation condition
    - Cylinder lubricating feed rate
    - Sulphur content of the fuel.

Note: The Base Number (BN), measured in mg KOH/g (test method ASTM D 2896), shows the alkalinity of the oil. The BN of the cylinder oil is a direct measure of alkalinity, but not an index for detergency.

You find a list of applicable and validated cylinder oils in paragraph 9.

3.2 Recommended Procedures

WinGD recommends the procedures that follow to get good performance of the piston running components:

1) Select the cylinder oil, refer to paragraph 3.2.1.
2) Do an engine screening procedure, refer to paragraph 3.2.2.
3) Do a piston underside drain oil sampling, refer to paragraph 3.2.3.
4) Do an interpretation of the oil analysis as follows:
    - For a cylinder oil with BN 25 or lower refer to paragraph 3.2.4.
    - For a cylinder oil with BN 40 or higher refer to paragraph 3.2.5.
5) Do an optimization of the feed rate, refer to paragraph 3.2.6.
6) Regularly do step 3 to step 5 again.

3.2.1 Selection of the Cylinder Oil

For the initial selection of the cylinder oil you can use the data given in Fig. 1. The higher the sulphur content of the fuel, the higher the BN of the cylinder oil must be.

WinGD recommends to select the cylinder oil as follows:

- Identify the sulphur content of the fuel, refer to 0710−1/A1 Diesel Engine Fuels.
- If the sulphur content of the fuel is less than 0.5% m/m, use a cylinder oil with BN 15 to BN 25.
- If the sulphur content of the fuel is higher than 0.5% m/m, use a cylinder oil with BN 40 or higher as referred to in Fig. 1.
- If you use the blending on board package you can get a “fit to purpose” cylinder oil.

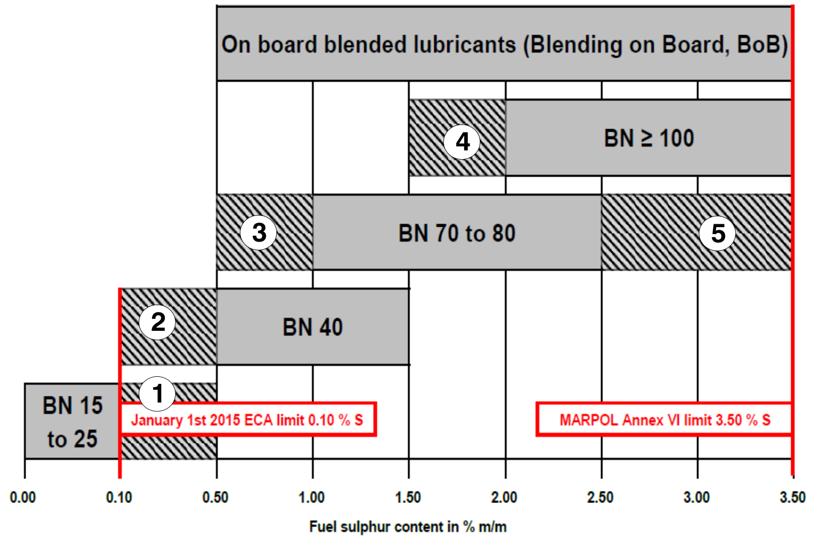


Fig. 1 Selection of Cylinder Oil BN related to the Fuel Sulphur Content

Related to the areas of operation in Fig. 1, WinGD recommends as follows:

1) **0.1% < sulphur < 0.5% m/m, BN 15 to BN 25**
   a) You must do a regular piston underside drain oil sampling and an interpretation of the oil analysis.
   b) Make sure that the piston underside residual BN is more than BN 10.
   c) Make sure that the iron (Fe) content is less than 500 ppm (mg/kg).
   d) Do regular checks of the piston and piston ring conditions through scavenge port inspections.
2) **0.1% < sulphur < 0.5% m/m, BN 40**
3) **0.5% < sulphur < 1.0% m/m, BN 70 to BN 80**
4) **1.5% < sulphur < 2.0% m/m, BN 100 or higher**
5) **2.5% < sulphur < 3.5% m/m, BN 70 to BN 80**

Note: In these areas make sure that you operate the engine in the safe area, refer to Fig. 4.

   a) You must do a regular piston underside drain oil sampling and an interpretation of the oil analysis.
   b) Do regular checks of the piston ring and the cylinder liner conditions through scavenge port inspections.

3.2.2 Engine Screening Procedure

After you have done the running–in of the engine, you can get initial data for the engine. WinGD recommends to do an engine screening procedure as follows:

1) Set the base feed rate to 0.9 g/kWh of the selected cylinder oil.

2) Operate the engine at different loads, e.g. 10%, 20%, 30% etc related to the sailing conditions.

3) For each load do a piston underside drain oil sampling, refer to paragraph 3.2.3.

4) For each load do an interpretation of the oil analysis, refer to paragraph 3.2.4 or paragraph 3.2.5.

3.2.3 Piston Underside Drain Oil Sampling

After the engine is in stable operation for a minimum of 12 hours, do a piston underside drain oil sampling and an oil analysis of each cylinder as follows:

CAUTION

Damage Hazard: The system oil is hot. Put on gloves and safety goggles to prevent injuries. Do the work carefully.

1) Do this procedure at a minimum of one time each week, and do it also in the conditions that follow:

- After a fuel change
- After a cylinder oil change
- After a feed rate change.

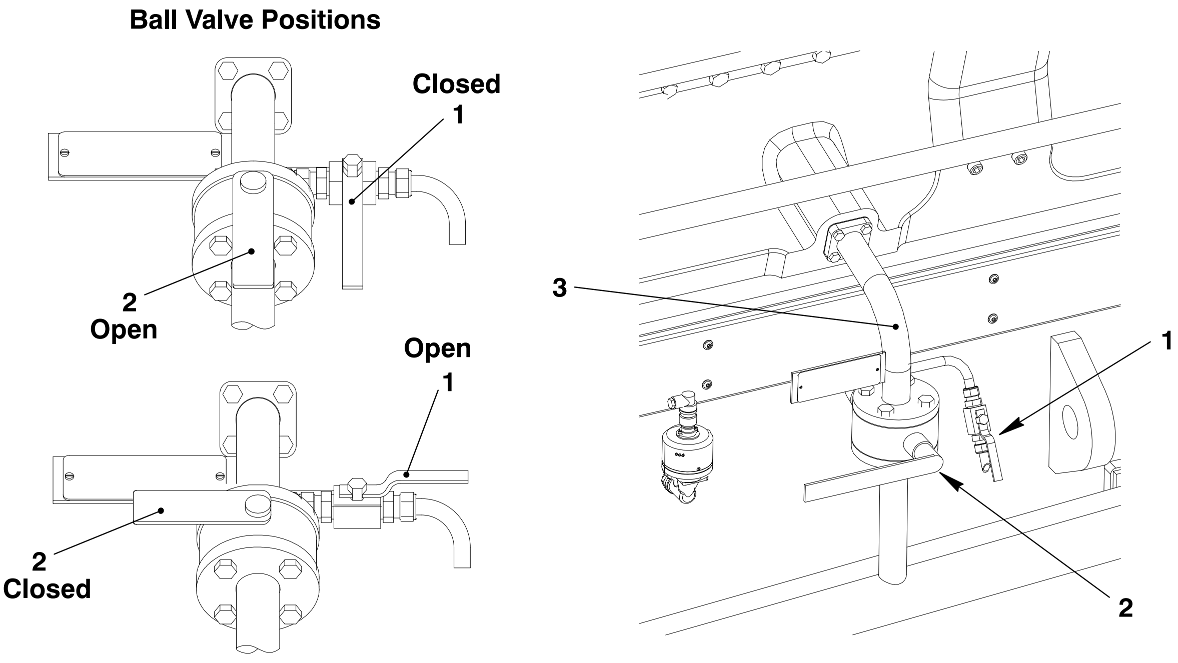


Fig. 2 Location of Ball Valves for Dirty Oil Samples

2) Flush the sample pipe of the related cylinder:
   a) Close the ball valve (2, Fig. 2) for approximately 30 minutes to 60 minutes.
   Note: Some parts can look different.
   b) Put an applicable container under the oil sample valve (1).
   c) Slowly open the oil sample valve (1) to flush out oil and possible dirt.
   d) Close the oil sample valve (1).
   e) Open the ball valve (2) to drain the remaining oil from the dirty oil pipe (3).
   f) Close the ball valve (2).
3) Get a sample of the drain oil.
   a) Make sure that the label on the sample bottle refers to the related cylinder.
   b) Wait approximately 10 minutes to 60 minutes.
   c) Put the sample bottle under the oil sample valve (1).
   d) Slowly open the oil sample valve (1) to fill the sample bottle.
   e) Close the oil sample valve (1).
   f) Open the ball valve (2) to drain the oil in the dirty oil pipe (3).
4) Do step 2 and step 3 again for each cylinder.
5) Write the applicable data on the oil analysis form (e.g. operation conditions, fuel parameters, cylinder lubricating feed rate etc.).
6) Do an oil analysis of the samples on−board. The oil analysis must include the data that follows:
   - Residual BN
   - Iron (Fe) content (if possible)
7) If necessary, do the applicable recommended procedures, refer to paragraph 3.2.4 or paragraph 3.2.5.
8) Send the oil samples to a laboratory for an oil analysis.
   a) Make sure that the sample bottles are tightly closed.
   b) Put the sample bottles in an applicable package.
9) Compare the oil analysis from the laboratory with the oil analysis from on−board.
10) If the oil analyses are different, do the applicable recommended procedures related to the oil analysis from the laboratory, refer to paragraph 3.2.4 or paragraph 3.2.5.

3.2.4 Interpretation of the Oil Analysis for a Cylinder Oil with BN 25 or lower

For a fuel with a sulphur content in the range between 0.0% m/m and 0.5% m/m and a cylinder oil with BN 25 or lower, refer to Fig. 3.

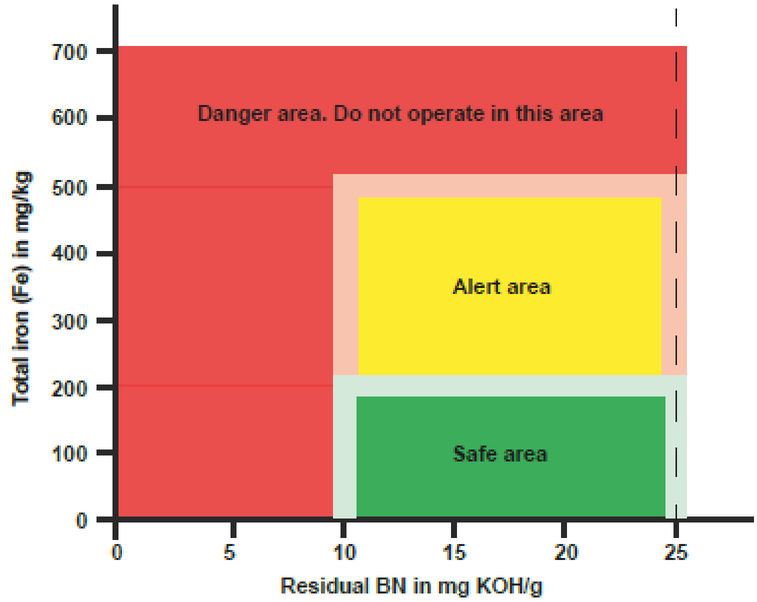


Fig. 3 Interpretation of the oil analysis for cylinder oils with BN 25 or lower

Note: There are smooth transitions between the different areas shown in Fig. 3.

Use the data that follows for an interpretation of the oil analysis:

- **Safe Area**

  If the residual BN is BN 10 or higher and the iron (Fe) content is less than 200 mg/kg, the operation is safe.

- **Alert Area**

  If the residual BN is BN 10 or higher and the iron (Fe) content is between 200 mg/kg and 500 mg/kg, damage of the piston running system can occur.

- **Danger Area**

  If the residual BN is less than BN 10 and/or the iron (Fe) content is more than 500 mg/kg, excessive corrosion can occur. Thus the piston rings and cylinder liners can become quickly worn. Also scuffing can occur.

3.2.5 Interpretation of the Oil Analysis for a Cylinder Oil with BN 40 or higher

For a fuel with a sulphur content in the range between 0.5% m/m and 3.5% m/m and a cylinder oil with BN 40 or higher, refer to Fig. 4.

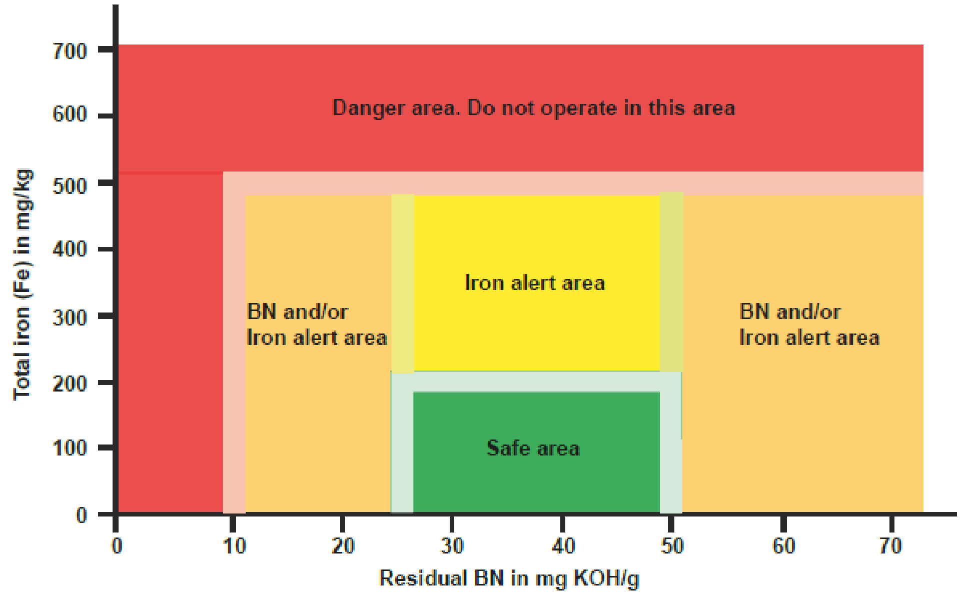


Fig. 4 Interpretation of the oil analysis for cylinder oils with BN 40 or higher

Note: There are smooth transitions between the different areas shown in Fig. 4.

Use the data that follows for an interpretation of the oil analysis:

- **Safe Area**

  If the residual BN is between BN 25 and BN 50, and the iron (Fe) content is less than 200 mg / kg, the operation is safe.

- **Alert Area**

  The lower alert range for piston underside residual BN is between BN 10 and BN 25. In this area there might be a risk of corrosion. This is because the base additives could be not sufficient to neutralize the sulphuric acid from the fuel.

  The upper alert limit for piston underside residual BN is above BN 50. Higher values can cause damages to the piston running system. This is because the alkalinity of the cylinder oil gets too high. This operation can cause excessive deposits on the piston. If there are excessive deposits on the piston, the lubricant film can break down and thus cause wear of the piston running system.

  The alert range for iron (Fe) content in the drain oil is between 200 mg/kg and 500 mg/kg.

- **Danger Area**

  The danger limit for piston underside residual BN is lower than BN 10. In this area it is possible that excessive corrosion can occur. Thus the piston rings and cylinder liners can become quickly worn. Also scuffing can occur. Piston rings can quickly become defective.

  The danger limit for iron (Fe) content in the drain oil is more than 500 mg/kg.

  Do not operate the engine in these danger areas.

3.2.6 Optimization of the Feed Rate

After you have done the interpretation of the oil analysis, you can do an optimization of the feed rate as follows:

1) If the analysis shows operation in the safe area, do one of the two instructions:
   a) Continue the operation with the set feed rate.
   b) Decrease the feed rate in small steps, e.g. in steps of 0.05 g/kWh.
2) If the analysis shows operation in one of the alert areas, do one of the two instructions:
   a) Increase or decrease the feed rate to get the operation in the safe area. If necessary, change the BN of the cylinder oil.
   b) Keep the feed rate and do regular checks of the piston ring and the cylinder liner conditions through scavenge port inspections.
3) If the analysis shows operation in the danger area, do as quickly as possible as follows:
   a) Increase or decrease the feed rate or change the BN of the cylinder oil to get the operation in the safe area.

Note: WinGD has made a tool (piston underside drain oil analysis) for easier interpretation of the oil analysis. If necessary, the tool gives you recommendations and procedures to make the cylinder oil system better. Only use the tool, if you use a cylinder oil with BN 40 or higher. If you want to use the tool, speak to or send a message to WinGD.

WinGD recommends to collect the data from the oil analyses. When you later use a fuel with the same sulphur content (±0.125% m/m) and a cylinder oil with the same BN, you can set the feed rate related to the collected data with the same conditions. You also can use these data to get continuously better parameters.

3.3 Effective Feed Rate

The cylinder lubricating feed rate that is set in the engine control system is the specific feed rate at 100% CMCR. At part load operation, a correction factor is applied in order to make sure a sufficient quantity of cylinder oil. Thus the effective feed rate at part load is higher than the set feed rate.

4. Turbocharger Oil

To select the turbocharger lubricating oil and keep this oil in a satisfactory condition, refer to the recommendations given in the turbocharger instruction manual.

The turbocharger lubricating oil is usually system oil or turbine oil.

5. Turning Gear Oil

To select the turning gear oil and keep this oil in a satisfactory condition, refer to the recommendations given in the instruction manual of the turning gear manufacturer.

6. Lubricants − Flywheel and Pinion Gear Teeth

To select and apply the lubricants for flywheel and pinion gear teeth, refer to the recommendations from the engine manufacturer.

Suppliers of applicable lubricants for flywheel and pinion gear teeth are given in paragraph 10.

For other applicable lubricants speak to the lubricant supplier.

7. Environmentally Acceptable Lubricants

Environmentally Acceptable Lubricants (EAL) are currently necessary for ships operating in USA waters, and this area may be extended in future.

These lubricants, which are necessary for all oil−to−sea interfaces (and include stern tubes, thrusters, rudders, stabilizers, variable pitch propellers, underwater ropes, machinery and underwater transmissions) are made with base oils and additives which are different to those used for system oils and cylinder oils.

Thus, EAL must not be mixed with system oils or cylinder oils. Contamination of EAL (related to base oil quality) in system oil or cylinder oil can cause different problems (eg elastomer compatibility, water emulsification, high temperature deposit formation).

8. List of System Oils

Always use system oils related to the WinGD general system oil specifications and recommendations given in the this manual.

The oil supplier gets all responsibility for the performance of the used system oils to the exclusion of any liability of WinGD and of companies that are part of the WinGD group. The oil supplier along with other possible manufacturers and distributors of the related products shall indemnify, compensate and hold harmless WinGD and companies that are part of the WinGD group from and against any claims, damages and losses caused by the used system oils.

Table 6: List of validated System Oils (SAE 30) (November 2017)

Oil Supplier	Brand	Base Number (BN)
Aegean	Alfasys 305	5
Castrol	CDX 30	5
Chevron	Veritas 800 Marine 30	5
CPC	Marilube Oil AC−30; Marilube Oil AC−30 Plus 1)	6 6
ENI	Cladium 50	5
ExxonMobil	Mobilgard 300 C	9
FL Selenia	MESYS 3006	5
GasPromNeft	Ocean CSO 7	7
Gulf Oil Marine	GulfSea Superbear 3006; GulfSea Superbear 3008	6 8
IOC	Servo Marine 0530	5
Iranol	Matisa 1)	8
JX Nippon Oil & Energy	Marine S30	7
LUKOIL	Navigo 6 CO	6
Pertamina	Medripal 307	7
Petrobras	Marbrax CAD−308	8
PetroChina	KunLun DCC3008; KunLun DCC3005H 1)	8 5
Premier Six	Opt−Max Shieldguard 3008	8
Shell	Melina S30	5
SINOPEC	Marine System Oil 3005; Marine System Oil 3006; Marine System Oil 3008	5 6 8
SK	Supermar AS 2)	5
Total	Atlanta Marine D 3005	5

1) This system oil is under testing and not yet validated.

2) Multiple formulations of this product are available. Not all of them are validated. Speak to the supplier for more data about the validated products.

Note: For system oils that are not listed in the table and for new system oils, speak to or send a message to WinGD.

9. List of Cylinder Oils

Always use cylinder oils related to the WinGD general lubricating oil specifications and recommendations given in the this manual.

The oil supplier gets all responsibility for the performance of the used cylinder oils to the exclusion of any liability of WinGD and of companies that are part of the WinGD group. The oil supplier along with other possible manufacturers and distributors of the related products shall indemnify, compensate and hold harmless WinGD and companies that are part of the WinGD group from and against any claims, damages and losses caused by the used cylinder oils.

Note: The Base Number (BN), measured in mg KOH/g (test method ASTM D 2896), shows the alkalinity of the oil.

Table 7: List of validated Cylinder Oils and Blending on Board Additives (November 2017)

Oil Supplier	15 ≤ BN ≤ 25	BN 40	50 ≤ BN ≤ 60	BN 70	BN 100	BN > 100
Aegean	Alfacylo 525 DF (BN 25)	–	–	Alfacyclo 570	Alfacyclo100 HS [1)]	–
Bardahl	–	–	–	Naval 50	–	–
Castrol	Cyltech ACT (BN 16)	Cyltech 40 SX	–	Cyltech 70	Cyltech 100	–
Chevron	Taro Special HT LF (BN 25)	Taro Special HT LS 40	Taro Special HT 55 (BN 55)	Taro Special HT 70; Taro Special 70; Taro Special HT 70X	Taro Special HT 100; [4)] Taro Special HT 100X	–
CPC	–	–	–	Marilube Oil CO−700 Plus	Marilube Oil CO−1000 Plus [1)]	–
ENI	Punica 525 (BN 25)	–	–	Punica 570	–	–
ExxonMobil	Mobilgard 525 (BN 25)	Mobilgard L 540	Mobilgard 560VS (BN 60)	Mobilgard 570	Mobilgard 5100 [8)]	–
FL Selenia	–	–	–	MECO 5070	–	–
GasProm-Neft	Ocean CCL 17 ULSF (BN 17)	Ocean CCL 40 LSF [1)]	–	Ocean CCL 70	Ocean CCL 100 HSF	–
Gdanska	–	–	–	Marinol RG 7050	–	–
Gulf Oil Marine	GulfSea Cyl-care ECA 50 (BN 17)	–	–	GulfSea Cyl-care DCA 5070H	GulfSea Cylcare 50100 [2)]	–
Hin Leong	–	–	–	Universal Cyl EN 7050 [2)]	–	–
IOC	–	–	–	Servo Marine 7050	–	–
Iranol	–	–	–	Oscar [1)]	–	–
JX Nippon Oil & Energy	Marine C255 (BN 25)	Marine C405; Marine C405Z	–	Marine C705	Marine C1005	–
LUKOIL	Navigo MCL Ultra (BN 20)	Navigo 40 MCL	–	Navigo 70 MCL	Navigo 100 MCL	–
		Navigo MCL Extra	Blended cylinder oil BN 60 to BN 100 using Lukoil Navigo 100 MCL and Lukoil Navigo 6 system oil			–

Lubricating Oils

Oil Supplier	15 ≤ BN ≤ 25	BN 40	50 ≤ BN ≤ 60	BN 70	BN 100	BN > 100
Mexicana de Lubricantes	–	–	–	Marinelub 7050	–	–
Pars Oil	–	–	–	Pars Oghya-nous 5070 1)	–	–
Pertamina	–	–	–	Medripal 570	–	–
Petrobras	–	Marbrax CID−54−APN	Marbrax CID−55 (BN 50)	Marbrax CID−57	–	–
PetroChina	–	–	–	KunLun DCA 5070H	–	–
Premier Six	–	Opt−Max BoB 300 additives for on−board blended cylinder oils (BN 40 to BN 120) 3)				
		Opt−Max Shieldguard 5040	–	Opt−Max Shieldguard 5070	–	Opt−Max Shieldguard 50110 (BN 110)
						Opt−Max Flex-guard 140 (BN 140) 1)
Shell	Alexia S3 (BN 25)	–	Alexia S4 (BN 60, SAE 40)	Alexia 50; Alexia S5 (BN 80); Alexia 70 1)	Alexia S6; 5) Alexia 100 1)	Alexia 140 (BN 140) 1)
SINOPEC	Cylinder Oil 5017(BN 17); Cylinder Oil 5025 (BN 25)	Cylinder Oil 5040 1)	–	Cylinder Oil 5070; Cylinder Oil 5070S; Cylinder Oil 5080S (BN 80)	Cylinder Oil 50100	–
SK	Supermar CYL 25 (BN 25)	Supermar CYL 40; Supermar CYL 40L	–	Supermar CYL 70 plus	Supermar CYL 100	–
Texas Petro-chemical	–	–	–	Texmarine 700	Texmarine 1000	–
Tongyi Lubri-cants	Huhangzhe M3 Cylinder Oil 2550 (BN 50)	–	–	–	–	–
Total	Talusia LS 25 (BN 25)	Talusia LS 40	Talusia Univer-sal (BN 57)	Talusia HR 70	Talusia Univer-sal 100; Talusia Optima 6)	–
United Oil Company Pte Ltd.	–	–	–	U Star Lube Star Marine 570	–	–

1) This cylinder oil is under testing and not yet validated.

2) Multiple formulations of this product are available. Not all of them are validated. Speak to the supplier for more data about the validated products.

3) Multiple blending combinations with different system oils are possible. Not all of them are validated. Speak to the supplier for more data about the validated products.

4) Use in combination with <0.1% sulphur ECA fuel for up to 100 h validated by field test.

5) Use in combination with <0.1% sulphur ECA fuel for up to 200 h validated by field test.

6) Use in combination with <0.1% sulphur ECA fuel for up to 300 h validated by field test.

7) Use in combination with <0.1% sulphur ECA fuel for up to 400 h validated by field test.

8) Use in combination with <0.1% sulphur ECA fuel for up to 500 h validated by field test.

Note: Intermediate cylinder oils (BN is between 50 mg KOH/g and 60 mg KOH/g) can be used with fuels in the sulphur range between 0.5% m/m and 2.5% m/m, but their performance must be regularly monitored with a piston underside drain oil analysis. The cylinder oil feed rate must be adjusted related to the results.

10. List of Lubricants − Flywheel and Pinion Gear Teeth

Always use lubricants for flywheel and pinion gear teeth related to the WinGD general lubricant specifications and recommendations given in the this manual.

The oil supplier gets all responsibility for the performance of the lubricant in service to the exclusion of any liability of WinGD and of companies that are part of the WinGD group. The oil supplier along with other possible manufacturers and distributors of the related products shall indemnify, compensate and hold harmless WinGD and companies that are part of the WinGD group from and against any claims, damages and losses caused by the used lubricants.

Table 8: List of Lubricants for Flywheel and Pinion Gear Teeth (16 October 2012)

Supplier	Brand
Lubrication Engineers Inc.	LE 5182 PYROSHIELD
Klüber Lubrication München KG	Klüberfluid C−F 3 ULTRA

Operating Media

Cooling Water / Cooling Water Treatment

1. General

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

2. Raw water for closed cooling water circuits

When the cooling system is replenished, the raw water must without fail be **totally desalinated water** or condensate water from the fresh water generators. Condensate water is highly corrosive and must therefore be made suitable as coolant by the addition of 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 salt content.

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

Parameter	Value
Hardness	3 to 10 °dH
Chlorides and sulphates content	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 **WinGD**.

Corrosion protective oils (emulsifiable oils) for treating the cooling water must not be used. Water-oil emulsions can lead to considerable risks of fouling the cooling system.

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. Inhibitors with NITRITE and BORATE active ingredients have provided good corrosion protection in service. A list of proven and tested marketed products can be obtained from **WinGD** upon request. The dosage must be strictly adhered to in accordance with the instructions of the manufacturer, and the coolant must be periodically checked in service to maintain the correct concentration.

It is recommended that suppliers of inhibitors who can also provide expert advice for the initial fill as well as for later in service queries be selected.

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

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

4. Cleaning the cooling water system

For a new fill the complete cooling system must be clean, free from grease and oil and must not contain any foreign particles or remnants such as swarf from the manufacturing process.

A replacement of the cooling system water may become necessary if the heat transfer and with it the cooling effect is diminished by oil or the gradual formation of sediment and deposits. 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 and solid sediments). Prior to filling with the prepared cooling water, the system has to be thoroughly rinsed and any residual acid remnants must be neutralized.

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

After the cooling system has been cleaned, it must be refilled with suitable water and corrosion inhibitors and monitored carefully to ensure a long and trouble free service life.

5. Anti freeze

Anti freeze is generally not required for ship engines in regular service, and should thus not be used during operation. However, there may be a need for anti freeze if vessels are laid up in areas where ambient temperatures can fall well below freezing. In such cases, the minimum amount of anti freeze to meet the coldest anticipated temperatures should be used. Most commercial anti freeze formulations are blended for a dilution ratio of about 50/50 with water. Ensure that enough compatible corrosion inhibitor is available in the anti freeze water blend to ensure satisfactory operation if a lower dilution ratio is used. The recommendations of the anti freeze and corrosion inhibitor suppliers must be obtained and adhered to.

The heat transfer rate of the cooling system fluid is reduced with increasing anti freeze content. Consequently the engine must be operated at reduced maximum power if more than 20% anti freeze is used in the cooling system.

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
- 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
- Malfunction of crank angle measuring system

1. Troubles during starting

(Designations and part code numbers see Control Diagram 4003−2)

Case of trouble	Possible causes	Remedial measures
Engine does not turn when starting	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 Restart oil pumps only if all exhaust valves are closed
Starting from control room:	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
Starting at the engine:	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 E	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 E	Clean or replace, check cabling
	Plug(s) removed from solenoid valve(s) in valve unit E	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 **A**
	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 2751–2)
	Starting valves jammed or plug not connected	Overhaul starting valves or reconnect plug
	Different causes	Try to start in opposite running direction
Engine oscillates on starting or fails to come up to speed	Individual cylinders receive either no, or insufficient starting air (restriction in starting air piping, solenoid valve(s) ZV7241 (to 48C) 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
	Stop valve 4.37 closed	Open stop valve 4.37
Engine turns on starting air but receives no fuel oil, regulation of fuel injection quantity is in Pos. 'zero' %	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
Engine turns on starting air but receives no fuel oil	Fuel rail pressure too low, connection between actuators and fuel pumps disconnected	Fit connecting elements (see Maintenance Manual 5801–1)
	Fuel rail pressure too low, regulating linkage blocked in position 'zero'	Check regulating linkage, repair damage
	Fuel rail pressure too low, fuel pressure control valve 3.06 open	Check fuel pressure control valve 3.06 (see 0515–1)
	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 0515–1)
	Heavy leakage in high pressure circuit (fuel) on engine	Check for leakage, see 8019–1 '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
No ignitions when starting	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 0120–1)

Troubles during Starting and Stopping

Case of trouble	Possible causes	Remedial measures
	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 pump, rising pipe, fuel rail, injection control unit)	Investigate and remedy leakage with servo oil service pump running; tool 94583 (pipe) between fuel rail and servo oil rail connected
Individual cylinders do not fire or do not fire properly when starting	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 0510–1)
	Connections leaking on injection control unit	Tighten properly, regrind sealing faces
	Solenoid valve(s) ZV7201C (to F) defective	Replace defective solenoid valve(s)
	No electric signal to solenoid valve(s) ZV7201C (to F)	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 08A/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 (E85), 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 0520–1)
	Starting valves do not open, either being stuck or damaged or getting no signal	Overhaul or replace starting valves, check cabling

Case of trouble	Possible causes	Remedial measures
Violent firing when starting	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 (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

Case of trouble	Possible causes	Remedial measures
Engine cannot be stopped with rotary switch or telegraph in control room	Cable connector defective	Stop engine with EMERGENCY STOP button (see Shutting Down 0310−1)
Engine cannot be stopped with rotary switch on local control panel	Cable connector defective	Stop engine with EMERGENCY STOP button (see Shutting Down 0310−1)

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
Scavenge air pressure drops	Scavenge air cooler fouled on air side Water separator fouled or damaged	See 6606−1 ’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 Silencer before turbocharger fouled Turbine rotor blading fouled or damaged Nozzle ring of turbocharger damaged	See Cleaning the Turbocharger in Operation 6510−1 and Manual of Turbocharger
	Exhaust gas boiler (plant side) fouled, increased resistance or back pressure after turbine respectively	Clean at first opportunity
Scavenge air pressure rises	Nozzle ring of turbocharger fouled or partially choked	See Cleaning the Turbocharger in Operation 6510−1
Exhaust temperature before turbocharger rises	Air deficiency due to defect or considerable fouling of turbocharger, silencer or scavenge air cooler	See Cleaning the Turbocharger in Operation 6510−1, 6606−1 ’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
Exhaust temp. of individual cylinders rises	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 0450−1
	Exhaust valve leaking	Grind valve seat and head
	Exh. thermometer of resp. cylinder defective	Replace
Exhaust temp. of individual cylinders drops	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 0510−1 & 0520−1)
	Exh. thermometer of resp. cylinder defective	Replace

Irregularities during Operation

Case of trouble	Possible causes	Remedial measures
Engine speed drops	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'
Exhaust smoky	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
Engine runs irregularly or misfires at times, individual or all cylinders	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
Engine stops by itself (without shut-down indication)	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 4002–3 'User parameters'
Irregularities in cylinder cooling water system ***Pressure fluctuates:***	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 0545–1
Increased cooling water temperature at outlet of individual cylinders:	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 0760–1
	Piston running hot	See Troubles and Damages with Engine Parts 0840–1
	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 0545–1
Increased cooling water temperature on all cylinders:	Plant side faulty (regulating valve, cooling water cooler etc.)	See plant instructions

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
Cylinder lubrication fails ***Lack of lubricating oil:***	Daily tank empty, ball valve after lubricating oil filter 8.17 closed or filter element clogged, ball valve after measurement tube 8.19 closed	Top up daily tank, open ball valve, exchange or clean filter element
	Air in cylinder lubricating system	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
Failure of lubricating pump:	No or too low servo oil pressure	Open stop valve 4.30–5, check servo oil pressure, adjust pressure on pressure reducing valve 8.11–1 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
Troubles with exhaust valve	Step piston in exhaust valve defective	Overhaul, replace
Exhaust valves knock:	Orifice or filter in exhaust valve control units clogged	Clean orifice or filter (see Maintenance Manual 5612–1)
	Strainer holes in orifice to exhaust valve considerably enlarged (erosion)	Replace orifice
	Leakage in hydraulic piping	Remedy leakage, replace piping
Exhaust valve does not open:	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 reconnect cable plug (see 0525–1)
Exhaust valve does not shut:	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
Surging of turbochargers	Overload, air deficiency	See Cleaning the Turbocharger in Operation 6510–1, 6606–1 '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

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 Stop engine as soon as the situation permits Investigate cause, remedy as far as possible (see Safety Precautions and Warnings 0210–1 & Troubles and Damages with Engine Parts 0840–1)

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 Scuffing at cylinder liner surface due to lack of cylinder lubricating oil	Cut out injection of affected cylinder for a while (see 0510−1) Increase cylinder lubrication oil feed rate of affected cylinder with user parameter 'Lubrication' –> 'Feed Rate' (see 7218−1 'Adjusting the feed rate of lubricating oil') Should temperature still not drop, or rise again after injection is cut in, cut injection out again (see 0510−1) and stop engine as soon as possible, then wait until cylinder and piston have cooled down Check running surface of piston and cylinder liner If the damage is slight, seizure portions can be smoothed out with an oil stone If the damage is heavy, replace piston, piston skirt and cylinder liner Should a replacement of these parts not be feasible for any reason, remove piston, taking necessary precautions (see 0540−1)

2. Hot running of running gear parts

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

Intentionally blank

Operating Troubles

Failures and Defects of WECS Components

Overview

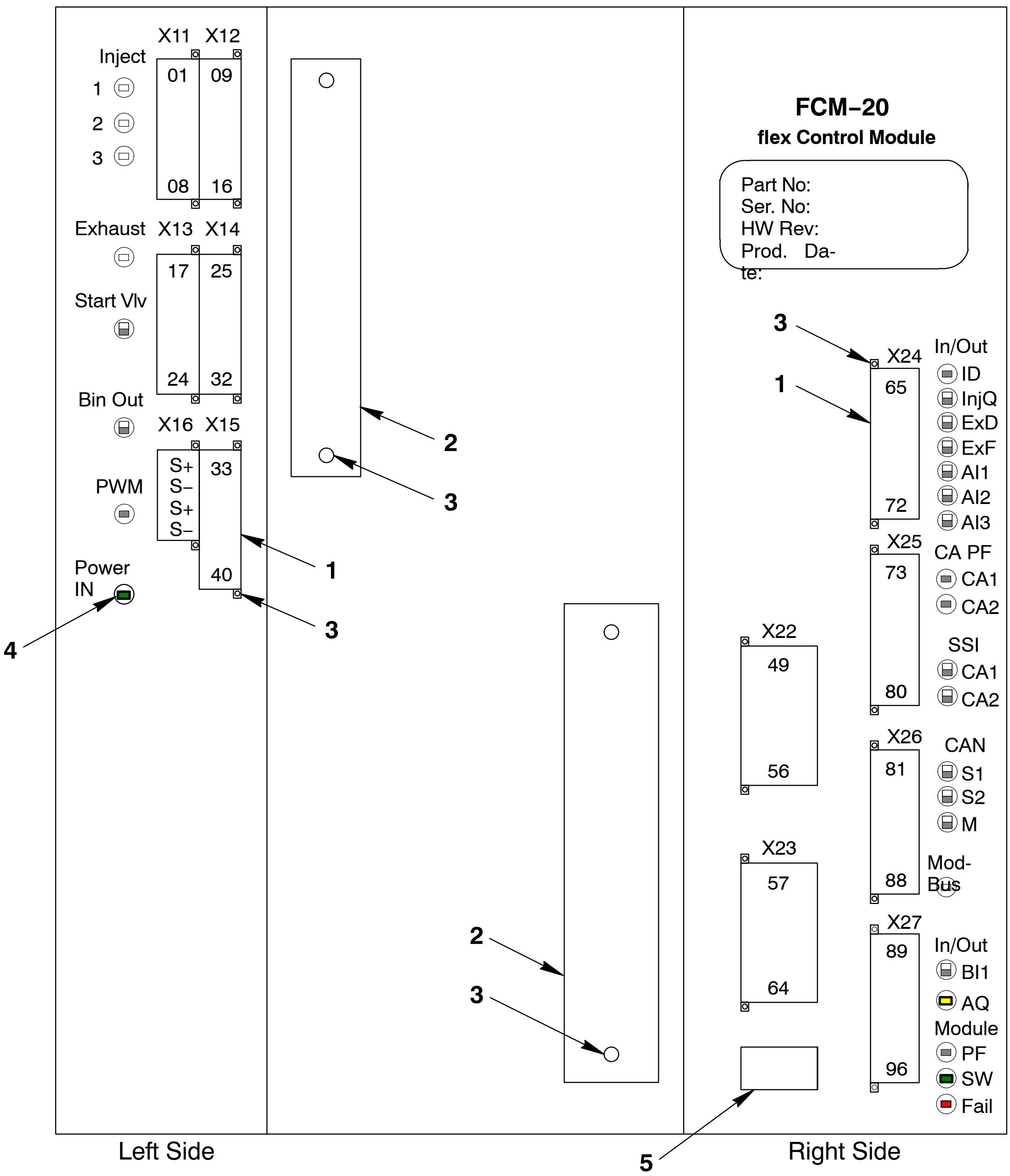
1. General

Failures and defects of WECS components cause failure messages to show on the operator flexView and alarm and monitoring system.

The tables that follow are an overview to help you understand all failure indications. A two digit LED display for failure ID is given on the FCM−20 modules. An LED code is given on the ALM−20 and ACM−20 modules that can show several accurate failure indications.

2. LED indications on FCM−20 module

A



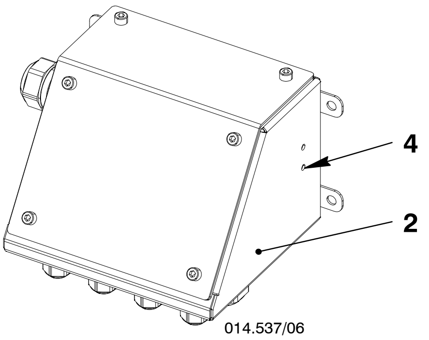
Key to Illustration: 'A'

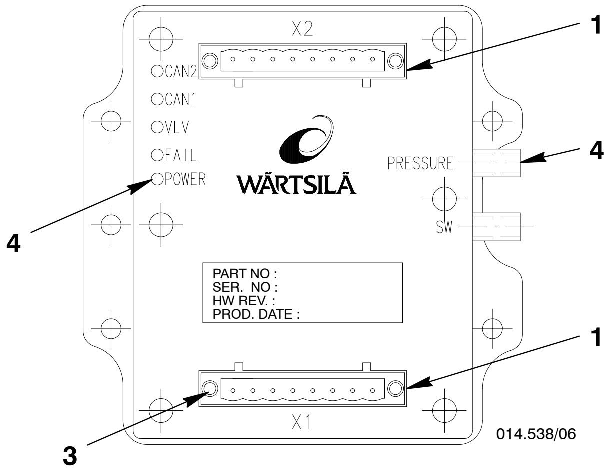
1 Connectors (COMBICON)
2 Cable holder
3 Screw
4 LEDs
5 Digital LED display

Remark: The screws 3 of connectors 1 and cable holders 2 must always be correctly installed.
The LEDs are not directly connected to the connector. The text labels next to the connectors show the LED code.

3. LED indications on ALM−20 module

(B)



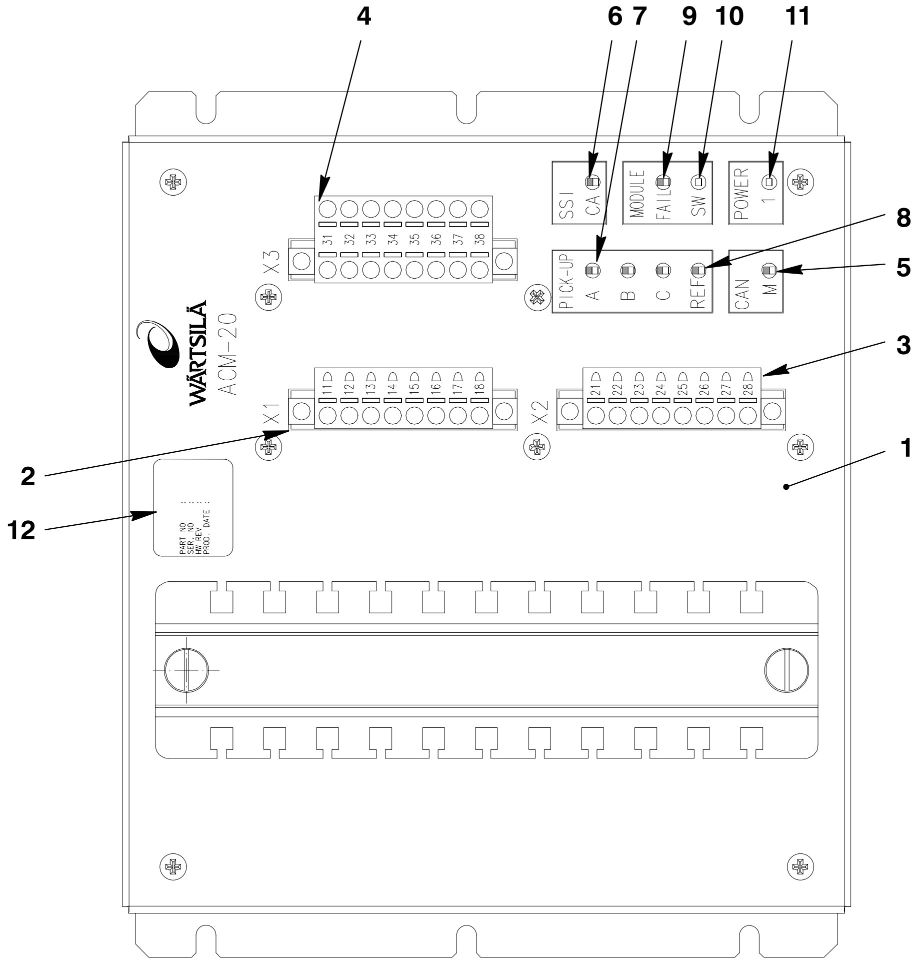


Key to Illustration: 'B'

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

4. LED indications on ACM–20 module

C



WCH00773

Key to Illustration: ’C’ ACM–20 module

1 ACM–20 module
2 Plug X1
3 Plug X2
4 Plug X3
5 CAN M LED
6 SSI CA LED
7 PICK-UP A, B, C LEDs
8 PICK-UP REF TDC or BDC LED
9 MODULE FAIL LED
10 MODULE SW LED
11 POWER LED
12 Nameplate

5. Failure indications

5.1 Failure grouping

All WECS failure indications are part of the following failure groups and are always shown together with the related 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, do not have much effect on engine operation	Investigate the cause and repair at the earliest opportunity
WECS cylinder failures	Failures that result in loss of a cylinder thus decreasing engine power, 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.) have an effect on whole engine, trigger an immediate slow-down in safety system	Do not override the slow-down. It is not recommended. Immediate repair is necessary for unrestricted engine operation
WECS critical failures (WECS engine failures)	Failures affecting an engine stop by the WECS	Must be repaired immediately to start the engine again

5.2 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 on a cylinder triggering a slow-down in the safety system	Immediate repair required for unrestricted engine operation Fuel injection of related cylinder must be cut out until failure has been corrected, see Operation with Injection Cut Out 0510–1
Cylinder lubrication malfunction	Failures that result in loss of cylinder lubrication triggering a slow-down in the safety system	Immediate repair required for unrestricted engine operation Fuel injection of related cylinder must be cut out until failure has been corrected, see Operation with Injection Cut Out 0510–1

flexView alarm journal data:

The flexView alarm journal shows more data that can help you. If necessary, you can change all parameters in the Adjust access level. See the Operator flexView manual for instructions about how to change parameters.

5.3 LED ON / OFF codes

Red LED Fail. and digital LED display:

The red Fail LED shows a failure on the related FCM−20 module and if the failure status is active or inactive (see Fig. 'A'). The failure code shown on the digital LED display is also shown on the flexView.

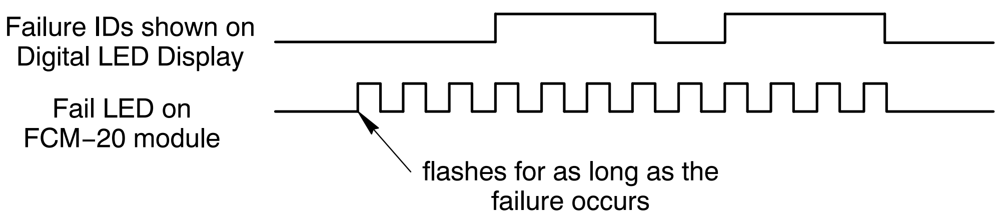
Failure status	Fail LED	Digital LED Display
Failure	flashes	flashes
Failure (history)	on (does not flash)	flashes
no failure	off	none

Function:

- Failure IDs give data about failures (see paragraph 5.4).
- The Fail LED flashes at the same time as the digital LED display.
- Failure IDs that are more than 99 are shown as a two-digit display e.g. Failure ID 125 is shown as 2.5.

Failure:

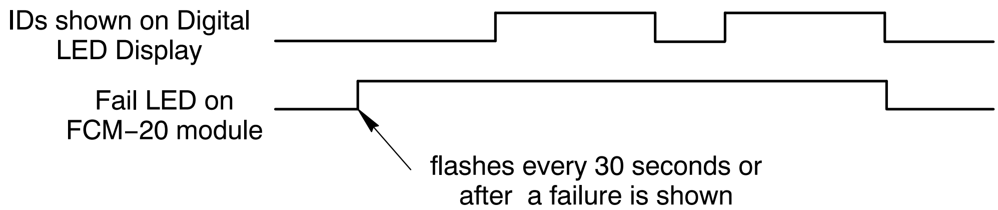
- The Fail LED flashes three times before the first failure ID is shown.
- Each failure ID is shown for 2.7 seconds, then there is a pause of 1.3 seconds before the the failure ID is shown again.
- If there are no more failures, the Fail LED goes off.



Failure (history):

- The Fail LED comes on for 2.4 seconds before the first failure ID is shown.
- Each failure ID is shown for 2.7 seconds, then there is a pause of 1.3 seconds before the the failure ID is shown again.
- After the failure before is shown, there will be a pause of 20 seconds between two failure IDs.
- If there is no more failure history, the fail LED goes off.

Failure (history) is shown during a 15 minute period (for approximately 30 seconds)



LED Indications on FCM−20 Module at start-up:

Right side:

After the power is set to on, the SSI CA1, CA2 and CAN S1, S2 and M LEDs show red for approximately four seconds. The Fail LED shows red for approximately two seconds. The yellow LEDs In/Out from InjQ to AI3, CAN S1, S2, and M and the green SW LED then come on.

Left side:

After the power is set to on, the green Power IN LED comes on.

5.4 Failure ID

Failure ID	Display	Failure text	Failure Group
1	1	ME crank angle #1+2 fail.	WECS critical
8	8	ME scavenge air pressure sensor #1 meas. fail.	WECS passive
8	8	ME scavenge air pressure sensor #2 meas. fail.	WECS passive
9	9	ME scavenge air pressure sensor #1+2 meas. fail.	WECS common
10	10	ME scavenge air pressure meas. fail. diff. high	WECS common
11	11	ME scavenge air pressure very high	WECS pressure
16	16	ME servo oil pressure sensor #1 meas. fail.	WECS passive
16	16	ME servo oil pressure sensor #2 meas. fail.	WECS passive
17	17	ME servo oil pressure sensor #1+#2 meas. fail.	WECS common
18	18	ME servo oil pressure meas. fail. diff. high	WECS common
19	19	ME servo oil pressure high	WECS common
20	20	ME servo oil pressure low	WECS common
21	21	ME servo oil pressure very low	WECS pressure
26	26	ME servo oil pump #1 fail.	WECS common
26	26	ME servo oil pump #2 fail.	WECS common
27	27	ME fuel rail pressure sensor #1 meas. fail.	WECS passive
27	27	ME fuel rail pressure sensor #2 meas. fail.	WECS passive
28	28	ME fuel rail pressure sensor #1+#2 meas. fail.	WECS common
29	29	ME fuel rail pressure meas. fail. diff. high	WECS common
30	30	ME fuel rail pressure high	WECS common
31	31	ME fuel rail pressure low	WECS common
32	32	ME fuel rail pressure very low	WECS pressure
33	33	WECS any FCM−20 module cyl. ID lost	WECS passive
38	38	WECS CAN M-bus fail. FCM−20 #01 to #05	WECS passive
39	39	WECS Modbus fail. FCM−20 #01 or #02	WECS passive
42	42	WECS CAN S-bus connection fail. FCM−20 #00	WECS passive
42	42	WECS CAN S-/ SSI bus connection fail. FCM−20 #nn	WECS passive
45	45	ME manual injection cutoff cylinder #nn	WECS cylinder
60	60	ME crank angle difference between #1 and #2	WECS common
62	62	ME TDC signal fail.	WECS common
63	63	ME crank angle #1 / TDC high shift	WECS common
64	64	ME crank angle #2 / TDC high shift	WECS common
65	65	ME both CA / TDC high shift	WECS critical
66	66	ME crank angle #1 / TDC low shift	WECS common
67	67	ME crank angle #2 / TDC low shift	WECS common
68	68	ME both CA / TDC low shift	WECS cylinder
69	69	ME excessive engine speed	WECS critical
71	71	ME exhaust valve #nn position meas. fail.	WECS passive
75	75	ME exhaust valve #nn fail. (late / not opening)	WECS cylinder
76	76	ME exhaust valve #nn fail. (early closing)	WECS cylinder

Failure ID	Display	Failure text	Failure Group
77	77	ME exhaust valve #nn fail. (late / not closing)	WECS cylinder
78	78	ME exhaust valve #nn fail.	WECS cylinder
79	79	ME exhaust valve #nn fail. (closing deadtime too long)	WECS cylinder
80	80	ME injection quantity sensor #nn meas. fail.	WECS common
87	87	ME injection timing fail. cylinder #nn (injection time too short)	WECS common
88	88	ME injection timing fail. cylinder #nn (injection time too long)	WECS common
90	90	ME injection quantity piston fail. cylinder #nn (late / no return)	WECS cylinder
91	91	ME injection quantity piston fail. cylinder #nn (no movement)	WECS cylinder
92	92	ME injection quantity piston fail. cylinder #nn (stuck in max. position)	WECS cylinder
93	93	ME injection quantity piston fail. cylinder #nn	WECS cylinder
94	94	WECS module FCM−20 #00 fail.	WECS passive
95 to 102	95 to 0.2	WECS module FCM−20 #nn fail.	WECS cylinder
109	0.9	ME fuel pump actuator fail.	WECS common
110	1.0	ME crank angle #1 fail.	WECS passive
111	1.1	ME crank angle #2 fail.	WECS passive
112	1.2	WECS CAN S1-bus fail.	WECS passive
113	1.3	WECS CAN S2-bus fail.	WECS passive
114	1.4	ME start pilot valve #nn loop fail.	WECS passive
125	2.5	WECS cylinder lubrication passive failure	WECS passive
126	2.6	ME cylinder lubrication malfunction cylinder #01	WECS passive

Remark: All Failure IDs and indications on this list are for Operator use.
All Failure IDs and indications that are not on this list are for the Experts.

5.5 WECS passive failure

Failure text	**ME scavenge air pressure sensor #1 meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03	AI2	8	**8**
Cause:	Sensor signal < 2mA or > 22mA			
Fault finding, remedies:	– Check pressure transmitter PT4043C – Check supply voltage 24 VDC on plug X27 (terminals 94+/96−) in E95.03 and on transmitter plug (2+/1−) – Check cabling from the pressure transmitter PT4043C to E12 and E95.03 – Re-establish proper wiring from pressure transmitter PT4043C to E95.03 – Exchange pressure transmitter PT4043C if necessary			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03	AI2	8	**8**
Cause:	A short circuit in the sensor power supply is in addition to the failure text indicated by a steady red LED			
Fault finding, remedies:	– Unplug pressure transmitter PT4043C and plug X27 in E95.03 – Measure cables with multimeter on plug X27 terminal 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 transmitter for earth fault, replace pressure transmitter PT4043C if required – If red LED remains with disconnected X27, replace FCM−20 module #03			
Failure text	**ME scavenge air pressure sensor #2 meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#04	AI2	8	**8**
Cause:	Sensor signal < 2mA or > 22mA			
Fault finding, remedies:	– Check pressure transmitter PT4044C – Check supply voltage 24 VDC on plug X27 (terminals 94+/96−) in E95.04 and on transmitter plug (2+/1−) – Check cabling from pressure transmitter PT4044C to E12 and E95.04 – Re-establish proper wiring from pressure transmitter PT4044C to E95.04 – Exchange pressure transmitter PT4044C if necessary			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#04	AI2	8	**8**
Cause:	A short circuit in the sensor power supply is in addition to the failure text indicated by a steady red LED			
Fault finding, remedies:	– Unplug pressure transmitter PT4044C and plug X27 in E95.04 – Measure cables with multimeter on plug X27 terminal 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 transmitter for earth fault, replace pressure transmitter PT4044C if required – If red LED remains with disconnected X27, replace FCM−20 module #04			

Failures and Defects of WECS Components

Failure text	**ME servo oil pressure sensor #1 meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01	AI2	16	**16**
Cause:	Sensor signal < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)			
Fault finding, remedies:	– Check pressure transmitter PT2071C on servo oil rail – Check supply voltage 24 VDC on plug X27 (terminals 94+/96–) in E95.01 and on transmitter plug – Check cabling from pressure transmitter PT2071C to E95.01 – Re-establish proper wiring from pressure transmitter PT2071C to E95.01 – Exchange pressure transmitter PT2071C if necessary – If no spare available, it is recommended to unplug the faulty transmitter temporarily			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01	AI2	16	**16**
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 PT2071C and plug X27 in E95.01 – 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 transmitter for earth fault, replace pressure transmitter PT2071C if required – If red LED remains with disconnected X27, replace FCM−20 module #01			
Failure text	**ME servo oil pressure sensor #2 meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#02	AI2	16	**16**
Cause:	Sensor signal < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)			
Fault finding, remedies:	– Check pressure transmitter PT2072C on servo oil rail – Check supply voltage 24 VDC on plug X27 (terminals 94+/96–) in E95.02 and on transmitter plug – Check cabling from pressure transmitter PT2072C to E95.02 – Re-establish proper wiring from pressure transmitter PT2072C to E95.02 – Exchange pressure transmitter PT2072C if necessary – If no spare available, it is recommended to unplug the faulty transmitter temporarily			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#02	AI2	16	**16**
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 PT2072C and plug X27 in E95.02 – 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 transmitter for earth fault, replace pressure transmitter PT2072C if required – If red LED remains with disconnected X27, replace FCM−20 module #02			

Failures and Defects of WECS Components

Failure text	**ME fuel rail pressure sensor #1 meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03	AI1	27	**27**
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 / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03	AI1	27	**27**
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 ***Remark:*** 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 with disconnected X25, replace FCM−20 module #03			
Failure text	**ME fuel rail pressure sensor #2 meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#04	AI1	27	**27**
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 / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#04	AI1	27	**27**
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 ***Remark:*** 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 with disconnected X25, replace FCM−20 module #04			

Failure text	**WECS module FCM−20 #00 fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#00 (E90)	Fail	94	**94**
Cause:	Missing communication on CAN S1 **and** CAN S2 bus on FCM−20 module #00 No heartbeat signal from this module received by the remaining modules in the system on **either** S-bus			
Fault finding, remedies:	– Check that both CAN S-bus connections on FCM−20 module #00 plug X22 (S1), terminals 49/50 and plug X23 (S2), terminals 57/58) for proper connection – Check power supply units U0.1 and U0.2 and their circuit breakers F0.1 and F0.2 in terminal box E85 – Measure supply voltage in E85 and in E90, should be around 24 VDC – Check terminating resistors 120 ohm on plug X22 (terminals 49/59) and plug X23 (terminals 57/58) (only on engines with E90 on FE) – Re-establish proper cable connection on plugs X22 and X23 – Re-establish proper terminating resistors 120 ohm on plug X22 and X23 – Replace FCM−20 ’online spare’ module if necessary			
	Remark: In case of this failure a service computer possibly connected to CAN M #0 will lose its communication			
Failure text	**WECS any FCM−20 module cyl. ID lost**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#00 to #08	ID	33	**33**
Cause:	Invalid identification jumper setting on X25			
Fault finding, remedies:	– Check cabling address on plug X25 of corresponding FCM−20 module – Re-establish proper wiring of identification jumpers on X25 of the corresponding FCM−20 module (refer to the correct wiring diagrams for E95 boxes)			
	Remark: If this failure occurs when running FCM−20 module, it will not affect engine operation 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 / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#00 (E90)	S1 or S2	42	**42**
Cause:	Missing bus connection on CAN S-bus #1 or CAN S-bus #2 on FCM−20 #00 module			
Fault finding, remedies:	– Check that both CAN S-bus plugs X22 and X23 are correctly inserted on the ’online spare’ module – Re-establish proper cable connection on plugs X22 and X23 on FCM−20 ’online spare’ module – Cycle module’s power supply off and on for this module – Replace the FCM−20 #00 module if failure persists			

<table>
<tr><th>Failure text</th><th colspan="4">WECS CAN S-/ SSI bus connection fail. FCM−20 #nn</th></tr>
<tr><td>Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td></td><td>#01 to #08</td><td>S1 and CA1 or S2 and CA2</td><td>42</td><td>42</td></tr>
<tr><td>Cause:</td><td colspan="4">Either both CAN S-bus #1 and crank angle signal #1 or CAN S-bus #2 and crank angle signal #2 missing on FCM−20 module</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– Check that plug X22 is correctly connected to the corresponding FCM−20 module
– Connect plug X22 properly to corresponding FCM−20 module
– Check that the plug X23 is correctly connected to the corresponding FCM−20 module
– Connect plug X23 properly to corresponding FCM−20 module
– Connect plug X23 properly to corresponding FCM−20 module</td></tr>
<tr><th>Failure text</th><th colspan="4">WECS CAN S1-bus fail.</th></tr>
<tr><td>Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td></td><td>#01 to #08</td><td>S1</td><td>112</td><td>1.2</td></tr>
<tr><td>Cause:</td><td colspan="4">CAN system bus #1 monitoring / CAN controller failure (failure signal release is 3 seconds delayed)</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– Check cable connection on corresponding FCM−20 module (plug X22, terminals 49/50)
– Check proper termination of S1-bus with 120 ohm resistors on FCM−20 module #01 and FCM−20 module #00 in E90 plug X22 (refer to el. drawings) (only if E90 is on the free end)
– Re-establish proper cable connection corresponding on FCM−20 module
– Replace the corresponding FCM−20 module if failure appears on one module only</td></tr>
<tr><th>Failure text</th><th colspan="4">WECS CAN S2-bus fail.</th></tr>
<tr><td>Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td></td><td>#01 to #08</td><td>S2</td><td>113</td><td>1.3</td></tr>
<tr><td>Cause:</td><td colspan="4">CAN system bus #2 monitoring / CAN controller failure (failure signal release is 3 seconds delayed)</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– Check cable connection on corresponding FCM−20 module (plug X23, terminals 57/58)
– Check proper termination of S2-bus with 120 ohm resistors on FCM−20 module #01 and FCM−20 module #00 in E90 plug X23 (refer to el. drawings)
– Re-establish proper cable connection corresponding on FCM−20 module
– Replace the corresponding FCM−20 module if failure appears on one module only</td></tr>
</table>

Failure text	WECS Modbus fail. FCM−20 #01 - #04			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 - #04	Modbus	39	**39**
Cause:	Modbus monitoring, no communication (failure signal release is 3 seconds delayed)			
Fault finding, remedies:	– Check cable connection in corresponding FCM−20 module (plug X23, terminals 63/64) if failure ID not displayed – Check cabling and connections in control boxes E90 and AMS / PCS boxes – Check proper termination of modbus with 120 ohm resistors on AMS / PCS side and FCM−20 side (refer to el. drawings) – Re-establish proper cabling, connection and termination in the corresponding FCM−20 module and control boxes – Replace the corresponding FCM−20 module if failure appears on one module only – Reset WECS and/or PCS or AMS			
Failure text	**WECS CAN M-bus fail. FCM−20 #01 to #08**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	M	38	**38**
Cause:	CAN M-bus monitoring, except FCM−20 #00 failure (failure signal release is 3 seconds delayed)			
Fault finding, remedies:	– Check cable connection in corresponding FCM−20 module (plug X22, terminals 55/56) – Check bus cabling and connections in control box E90: – Check bus cabling on PCS side and FCM−20 #01 and #02 – Check bus cabling on ECR manual control panel side and FCM−20 #03 – Check bus cabling on LC manual control panel side and FCM−20 #04 – Check CAN M-bus cabling on ACM−20 modules #1 and #2 to FCM−20 modules of last and second last cylinders – Re-establish proper cabling, connection and termination at the corresponding FCM−20 module and control boxes – Replace the corresponding FCM−20 module if necessary			

Failure text	**ME crank angle #1 fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	**SSI** CA1	110	**1.0**
Cause:	No angle information is received from ACM−20 module #1 in E96.1			
Fault finding, remedies:	– Check power supply between FCM−20 module #04 plug X26 (terminals 83/84) and ACM−20 module #1 plug X1 (terminals 11/12) – Check SSI #1 between FCM−20 module #01 plug X22 (terminals 51/52, 53/54) and ACM−20 module #1 plug X3 (terminals 31/32, 33/34) – Check directly status LED on ACM−20 module #1 (see 9223−1 ’LED indications’) – Check SSI-bus terminating resistors 120 ohm on plug X22 (terminals 51/52, 53/54) of last FCM−20 module – Check SSI #1 on all FCM−20 modules plug X22 (terminals 51/52, 53/54) – Run ’CAS’ trend in flexView – Re-establish proper cabling and connection in the corresponding modules – Re-establish proper SSI-bus terminating resistors 120 ohm on plug X22 (terminals 51/52, 53/54) of last FCM−20 module – Replace the corresponding FCM−20 module or ACM−20 module if required			
Failure text	**ME crank angle #2 fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	**SSI** CA2	111	**1.1**
Cause:	No angle information is received from ACM−20 module #2 in E96.2			
Fault finding, remedies:	– Check power supply between FCM−20 module #05 plug X26 (terminals 83/84) and ACM−20 module #2 plug X1 (terminals 11/12) – Check SSI #2 between FCM−20 module #01 plug X23 (terminals 59/60, 61/62) and ACM−20 module #2 plug X3 (terminals 31/32, 33/34) – Check directly status LED on ACM−20 module #2 (see 9223−1 ’LED indications’) – Check SSI-bus terminating resistors 120 ohm on plug X23 (terminals 59/60, 61/62) of last FCM−20 module – Check SSI #1 on all FCM−20 modules plug X22 (terminals 51/52, 53/54) – Run ’CAS’ trend in flexView – Re-establish proper cabling and connection in the corresponding modules – Re-establish proper SSI-bus terminating resistors 120 ohm on plug X23 (terminals 59/60, 61/62) of last FCM−20 module – Replace the corresponding FCM−20 module or ACM−20 module if required			

Failures and Defects of WECS Components

Failure text	**ME exhaust valve #nn position meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	Ex.D	71	**71**
Cause:	Sensors ZT5421C to 28C, signal < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)			
Fault finding, remedies:	– Check plug on corresponding terminal box E95.21 to E95.28 at cylinder cover – Check corresponding cabling to sensor and FCM−20 module (plug X24, terminals 68 to 72) – Re-establish proper cabling and connections in the corresponding FCM−20 module and in the terminal box – Replace corresponding sensor if necessary – If failure appears periodically, temporarily plug can be disconnected on terminal box until repair is possible			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	Ex.D	71	**71**
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:	– Check corresponding cabling to sensor and FCM−20 module (plug X24, terminals 68 to 72) – Re-establish proper cabling and connections in the corresponding FCM−20 module and in the terminal box – Replace corresponding sensor if necessary – If failure appears periodically, exchange cable-plug assembly to E95 with spare			
	Remark: Temporarily plug can be disconnected on terminal box until repair is possible			
Failure text	**ME start pilot valve #nn loop fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	Start Vlv	114	**1.4**
Cause:	Broken connection or short circuit			
Fault finding, remedies:	– Check cabling between corresponding solenoid valve and FCM−20 module (plug X15, terminals 33/34) for earth faults, short circuit or bad contact – Re-establish proper cabling and connections between corresponding solenoid valve and FCM−20 module (plug X15)			
Failure text	**WECS cylinder lubrication passive failure**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
		None	125	**2.5**
Cause:	Interrupted power supply #1 or #2			
Fault finding, remedies:	– Check cabling in E85, E90 and E41.xx – Check whether power supply is interrupted by circuit breakers in E85 – Re-establish proper cabling and connections in E85 (terminals 25/26), E90 (terminals 40/41) and E41.xx (plug X2, terminals 21/22)			

Failures and Defects of WECS Components

Failure text	**WECS cylinder lubrication passive failure**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	Last or second last	None	125	**2.5**
Cause:	No signal communication CAN #1 or #2			
Fault finding, remedies:	– Check cabling in FCM−20 module of last and second last cylinders (plug X22, terminals 55/56) – Check whether defective CAN M-Bus is indicated on ALM−20 modules (LED: CAN1 or CAN2) – Re-establish proper cabling and connections in FCM−20 module of last and second last cylinders (plug X22, terminals 55/56) – Re-establish proper wiring of corresponding CAN M-Bus			
Failure LED:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	Fail	Red	3 x
Cause:	ALM−20 module occurs an identification failure			
Fault finding, remedies:	– Check corresponding ALM−20 module is active, however, after a restarting of all ALM−20 modules, corresponding ALM−20 remains inactive – Check cabling address on plug X1 of corresponding ALM−20 module – Check on ALM−20 modules (plug X1, terminals 16/17) and corresponding resistor (for values see 7218−1 ’Resistor on plug X1) – Re-establish correct connections in corresponding ALM−20 module (plug X1, terminals 16/17) – Replace resistor on plug X1 of corresponding ALM−20 module – Replace corresponding ALM−20 if necessary			
Failure text	**ME cylinder lubrication malfunction cylinder #01 to #08**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	None	126	**2.6**
Cause:	No pulse lubrication, cylinder lubrication malfunction			
Fault finding, remedies:	– Check detailed troubleshooting advise (see section 5.9)			

5.6 WECS common failure

Failure text	**ME scavenge air pressure sensor #1+2 meas. fail.**			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #04	AI2	9	**9**
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 / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #04	AI2	9	**9**
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 with disconnected plug X27, replace corresponding FCM–20 module			
Failure text	**ME scavenge air pressure meas. fail. diff. high**			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #04	AI2	10	**10**
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			

Failure text	ME servo oil pressure sensor #1+#2 meas. fail.			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 and #02	AI2	17	**17**
Cause:	Both sensor signals < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)			
Fault finding, remedies:	– Check pressure transmitters PT2071C and PT2072C on servo oil rail – Check supply voltage 24 VDC on plugs X27 (terminals 94+/96−) in E95.01 and E95.02 and on transmitter plugs – Check cabling to E95.01 an E95.02 – Re-establish proper wiring from pressure transmitter to E95.01 or E95.02 – Replace at least one pressure transmitter immediately			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 and #02	AI2	17	**17**
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 PT2071C and PT2072C and plugs X27 – Measure cables with multimeter on plugs 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 pressure transmitter if required – If red LED remains with disconnected plug X27, replace corresponding FCM−20 module			
Failure text	**ME servo oil pressure meas. fail. diff. high**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 and #02	AI2	18	**18**
Cause:	Sensor PT2071C and PT2072C ok, but difference > 30 bar (failure signal release is 7 seconds delayed)			
Fault finding, remedies:	– Compare both servo oil pressure indications – With engine stopped and servo oil rail depressurised, establish which of the pressure transmitters deviates – If possible, change engine load through a wider range and verify which pressure transmitter does not follow linearly to the changing servo oil pressure – Check cabling in E95.01 and E95.02 of differing pressure transmitter (plug X27, terminals 94/95) – Re-establish proper cabling of differing pressure transmitter – Replace pressure transmitter PT2071C or PT2072C			
Failure text	**ME servo oil pressure high**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 and #02	AI2	19	**19**
Cause:	Servo oil pressure 15 bar > setpoint, engine speed > 8% (failure signal release is 5 seconds delayed) ***Remark:*** Failure is suppressed under following conditions: Slow turning, air run Pressure controllers not properly adjusted in servo oil pumps after overhaul Dirt particle obstructs the function of a pressure controller			
Fault finding, remedies:	– Adjust pressure controllers in servo oil pumps			

Failures and Defects of WECS Components

Failure text	**ME servo oil pressure low**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 and #02	AI2	20	**20**
Cause:	Servo oil pressure 15 bar < setpoint, engine speed > 8% (failure signal release is 10 seconds delayed) ***Remark:*** Failure is suppressed under following conditions: Slow turning, air run, shut-down and servo oil pressure very low, control oil meas. fail.			
Fault finding, remedies:	– 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 temperature low, no vibrations) or pump defective – Leakages on the rising pipes between servo oil pumps and servo oil rail (leakage alarm?) – Exchange pressure controller (CV7221C, CV7222C) if necessary – Eliminate leakages ***Remark:*** In severe cases temporarily switch off injection and exhaust valve operation on 1 or 2 units to raise servo oil pressure ***Attention:*** 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 / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03	PWM	26	**26**
Cause:	Difference too high between PWM setpoint and current			
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 / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#04	PWM	26	**26**
Cause:	Difference too high between PWM setpoint and current			
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			

<table>
<tr><th>Failure text</th><th colspan="4">ME fuel rail pressure sensor #1+#2 meas. fail.</th></tr>
<tr><td rowspan="2">Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td>#03 and #04</td><td>AI1</td><td>28</td><td>28</td></tr>
<tr><td>Cause:</td><td colspan="4">Both sensor signals < 2 mA or > 22 mA (failure signal release is 3 seconds delayed)</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– 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 and on pressure transmitter plug
– Check cabling from pressure transmitters 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</td></tr>
<tr><td rowspan="2">Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td>#03 and #04</td><td>AI2</td><td>28</td><td>28</td></tr>
<tr><td>Cause:</td><td colspan="4">A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– Unplug pressure transmitters PT 3461C and PT3462C and plugs X25
Remark: ID fault on FCM−20 module #03 and #04 will be displayed
– 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</td></tr>
<tr><th>Failure text</th><th colspan="4">ME fuel rail pressure meas. fail. diff. high</th></tr>
<tr><td rowspan="2">Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td>#03 and #04</td><td>AI1</td><td>29</td><td>29</td></tr>
<tr><td>Cause:</td><td colspan="4">Sensor PT3461C and PT3462C ok, but difference > 50 bar (failure signal release is 7 seconds delayed)</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– 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 in E95.3 and E95.4 of differing pressure transmitter (plug X25, terminal 79/80)
– Re-establish proper cabling of differing pressure transmitter
– Replace pressure transmitter if necessary</td></tr>
</table>

Failure text	**ME fuel rail pressure high**			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #04	AI1	30 or 109	**30 or 0.9**
Cause:	Fuel rail pressure 50 bar > fuel pressure setpoint (failure signal release is 10 seconds delayed) ***Remark:*** Failure is suppressed at engine stand still			
Fault finding, remedies:	– Check if fuel pump actuators are switched on and working – All fuel pump racks must move freely – Check for actuator alarms in alarm monitoring system – 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% ***Remark:*** Can appear if engine is repeatedly started and stopped without having any fuel injection release in between – If required exchange damaged fuel pump actuators			
Failure text	**ME fuel rail pressure low**			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #04	AI1	31	**31**
Cause:	Fuel rail pressure 50 bar < fuel pressure setpoint (failure signal release is 10 seconds delayed) ***Remark:*** Failure is suppressed under following conditions: No engine running, no start command, fuel rail pressure very low			
Fault finding, remedies:	– Check whether fuel pump actuators are switched on and act properly – All fuel pump racks must move freely – Check actuator alarms in AMS – Check whether fuel supply pressure of 7 to 10 bar is ok – Any leakage alarms active? – Check whether oil supply to fuel pressure control valve 3.06 is ok or valve seat seized – Check if fuel pressure control valve 3.06 is leaking (this can be heard by a whistling sound) – Fuel overpressure safety valve 3.52 leaking – Non-return valves 3.81 (–1 to –3) on fuel rail and 3.22 in fuel pump covers damaged? – Check: Fuel pump plunger seized (fuel pump does not deliver) – If required exchange damaged fuel pump actuators – Eliminate leakages – Replace defective valves – Grind sealing surfaces again on rising pipes between fuel pump and fuel rail if there are leakages discovered			

Failures and Defects of WECS Components

Failure text	**ME fuel pump actuator fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #05	None	109	**0.9**
Cause:	Fuel pressure control output / fuel pump actuator command max. limit > 1 (failure signal release is 10 seconds delayed)			
Fault finding, remedies:	– Check: Fuel pump plunger seized – Check: Supply voltage 24 VDC in E85 switched off – Check cabling between actuator and corresponding FCM−20 module (plug X27, terminals 92/93) – Check proper actuator adjustments according to relevant governor manual – Make sure the diodes in the E85 box power supply terminals for the actuator are connected – Exchange damaged fuel pump – Re-establish proper cabling between corresponding FCM−20 module and actuator – Readjust actuator if necessary – Replace damaged diodes in E85 box			
Failure text	**ME crank angle difference between #1 and #2**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	**SSI** CA1/CA2	60	**60**
Cause:	Crank angle measuring system #1 and #2 ok, but an angle deviation has occurred between the two systems (difference > 1.0°)			
Fault finding, remedies:	– When flywheel is at TDC of Cyl. 1, both sensors must indicate 0° CA (in 'operator interface') – Check CAS offset adjustment – Adjust offset parameter in flexView – Engine stopped: Run a crank angle sensor trend in flexView by means of the turning gear – Check that both trend lines for CAS #1 and CAS #2 are matching (parallel) – Change faulty CAS if necessary and temporarily disconnect faulty CAS			
Failure text	**ME crank angle #1 / TDC low shift**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#05	BI1	66	**66**
Cause:	Difference between TDC pickup (measured angle) and crank angle measuring system #1 > 2.0° and < 4.0° has occurred ***Remark:*** Failure is suppressed at shut-down			
Fault finding, remedies:	– Check for wrong TDC offset adjustment – Check possibility of shifted crankshaft – Check CAS1 offset adjustment – Adjust correct distance of TDC pickup to target – Engine stopped: Run a crank angle sensor trend in flexView by means of the turning gear – Check that both trend lines for CAS #1 and CAS #2 are matching (parallel)			

Failure text	ME crank angle #2 / TDC low shift			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#05	BI1	67	**67**
Cause:	Difference between TDC pickup (measured angle) and crank angle measuring system #2 > 2.0° and < 4.0° has occurred ***Remark:*** Failure is suppressed at shut-down			
Fault finding, remedies:	– Check for wrong TDC offset adjustment – Check possibility of shifted crankshaft – Check CAS2 offset adjustment – Adjust correct distance of TDC pickup to target – Engine stopped: Run a crank angle sensor trend in flexView by means of the turning gear – Check that both trend lines for CAS #1 and CAS #2 are matching (parallel)			
Failure text	**ME crank angle #1 / TDC high shift**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#05	BI1	63	**63**
Cause:	Difference between TDC pickup (measured angle) and crank angle measuring system #1 > 4.0° ***Remark:*** Failure is suppressed at shut-down			
Fault finding, remedies:	– Check for wrong TDC offset adjustment – Check possibility of shifted crankshaft – Check CAS1 offset adjustment – Adjust correct distance of TDC pickup to target – Engine stopped: Run a crank angle sensor trend in flexView by means of the turning gear – Temporarily disconnect CAS#1 – Check that both trend lines for CAS #1 and CAS #2 are matching (parallel)			
Failure text	**ME crank angle #2 / TDC high shift**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#05	BI1	64	**64**
Cause:	Difference between TDC pickup (measured angle) and crank angle measuring system #2 > 4.0° ***Remark:*** Failure is suppressed at shut-down			
Fault finding, remedies:	– Check for wrong TDC offset adjustment – Check possibility of shifted crankshaft – Check CAS2 offset adjustment – Adjust correct distance of TDC pickup to target – Engine stopped: Run a crank angle sensor trend in flexView by means of the turning gear – Temporarily disconnect CAS#2 – Check that both trend lines for CAS #1 and CAS #2 are matching (parallel)			

<table>
<tr><th>Failure text</th><th colspan="4">ME TDC signal fail.</th></tr>
<tr><td rowspan="2">Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td>#05</td><td>BI1</td><td>62</td><td>62</td></tr>
<tr><td>Cause:</td><td colspan="4">No TDC signal from pickup ZS5123C (failure signal release is 10 seconds delayed)</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– 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 target tooth if necessary
– Replace pickup if necessary
– For emergency operation disconnect TDC pickup temporarily if pickup fault prevents engine operation</td></tr>
<tr><td rowspan="2">Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td>#05</td><td>BI1</td><td>62</td><td>62</td></tr>
<tr><td>Cause:</td><td colspan="4">A short circuit of the sensor power supply is in addition to the failure text indicated by a steady red LED</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– 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 with disconnected X27, replace FCM−20 module #05</td></tr>
</table>

Failure text	**ME injection quantity sensor #nn meas. fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	80	**80**
Cause:	Sensor signal ZT5461C to 68C < 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 rod – 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 / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	80	**80**
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 – 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 with disconnected plug X26, replace corresponding FCM−20 module			

Failure text	ME injection timing fail. cylinder #nn (injection time too short)			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	87	**87**
Failure text	**ME injection timing fail. cylinder #nn (injection time too long)**			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	88	**88**
Cause:	Ratio of injection timing on single unit to average injection time exceeds the permitted range e.g. < 0.6 too short, < 1.5 too long ***Remark:*** Failure is suppressed under following conditions: Engine speed below low load, injection cylinder #nn cut off			
Fault finding, remedies:	– 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			

5.7 WECS cylinder failure

Failure text	**WECS module FCM−20 #nn fail.**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	Fail	95 to 102	**95 to 0.2**
Cause:	Can S1 and S2 bus monitoring FCM #01 to #08 no heartbeat (failure signal release is 12 seconds delayed)			
Fault finding, remedies:	– Check LEDs on corresponding FCM−20 module – Check power supply in terminal box E85 for the related unit – Red LED lights up: Check cabling on corresponding FCM−20 module and plugs X22 (terminals 49/50) and X23 (terminals 57/58) – Check terminating resistors 120 ohm on FCM−20 module #01 and FCM−20 module #00 plug X22 between terminals 49/50 and plug X23 terminals 57/58 – Re-establish proper cabling on corresponding FCM−20 module and plugs X22 and X23 – Re-establish proper SSI-bus terminating resistors 120 ohm – Replace corresponding FCM−20 module if failure occurs on one module only			
Failure text	**ME both CA / TDC low shift**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#05	BI1	68	**68**
Cause:	Difference between TDC pickup (measured angle) and crank angle measuring system #1 and #2 > 2.0° and < 4.0° has occurred			
Fault finding, remedies:	– Check for wrong TDC offset adjustment – Check CAS1 / CAS2 offset adjustment – Check possibility of shifted crankshaft – Adjust correct distance of TDC pickup to target – Engine stopped: Run a crank angle sensor trend in flexView by means of the turning gear – Check that both trend lines for CAS #1 and CAS #2 are matching (parallel)			
Failure text	**ME exhaust valve #nn fail. (late / not opening)**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	Ex.D	75	**75**
Cause:	Late opening >15° dev. from setpoint (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 in exhaust valve control unit 4.10 for blockage – 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			

<table>
<tr><th>Failure text</th><th colspan="4">ME exhaust valve #nn fail. (early closing)</th></tr>
<tr><td>Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td></td><td>#01 to #08</td><td>Ex.D</td><td>76</td><td>76</td></tr>
<tr><td>Cause:</td><td colspan="4">Early closing ≥10° dev. from setpoint (failure signal release is 2 revolutions delayed)</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– Check air spring pressure (too high?)
– Check: Orifice in exhaust valve control unit 4.10 for blockage
– Seized hydraulic piston in valve drive 4.03
– Check: Mechanical failure in exhaust valve control unit 4.10
– Check: Leakages in the hydraulic system (actuator pipes etc.)
– Check: FCM−20 module defective
– Replace corresponding FCM−20 module or exhaust valve control unit if necessary</td></tr>
<tr><th>Failure text</th><th colspan="4">ME exhaust valve #nn fail. (late / not closing)</th></tr>
<tr><td>Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td></td><td>#01 to #08</td><td>Ex.D</td><td>77</td><td>77</td></tr>
<tr><td>Cause:</td><td colspan="4">Late closing ≥15° dev. from setpoint (Failure signal release is 3 revolutions delayed)</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– 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
– Replace corresponding FCM−20 module or exhaust valve control unit if necessary
– Replace rail valve or non-return valve 4.06 if necessary</td></tr>
<tr><th>Failure text</th><th colspan="4">ME exhaust valve #nn fail. (closing deadtime too long)</th></tr>
<tr><td>Failure LED / Failure ID:</td><td>FCM−20 No.</td><td>LED</td><td>Failure ID</td><td>Display</td></tr>
<tr><td></td><td>#01 to #08</td><td>Ex.D</td><td>79</td><td>79</td></tr>
<tr><td>Cause:</td><td colspan="4">Closing deadtime Cyl. #nn / Closing deadtime average >1.5 (failure signal release is 4 revolutions delayed)
Remark: Failure is suppressed at shut-down</td></tr>
<tr><td>Fault finding, remedies:</td><td colspan="4">– 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
– Replace corresponding valve drive or exhaust valve control unit, if necessary
– Replace rail valve or non-return valve 4.06 if necessary</td></tr>
</table>

Failures and Defects of WECS Components

Failure text	ME exhaust valve #nn fail.			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	Ex.D	78	**78**
Cause:	Exhaust valve is NOT opening/closing as per WECS setpoints, causing a SLD			
Fault finding, remedies:	– Check for co-alarms as Exh. v/v late / not opening, Exh. v/v early closing or Exh. v/v late / not closing for the corresponding unit – Troubleshoot according co-alarm fault finding, remedies			
Failure text	**ME manual injection cutoff cylinder #nn**			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	None	45	**45**
Cause:	Indication of a manually selected cut-off, no failure!			
Failure text	**ME injection quantity piston fail. cylinder #nn (late / no return)**			
Failure LED / Failure ID:	**FCM–20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	90	**90**
Cause:	Injection quantity piston return value > 5.5 mA (failure signal release is 30 seconds delayed) ***Remark:*** Failure is suppressed under following conditions: Engine stand still, injection quantity piston stuck in max. position, injection quantity measurement fail			
Fault finding, remedies:	– Consequence of rail valve 3.76 failure: Check ’return ON-time’ in ’operator interface’ – Check injection curve with flexView – Check: Plug must fit tightly on socket – Make sure measuring sleeve is properly mounted on fuel quantity piston – Check: Viscosity of fuel too high? (after longer engine stop and shut off heating) – Replace quantity sensor if feedback is instable or disconnect plug temporarily if no spares available – Press shortly manual lever on fuel shut-down pilot valve 3.08 – Briefly turn off the power to the corresponding FCM–20 module – Replace rail valve if necessary – Can also hint on seized quantity piston, replace injection control unit if confirmed			

Failure text	**ME injection quantity piston fail. cylinder #nn (no movement)**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	91	**91**
Cause:	No piston movement sensed at injection begin angle (failure signal release is 3 revolutions delayed) ***Remark:*** Can occur at very low engine loads Failure is suppressed under following conditions: Engine stand still, injection quantity piston stuck in max. position, injection quantity measurement fail			
Fault finding, remedies:	– Consequence of rail valve 3.76 failure: Check ’inject ON-time’ in ’operator interface’ – Check injection curve with flexView – Make sure measuring sleeve is properly mounted on fuel quantity piston – Check: Viscosity of fuel too high? (after longer engine stop and shut off heating) – Replace rail valve if necessary ***Remark:*** Failure can appear if injection control unit is operated with disconnected fuel quantity sensor and fV Adjust PARA Art.InjQtyRate is set too high			
Failure text	**ME injection quantity piston fail. cylinder #nn (stuck in max. position)**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	92	**92**
Cause:	Injection quantity piston return value > 18 mA (failure signal release is 30 seconds delayed) Failure signal recovery is 10 seconds delayed			
Fault finding, remedies:	– Consequence of rail valve 3.76 failure: Check ’return ON-time’ in ’operator interface’ – Check injection curve with flexView – Check: Plug must fit tightly on socket – Make sure measuring sleeve is properly mounted on fuel quantity piston – Check: Viscosity of fuel too high? (after longer engine stop and shut off heating) – Replace sensor if feedback is instable or disconnect plug temporarily if no spares available – Press shortly manual lever on fuel shut-down pilot valve 3.08 – Replace rail valve if necessary – Can also hint on seized fuel quantity piston, replace injection control unit ***Remark:*** Failure can appear if injection control unit is operated with disconnected fuel quantity sensor and fV Adjust PARA Art.InjQtyRate is set too low			
Failure text	**ME injection quantity piston fail. cylinder #nn**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	InjQ	93	**93**
Cause:	ME injection quantity piston fail. is a consequence of one of the following: ME injection quantity piston fail. late / no return (ID 90) ME injection quantity piston fail. no movement (ID 91) ME injection quantity piston fail. stuck in max. position (ID 92)			
Fault finding, remedies:	– Troubleshooting according co-alarm fault finding, remedies			

5.8 WECS pressure failure

Failure text	ME scavenge air pressure very high			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #04	AI2	11	**11**
Cause:	Scavenge air pressure > 3.2 bar (failure signal release is 2 seconds delayed) ***Remark:*** Failure is suppressed under following conditions: Shut-down, stop command, scavenge air pressure sensor #1+2 meas. fail.			
Fault finding, remedies:	– Reduce engine power – Take countermeasures (see manual of turbocharger manufacturer) – If there is sensor drift, disconnect the faulty sensor			
Failure text	**ME servo oil pressure very low**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 and #02	AI2	21	**21**
Cause:	Servo oil pressure 50 bar < setpoint, engine speed > 8% (failure signal release is 5 seconds delayed) ***Remark:*** Failure is suppressed under following conditions: 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 – Check control signals and cabling to servo oil pumps – Safety valve 4.23 open? – Pump drive, shaft 4.50 broken (pump temperature low, no vibrations) or pump defective – Leakages on the rising pipes between servo oil pumps and servo oil rail (leakage alarm? – Exchange pressure controller (CV7221C, CV7222C) if necessary – Eliminate leakages – Grind sealing surfaces again on rising pipes between servo oil pump and servo oil rail, if there are leakages discovered ***Remark:*** In severe cases you can temporarily switch off injection and exhaust valve operation on 1 or 2 units to raise servo oil pressure ***Attention:*** 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 / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#03 and #04	AI1	32	**32**
Cause:	Fuel rail pressure 150 bar < fuel pressure setpoint (failure signal release is 10 seconds delayed) ***Remark:*** Failure is suppressed under following conditions: Stop command, shut-down, engine stand still, fuel rail pressure sensor #1+2 meas. fail.			
Fault finding, remedies:	– Check whether fuel pump actuators are switched on and act properly – All fuel pump racks must move freely – Check actuator alarms in AMS – Check whether fuel supply pressure of 7 to 10 bar is ok – Any leakage alarms active? – Check whether oil supply to fuel pressure control valve 3.06 is ok or valve seat seized – Check if fuel pressure control valve 3.06 is leaking (this can be heard by a whistling sound) – Fuel overpressure safety valve 3.52 leaking – Non-return valves 3.81 (−1 to −3) on fuel rail and 3.22 in fuel pump covers damaged? – Check: Fuel pump plunger seized (fuel pump does not deliver) – If required exchange damaged fuel pump actuators – Eliminate leakages – Replace defective valves – Grind sealing surfaces again on rising pipes between fuel pump and fuel rail if there are leakages discovered			

5.9 **WECS critical failure** (WECS engine failure)

Failure text	ME crank angle #1+2 fail.			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#01 to #08	**SSI** CA1 and CA2	1	**1**
Cause:	Both crank angle measuring systems have failed			
Fault finding, remedies:	– Check power supply between FCM−20 module #04 plug X26 (terminals 83/84) and ACM−20 module #1 plug X1 (terminals 11/12) ANGELA only – Check power supply between FCM−20 module #05 plug X26 (terminals 83/84) and ACM−20 module #2 plug X1 (terminals 11/12) ANGELA only – Check directly status LED on ACM−20 module #1 and #2 (see 9223−1 'LED indications') – Check SSI-bus terminating resistors 120 ohm on plug X22 (terminals 51/52, 53/54) and plug X23 (terminals 59/60, 61/62) of last FCM−20 module – Run 'CAS' trend in flexView – Re-establish proper cabling and connection in the corresponding modules – Re-establish proper SSI-bus terminating resistors 120 ohm on plug X22 (terminals 51/52, 53/54) and plug X23 (terminals 59/60, 61/62) of last FCM−20 module – Replace the corresponding FCM−20 module or ACM−20 module if required			
Failure text	**ME both CA / TDC high shift**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
	#05	BI1	65	**65**
Cause:	Difference between TDC pickup (measured angle) and crank angle measuring system #1 and #2 > 4.0° has occurred			
Fault finding, remedies:	– Check for wrong TDC offset adjustment – Check CAS1 / CAS2 offset adjustment – Check for wrong CAS offset adjustment – Adjust correct distance of TDC pickup to target – Check possibility of shifted crankshaft – Adjust correct distance of TDC pickup to target – Engine stopped: Run a crank angle sensor trend in flexView by means of the turning gear – Check that both trend lines for CAS #1 and CAS #2 are matching (parallel)			
Failure text	**ME excessive engine speed**			
Failure LED / Failure ID:	**FCM−20 No.**	**LED**	**Failure ID**	**Display**
		None	69	**69**
Cause:	Engine was overspeeding (> 115% nominal speed)			
Fault finding, remedies:	– Check separate alarms from CA sensors – Reduce engine speed in case of heavy sea – Overspeed indication from safety system as well?			

5.10 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:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	CAN1 and/or CAN2	Red	None
Cause:	LED indication on **one** module: Cable break on plug X2 on corresponding ALM−20 module LED indication on **all** modules: CAN Bus #1 / #2 malfunction			
Fault finding, remedies:	– LED indication on **one** 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 – LED indication on **all** modules: Check CAN module bus from the last and the penultimate cylinder on FCM−20 module (plug X22, terminals 55 and 56) – Replace ALM−20 module if necessary			
Failure LED:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	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 38C)			
Fault finding, remedies:	– Check corresponding cabling, if cabling ok: 4/2-way solenoid valve malfunction (coil R~18 ohm) – Re-establish proper corresponding cable connection between ALM−20 module (plug X1, terminals 11 and 12) and 4/2-way solenoid valve – Replace corresponding 4/2-way solenoid valve if necessary (see 0820−1 'Cylinder lubrication')			
Failure LED:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	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 38C)			
Fault finding, remedies:	– Check corresponding cabling, if cabling ok: 4/2-way solenoid valve malfunction (coil R~18 ohm) – Re-establish proper corresponding cable connection between ALM−20 module (plug X1, terminals 11 and 12) and 4/2-way solenoid valve – Replace corresponding 4/2-way solenoid valve if necessary (see 0820−1 'Cylinder lubrication')			
Failure LED:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	Fail	Red	None
Cause:	Short circuit of cabling from ALM−20 module (plug X1, terminals 13 and 14) to pressure transmitter (PT3131 to 38C)			
Fault finding, remedies:	– Check cabling on corresponding ALM−20 module, if cabling ok: pressure transmitter malfunction – Re-establish proper corresponding cable connection between ALM−20 module (plug X1, terminals 13 and 14) and pressure transmitter – Replace corresponding pressure transmitter (PT3131 to 38C) if necessary (see 0820−1 'Cylinder lubrication')			

Failure text	**ME cylinder lubrication malfunction cylinder #nn**			
Failure LED:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	Fail	Red	2x
Cause:	Cable break of cabling from ALM−20 module (plug X1, terminals 13 and 14) to pressure transmitter (PT3131 to 38C)			
Fault finding, remedies:	– Check cabling on corresponding ALM−20 module, if cabling ok: pressure transmitter malfunction – Re-establish proper corresponding cable connection between ALM−20 (plug X1, terminals 13 and 14) and pressure transmitter – Replace corresponding pressure transmitter (PT3131 to 38C) if necessary (see 0820−1 'Cylinder lubrication')			
Failure LED:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	Power	Dark	None
Cause:	No power supply of individual ALM−20 module			
Fault finding, remedies:	– Check power supply units U500 / U501 and their circuit breakers F500 / F501 in E85 – If green LED 'DC OK' is ON, check cabling on corresponding ALM−20 module (plug X2, terminals 21 and 22 or 23 and 24) – f green LED 'DC OK' is flashing, check cabling on corresponding ALM−20 module and / or corresponding ALM−20 module (short circuit?) – Re-establish proper cable connection between E85 and corresponding ALM−20 module (plug X2, terminals 21 and 22 or 23 and 24) – Replace corresponding ALM−20 module (short circuit?)			
Failure text	**ME cylinder lubrication malfunction**			
Failure LED:	**ALM−20 No.**	**LED**		**Blink intervals**
	#01 to #08	Pressure	Yellow	None
Cause:	No successful pulse lubrication Cylinder lubricating pumps malfunction Malfunction of one or all cylinder lubrication triggers a slow-down			
Fault finding, remedies:	– Electrically defect: check cabling to pressure transmitter, 4/2-way solenoid valve and WECS−9520 – Check malfunction of ALM−20 module – Check: No or too low servo oil pressure – Check lubrication pump components (see 0820−1 'Cylinder lubrication fails') – Re-establish proper cabling to pressure transmitter, 4/2-way solenoid valve and WECS−9520 – Replace corresponding ALM−20 module or lubrication pump components, if necessary (see 0820−1 'Cylinder lubrication fails')			

5.11 Malfunction of crank angle measuring system

Malfunctions and defects of the crank angle measuring system are indicated by LEDs on the ACM−20 modules (see Fig. 'C').

For more information see also 9223−1 'LED indications'.

Failure text	**Crank angle #1 is not determined**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	Module Fail	Red	None
Cause:	The crank angle from set #1 is not known The ACM−20 module #1 has lost the absolute crank angle information ***Remark:*** This happens after black-out of the system or after ACM−20 reset. No actions are necessary			
Fault finding, remedies:	***Remark:*** The Message will disappear during engine start or if the engine is turned with the turning gear. When the related reference flag (REF1/ZS5124C) has passed, the message will disappear.			
Failure text	**Crank angle #2 is not determined**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	Module Fail	Red	None
Cause:	The crank angle from set #2 is not known The ACM−20 module #2 has lost the absolute crank angle information ***Remark:*** This happens after black-out of the system or after ACM−20 reset. No actions are required			
Fault finding, remedies:	***Remark:*** The message will disappear during engine start or if the engine is turned by turning gear. When the corresponding reference flag (REF2/ZS5125C) has been passed, the message will disappear.			
Failure text	**ACM #1 reports pickup #n signal failure**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	Pick-up (1, 2, 3)	red	fast blinking
Cause:	A signal failure has occurred, the signal sequence 'A', 'B', 'C' is incorrect The reason could be that one pickup signal is missing or that the pickups are not correctly mounted ***Remark:*** Also, passive failure 'ME crank angle #1 failure' shows			
Fault finding, remedies:	− Do a check of the pickup set #1 (ST5131C/A1, ST5132C/B1, ST5133C/C1) − Turn the engine clockwise with the turning gear and make sure that the pickup signal sequence is correct − Open the control box E96.1 and do a check of the sequence on ACM−20 module directly ***Remark:*** The sequence must be 'A', 'B', 'C' − Do a check of the distance between the pickup tip and the gear wheel tooth			

Failure text	**ACM #2 reports pickup #n signal failure**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	Pick-up (1, 2, 3)	red	fast blinking
Cause:	A signal failure has occurred, the signal sequence ’A’, ’B’, ’C’ is incorrect The reason could be that one pickup signal is missing, or the pickups are not correctly mounted ***Remark:*** Also, passive failure ’ME crank angle #2 failure’ shows			
Fault finding, remedies:	– Do a check of the pickup set #2 (ST5134C/A2, ST5135C/B2, ST5136C/C2) – Turn the engine clockwise with the turning gear and make sure that the pickup signal sequence is correct – Open control box E96.2 and check the sequence on ACM−20 module directly ***Remark:*** The sequence must be ’A’, ’B’, ’C’ – Check the distance between pickup tip and gear wheel tooth			
Failure text	**ACM #1 reports no reference signal, REF1 failure**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	Pick-up (REF)	red	fast blinking
Cause:	No reference signal found (Failure is triggered after 5 turns without reference signal) ***Remark:*** Also passive failure ’ME crank angle #1 failure’ appears			
Fault finding, remedies:	– Do a check of the pickup ZS5124C/REF1 and related signal input on ACM−20 module #1 in E96.1			
Failure text	**ACM #1 reports no reference signal, REF2 failure**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	Pick-up (REF)	red	fast blinking
Cause:	No reference signal found (Failure is triggered after 5 turns without a reference signal) ***Remark:*** Also, passive failure ’ME crank angle #1 failure’ appears			
Fault finding, remedies:	– Do a check of the pickup ZS5125C/REF2 and related signal input on ACM−20 module #2 in E96.2			
Failure text	**ACM #1 reports reference signal at wrong position**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	Pick-up (REF)	red	fast blinking
Cause:	Signal failure Reference signal is shown in accordance with calculation by ACM−20 module #1 at incorrect position ***Remark:*** Also, passive failure ’ME crank angle #1 failure’ appears			
Fault finding, remedies:	– Do a check of the pickup ZS5124C/REF1 and related signal input on ACM−20 module #1 in E96.1 – Possible reference mark damage – Pickup not correctly adjusted – The recommended clearance between pickup and reference mark is not correct – Mixing of TDC and BDC signals / wirings (ZS5124C/REF1 and ZS5125C/REF2) – Is the parameter number of teeth on gear wheel incorrectly set in WECS−9520?			

Failure text	ACM #2 reports reference signal at wrong position		
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	Pick-up (REF)	red	fast blinking
Cause:	Signal failure Reference signal is shown in accordance with calculation by ACM−20 module #2 at incorrect position ***Remark:*** Also, passive failure ’ME crank angle #2 failure’ shows			
Fault finding, remedies:	– Do a check of the pickup ZS5125C/REF1 and related signal input on ACM−20 module #2 in E96.2 – Possible reference mark damage – Pickup not correctly adjusted – The recommended clearance between pickup and reference mark is not correct – Mixing of TDC and BDC signals / wiring (ZS5124C/REF1 and ZS5125C/REF2) – Is the parameter number of teeth on gear wheel incorrectly set in WECS−9520?			
Failure text	**ACM #1 reports pickup #n disconnected**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	Pick-up (1, 2, 3)	red	none
Cause:	No pickup is connected The electric current of the related pickup is below the threshold of 1mA			
Fault finding, remedies:	– Do a check of the wiring of pickup set #1 (ST5131C/A1, ST5132C/B1, ST5133/C1, ZS5124C/REF1) – If wiring is serviceable, replace the related pickup			
Failure text	**ACM #2 reports pickup #n disconnected**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	Pick-up (1, 2, 3)	red	none
Cause:	No pickup is connected The electric current of the related pickup is below the threshold of 1mA			
Fault finding, remedies:	– Do a check of the wiring of pickup set #2 (ST5134C/A2, ST5135C/B2, ST5136/C2, ZS5125C/REF2) – If wiring is serviceable, replace the related pickup			
Failure text	**ACM #1 reports short circuit on pickup #n**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	Pick-up (1, 2, 3)	red	single flash
Cause:	A short circuit on the related pickup The electric current of this line is above 100mA			
Fault finding, remedies:	– Do a check of the wiring of pickup set #1 (ST5131C/A1, ST5132C/B1, ST5133/C1, ZS5124C/REF1) – If wiring is serviceable, replace the related pickup			

Failure text	ACM #2 reports short circuit on pickup #n			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	Pick-up (1, 2, 3)	red	single flash
Cause:	A short circuit on the related pickup The electric current of this line is more than 100mA			
Fault finding, remedies:	– Do a check of the wiring of pickup set #2 (ST5134C/A2, ST5134C/B2, ST5136/C2, ZS5125C/REF2) – If wiring is serviceable, replace the related pickup			
Failure text	**ACM #1 reports power supply out of range**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	Power	green	off
Cause:	Power supply is below 15 volts ***Remark:*** The specified minimum supply voltage is 18 volts			
Fault finding, remedies:	– Measure the voltage at ACM−20 module #1 – Do a check of the power supply line between FCM−20 module #04 and ACM−20 module #1 – Re-establish the power supply line			
Failure text	**ACM #2 reports power supply out of range**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	Power	green	off
Cause:	Power supply is below 15 volts ***Remark:*** The specified minimum supply voltage is 18 volts			
Fault finding, remedies:	– Measure the voltage at ACM−20 module #2 – Do a check of the power supply line between FCM−20 module #05 and ACM−20 module #2 – Re-establish power supply line			
Failure text	**ACM #1 reports temperature out of range**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	none	none	none
Cause:	The ambient temperature is above the specified range ***Remark:*** ACM−20 unit #1 reports that the circuit board temperature is above 70°C			
Fault finding, remedies:	– This is possible during very high ambient conditions			
Failure text	**ACM #2 reports temperature out of range**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	none	none	none
Cause:	The ambient temperature is above the specified range ***Remark:*** ACM−20 unit #2 reports that the circuit board temperature is above 70°C			
Fault finding, remedies:	– This is possible during very high ambient conditions only			

Failure text	ACM #1 reports that the automatic calibration process is running		
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	none	none	none
Cause:	The auto calibration process must be done during commissioning The procedure determines the offsets between the pickups ST5131C/A1, ST5132C/B1, ST5133C/C1, ZS5124C/REF1 ***Remark:*** The data found are the basis for the crank angle measuring system. The message is released when the automatic calibration is being executed			
Failure text	**ACM #2 reports that the automatic calibration process is running**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	none	none	none
Cause:	The auto calibration process must be done during commissioning The procedure determines the offsets between the pickups ST5134C/A2, ST5135C/B2, ST5136C/C2, ZS5125C/REF2 ***Remark:*** The data found are the basis for the crank angle measuring system. The message is released when the automatic calibration is being executed			
Failure text	**Both crank angle sensors (CA#1, CA#2) are not determined**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1 and #2	Module Fail	Red	None
Cause:	The crank angle from set #1 and #2 are not known The ACM−20 module #1 and #2 has lost the absolute crank angle information ***Remark:*** This happens after black-out of the system or after software reset. No actions are required			
Fault finding, remedies:	***Remark:*** The Message will disappear during engine start or if the engine is turned with turning gear. When the related reference flag (REF1/ZS5124C) and (REF2/ZS5125C) has passed, the message will disappear.			
Failure text	**CA #1 and CA #2 run in the opposite direction**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1 and #2	Pick-up (1, 2, 3)	red	fast blinking
Cause:	The rotational direction of CA #1 and CA #2 does not correspond One channel runs clockwise while the other channel runs counterclockwise ***Remark:*** Also critical failure 'ME crank angle #1 + #2 failure' comes up			
Fault finding, remedies:	− Turn the engine clockwise with the turning gear and make sure that the pickup signal sequence is correct − Open control box E96.1 and E96.2 and check the sequence on ACM−20 modules directly ***Remark:*** The sequence must be 'A', 'B', 'C' on each channel − Do a check of the distance between pickup tip and gear wheel tooth			

Failure text	CAN M bus ACM #1 failure			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	CAN M	red	none
Cause:	No heartbeat from ACM−20 module #1 in E96.1 CAN-M bus line is interrupted or disturbed ***Remark:*** Failure does not cut off the crank angle data flow from ACM−20 to WECS−9520 Also, passive failure 'FCM #4 CAN-M bus failure' shows			
Fault finding, remedies:	– Do a check of the bus line wiring from FCM−20 module #04 in E95.4 to ACM−20 module #1 in E96.1 and the bus termination (resistor 120 ohm) – Make sure that the wiring line and connections between FCM−20 module #04 and ACM−20 module #1 are correct – If wiring is serviceable replace ACM−20 module			
Failure text	**CAN M bus ACM #2 failure**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	CAN M	red	none
Cause:	No heartbeat from ACM−20 module #2 in E96.2 CAN-M bus line is interrupted or disturbed ***Remark:*** Failure does not cut off the crank angle data flow from ACM−20 to WECS−9520 Also, passive failure 'FCM #5 CAN-M bus failure' shows			
Fault finding, remedies:	– Do a check of the bus line wiring from FCM−20 module #05 in E95.5 to ACM−20 module #2 in E96.2 and the bus termination (resistor 120 ohm) – Make sure that the wiring line and connections between FCM−20 module #05 and ACM−20 module #2 are correct – If wiring is serviceable replace ACM−20 module			
Failure text	**CAN M bus ACM #1 failure**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#1	CAN M	red	none
Cause:	Message on flexView - ACM−20 #1 contains incorrect boot loader software The ACM−20 #1 in E96.1 has the incorrect boot loader software. Replace the module, or download the latest boot loader software. ***Remark:*** For WECS−9520 SW034 build 107 or higher, the new boot loader is necessary. This makes sure that the functions that automatically download data to the ACM−20 module operate correctly.			
Fault finding, remedies:	– Use the dedicated PC tool to do the software update (boot loader exchange)			
Failure text	**CAN M bus ACM #2 failure**			
Failure LED:	**ACM−20 No.**	**LED**		**Blink intervals**
	#2	CAN M	red	none
Cause:	Message on flexView - ACM−20 #1 contains incorrect boot loader software The ACM−20 #2 in E96.1 has the incorrect boot loader software. Replace the module, or download the latest boot loader software. ***Remark:*** For WECS−9520 SW034 build 107 or higher, the new boot loader is necessary. This makes sure that the functions that automatically download data to the ACM−20 module operate correctly.			
Fault finding, remedies:	– Use the dedicated PC tool to do the software update (boot loader exchange)			

Bedplate and Tie Rod — Group 1

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1. General

The main bearing has a lower bearing shell 2 and an upper bearing shell 3. White metal ’WM’ lines the running surfaces of these bearing shells.

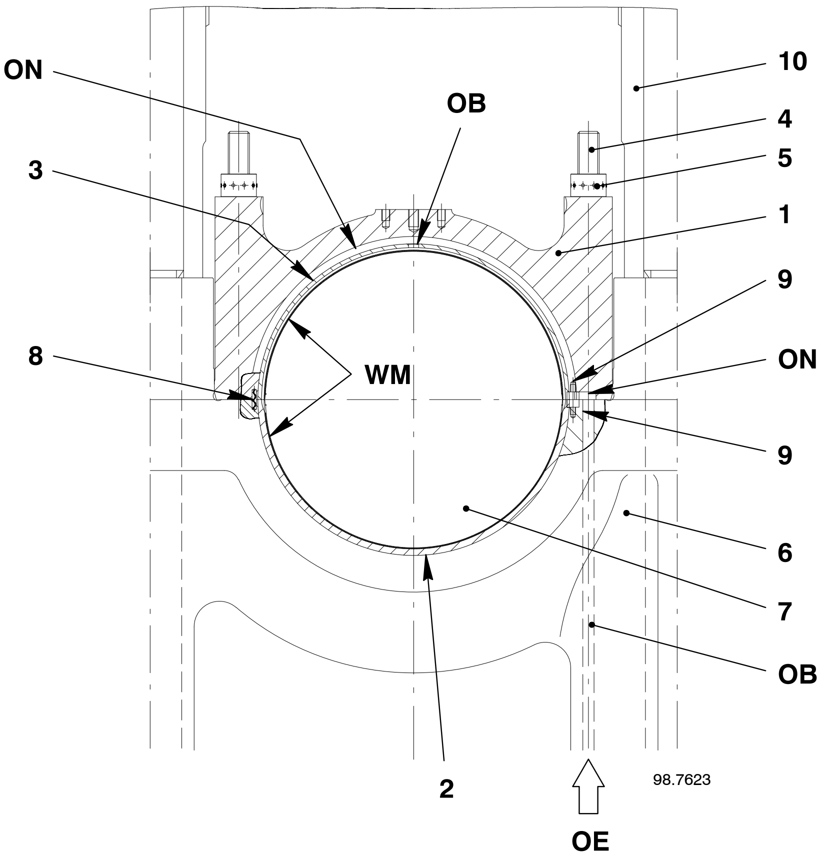
The lower main bearing shell 2 is placed into the bearing girder 6 of the bedplate. The upper main bearing shell 3 is placed in the bearing cover 1. The spring dowel pins 8 help to get the upper and lower main bearing shells in position.

The screws 9 attach the upper main bearing shell 3 to the bearing cover 1 and the lower main bearing to the bearing girder 6.

A non-hardening locking compound is applied to the elastic studs 4. Hydraulic pretension is applied to the elastic studs 4, then the round nuts are tightened to hold the bearing cover against the bearing girder 6.

2. Lubrication

Oil from the bedplate side ’OE’ supplies the main bearings with oil. The oil flows to the bearing running surface through grooves ’ON’ and bores ’OB’.



Key:

1 Bearing cover
2 Lower main bearing shell
3 Upper main bearing shell
4 Elastic stud
5 Round nut
6 Bearing girder
7 Crankshaft
8 Spring dowel pin
9 Screw
10 Column

OB Bore
OE Oil inlet, bedplate side
ON Groove
WM White metal

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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 the thrust bearing flange 'DF' on the crankshaft through the thrust pads into bedplate 9.

The retaining clips 11 keep the thrust pads in position.

Depending on the direction of rotation of the crankshaft or propeller, thrust pads 2 or 3 take up the axial thrust forces.

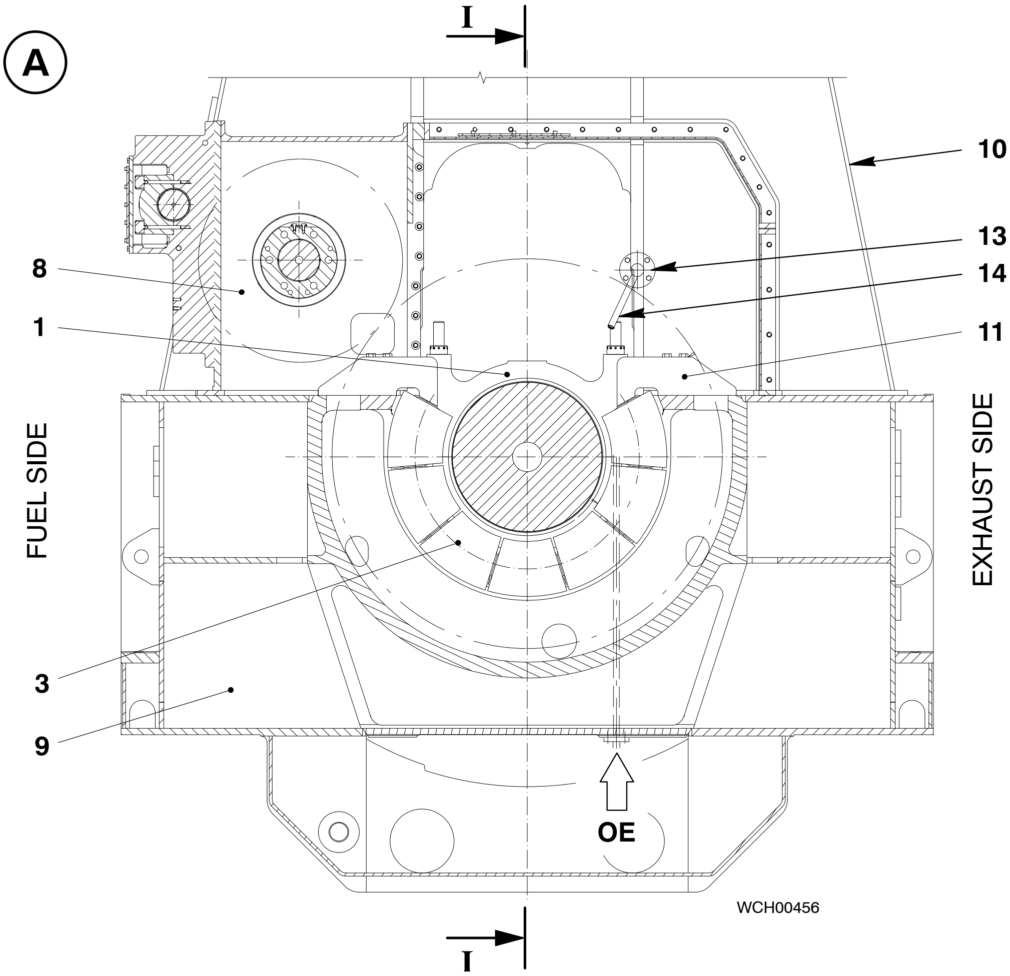
In fixed pitch propeller plants: clockwise and counterclockwise rotating engines have seven thrust pads each side of the thrust bearing flange. Each set of seven thrust pads is related to the rotation direction.

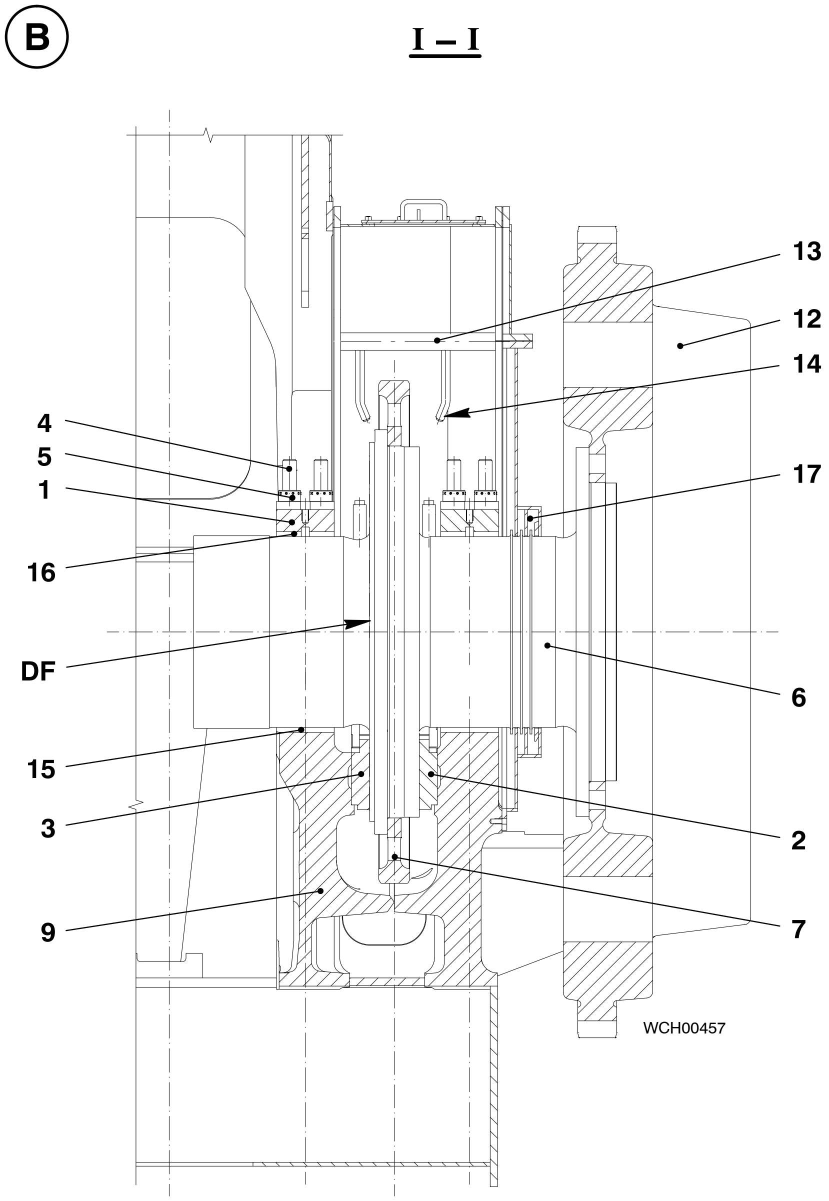
In controllable pitch propeller plants: the thrust bearing has seven thrust pads of two different variants installed on the driving end for clockwise or counterclockwise rotating engines.

The gear wheel 7 on the crankshaft 6 is mounted on the thrust bearing flange 'DF'. The gear wheel 7 drives the intermediate wheel for the supply unit 8.

2. Lubrication

During operation, bearing oil flows through the oil pipe 13 to the two spray nozzles 14. The spray nozzles 14 lubricate the thrust pads 2 and 3 with an oil mist. The oil mist forms a hydraulic wedge between the thrust bearing flange 'DF' and the thrust pads.





Key to Illustrations: 'A' Longitudinal section
'B' Cross section

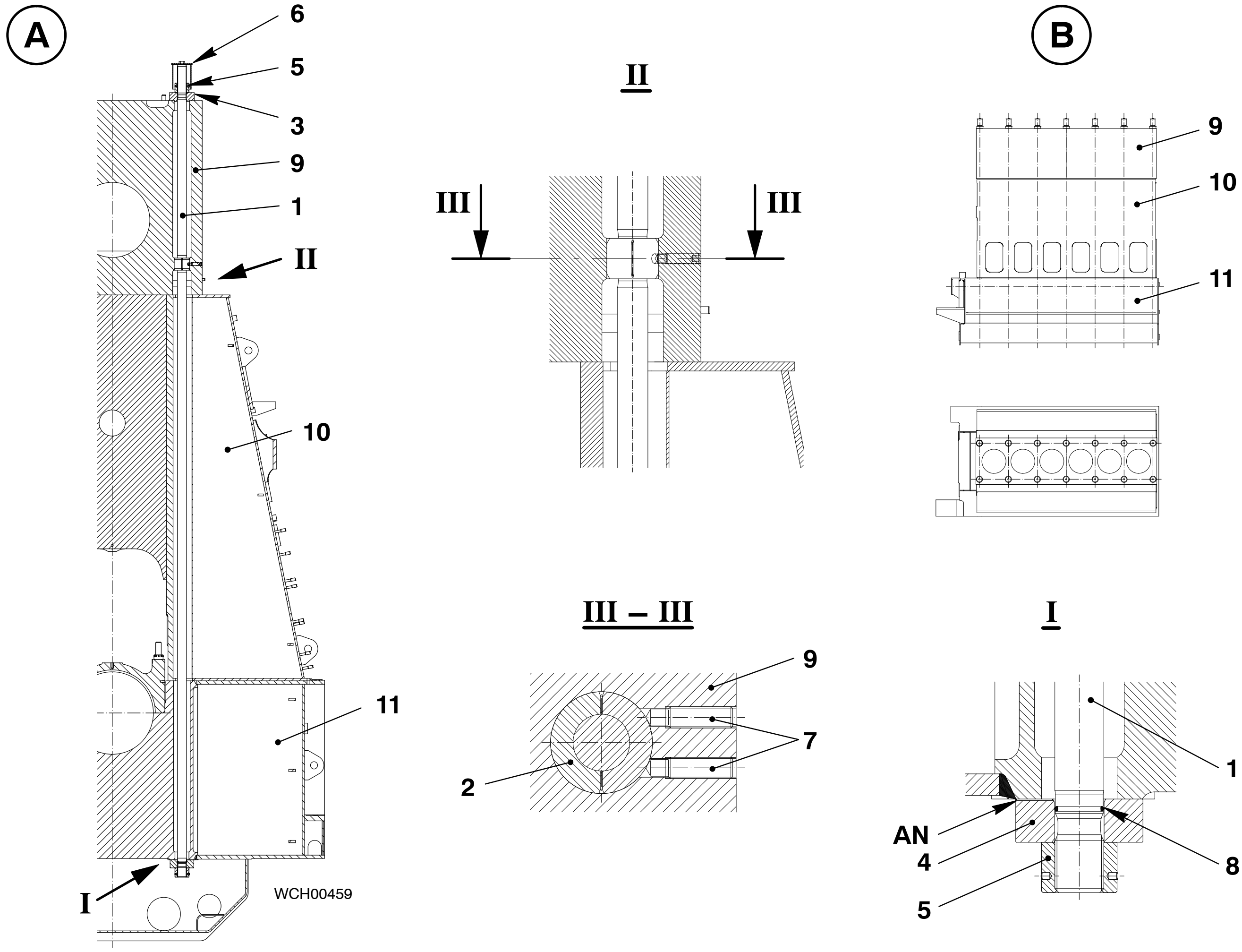
1	Bearing cover	12	Flywheel
2	Thrust pads to driving end	13	Oil pipe
3	Thrust pads to free end	14	Spray nozzle
4	Elastic stud for bearing cover	15	Lower main bearing shell
5	Round nut	16	Upper main bearing shell
6	Crankshaft	17	Two-part oil baffle
7	Gear wheel		
8	Intermediate wheel for supply unit		
9	Bedplate		
10	Column	DF	Thrust bearing flange
11	Retaining clip	OE	Bearing oil inlet

1. General

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

Each tie rod has a two-part bush 2 located at the bottom of the cylinder block 9. The two set screws 7 firmly fasten the two-part bush (see detail II). The two-part bushes 2 prevent tie rod vibration. For additional vibration damping, the space around the lower part of the tie rod up to mid-column is filled with oil. The oil enters through a filling bore in the crosshead guide plate.

The lower thread (detail I) of the intermediate ring has a drain groove 'AN'. Some of the oil and possible condensate water can drain through the drain groove 'AN'. (when the engine is at standstill).



Key to Illustrations: **'A' Tie rod**
'B' Tie rod arrangement (6 cylinder engine)

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

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Cylinder Liner and Cylinder Cover Group 2

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1. General

The cylinder liner 1 is installed in the cylinder block 4 with supporting ring 2. The nuts of the elastic studs attach the cylinder cover 6, the cylinder liner 1 and the supporting ring 2 to the cylinder block 4. The three screws 8 also attach the supporting ring 2 to the cylinder block 4. This makes sure that the supporting ring 2 stays attached to the cylinder block 4 when the cylinder liner 1 is removed.

2. Cooling

The cooling water enters the water space 'WR' through the cooling water inlet 'KE'. The cooling water flows through the water space 'WR' to the cooling bores 'KB', then through the horizontal bores into the water guide jacket 3. The cooling water flows through the vertical bores in the water guide jacket 3 into the annular space 'RR'. This cools the cylinder cover 6 and the exhaust valve cage.

The insulating band 11 attached to the cylinder liner 1, keeps the wall temperature of the cylinder liner at an optimum temperature.

The antipolishing ring 12 installed on the cylinder liner 1, removes heavy coke deposits from the piston crown during operation.

Remark: The automatic cooling water temperature control keeps the cooling water as steady as possible at a constant temperature during all load conditions. This prevents too much expansion and contraction of the top part of the cylinder liners. The maximum permitted temperature fluctuations are:

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

The O-ring 9 prevents cooling water leakage from the water space 'WR' into the the annular space 'RR_1'. The O-ring 10 prevents a possible cooling water leak from the water space 'WR' into the the scavenge air space 'SR'. If cooling water leaks through the check bore 'KC', or there is water in the scavenge space 'SR', the O-rings 9, 10 must be replaced at the next opportunity.

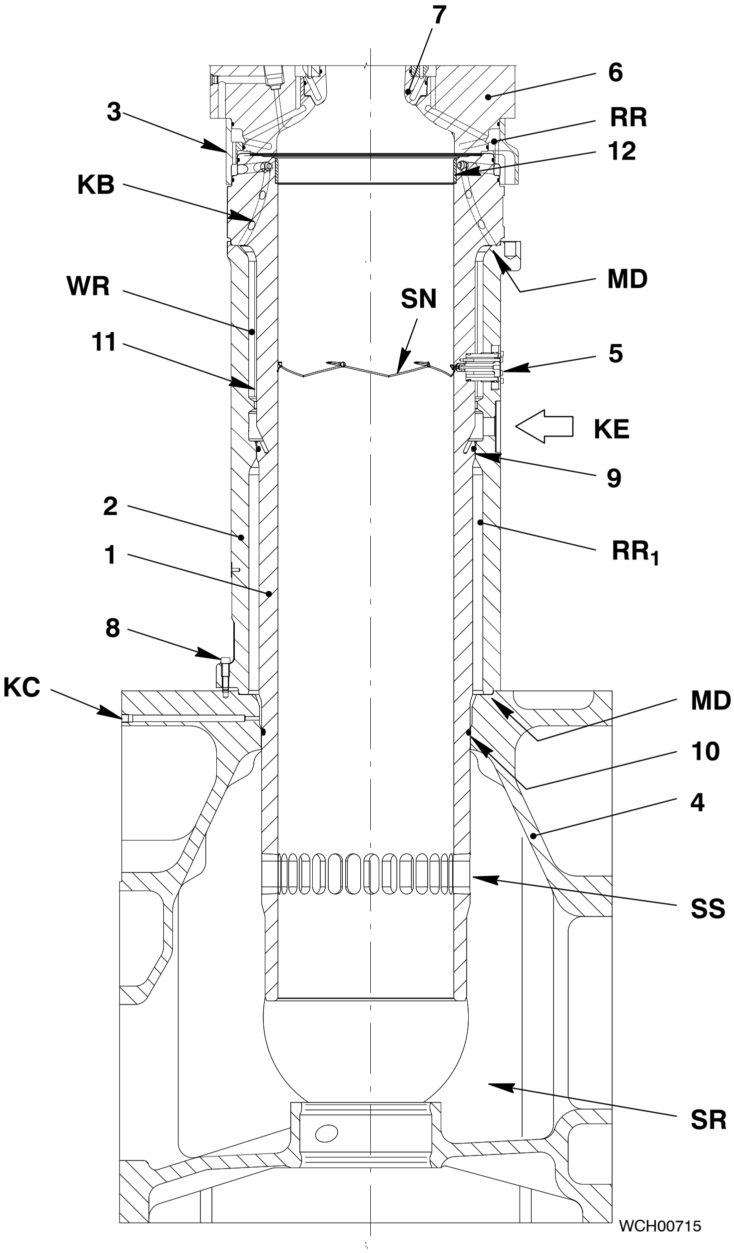
A non-hardening compound seals the two metallic sealing surfaces 'MD' between the supporting ring 2, the cylinder liner 1 and the cylinder block 4.

3. Lubrication

Cylinder lubricating oil flows through six lubricating quills 5 to the running surface of the cylinder liner. The row of lubrication grooves 'SN', milled around the circumference of the running surface of the cylinder liner 1, makes sure that lubricating oil is equally distributed (see Lubricating Quill 2138–1).

The arrangement and function of the pulse lubrication is described in 7218–1.

Cylinder Liner



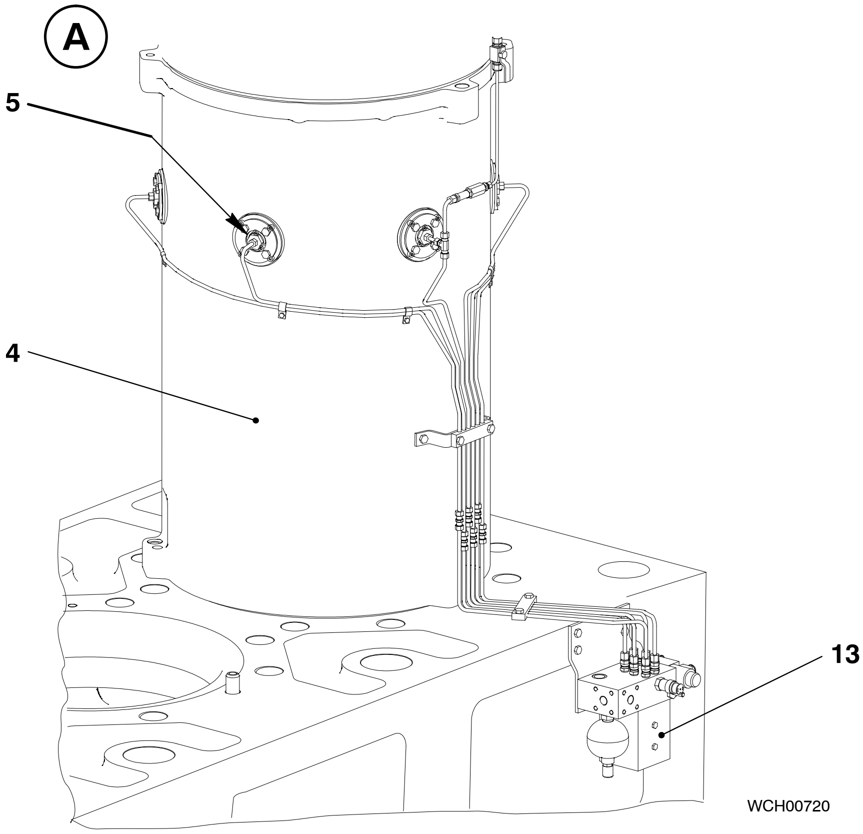
Key:

1	Cylinder liner	KB	Cooling bores in the cylinder liner
2	Supporting ring	KC	Check bore
3	Water guide jacket	KE	Cooling water inlet
4	Cylinder block	MD	Metallic sealing
5	Lubricating quill	RR	Annular space
6	Cylinder cover	RR_1	Annular space void of water
7	Valve seat for exhaust valve	SN	Row of lubricating grooves
8	Screw	SR	Scavenge space (piston underside)
9	O-ring	SS	Scavenge ports
10	O-ring	WR	Water space
11	Insulating band		
12	Antipolishing ring		

1. General

Three screws 12 attach each of the six the lubricating quills 5 around the circumference of the cylinder liner 4.

The bush 6 and the flange 10 seal the water space ’WR’ (Fig. ’B’).

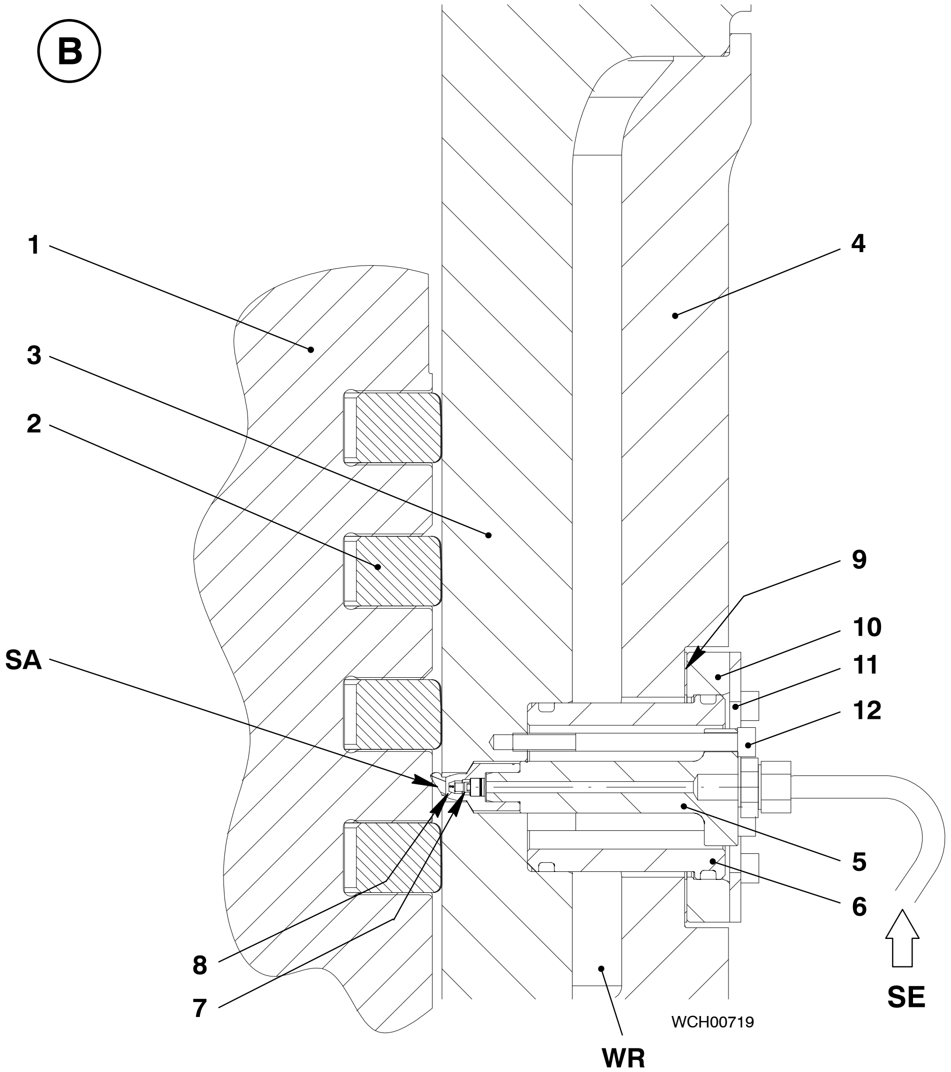


2. Function

The lubricating pump 13, delivers high-pressure oil at a pre-set feed rate through the lubricating oil inlet ’SE’ into the lubricating quills 5. The non-return valve 7 opens and lubricating oil is injected through the nozzle tip 8 into the grooves and equally distributed on the cylinder liner wall (see also Cylinder Liner 2124−1 and Cylinder Lubrication 7218−1).

After delivery of the lubricating oil, the oil pressure decreases and spring pressure closes the non-return valve 7.

Lubricating Quills on Cylinder Liner

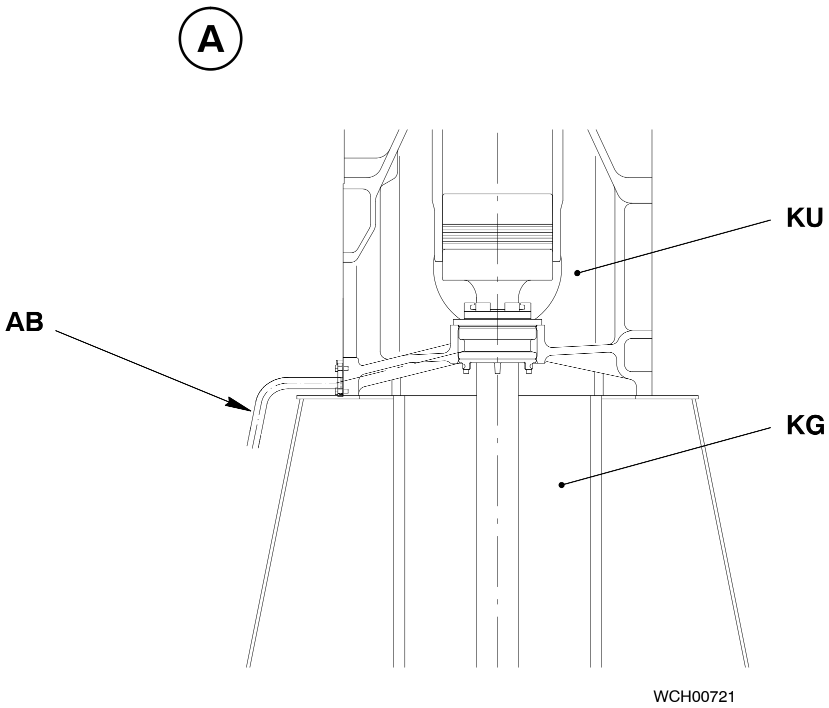


Key to Illustrations: **'A' Arrangement of lubricating quills**
'B' Lubricating quill

1	Piston	10	Flange
2	Piston ring	11	Flange
3	Cylinder liner	12	Screw
4	Supporting ring	13	Lubricating pump
5	Lubricating quill		
6	Bush		
7	Non-return valve	SA	Lubricating point in cylinder liner
8	Nozzle tip	SE	Lubricating oil inlet
9	Seal	WR	Water space

1. General

The piston rod gland prevents contamination of the bearing oil from combustion residue. The piston rod gland also seals the scavenge space 'KU' from the crankcase 'KG' (see Fig. 'A').



2. Function

The three scraper rings 3 remove dirty oil from the piston rod 10 (see Fig. 'B'). This dirty oil flows through the oil bores 'OB', to the bottom of the scavenge space 'KU'. The dirty oil is then discharged through the drain on the fuel side.

Attention! The dirty oil drain from the 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 gaskets 6 and 6a prevent the escape of scavenge air into the crankcase. The low air pressure caused by gap losses is released through a vent in the plant.

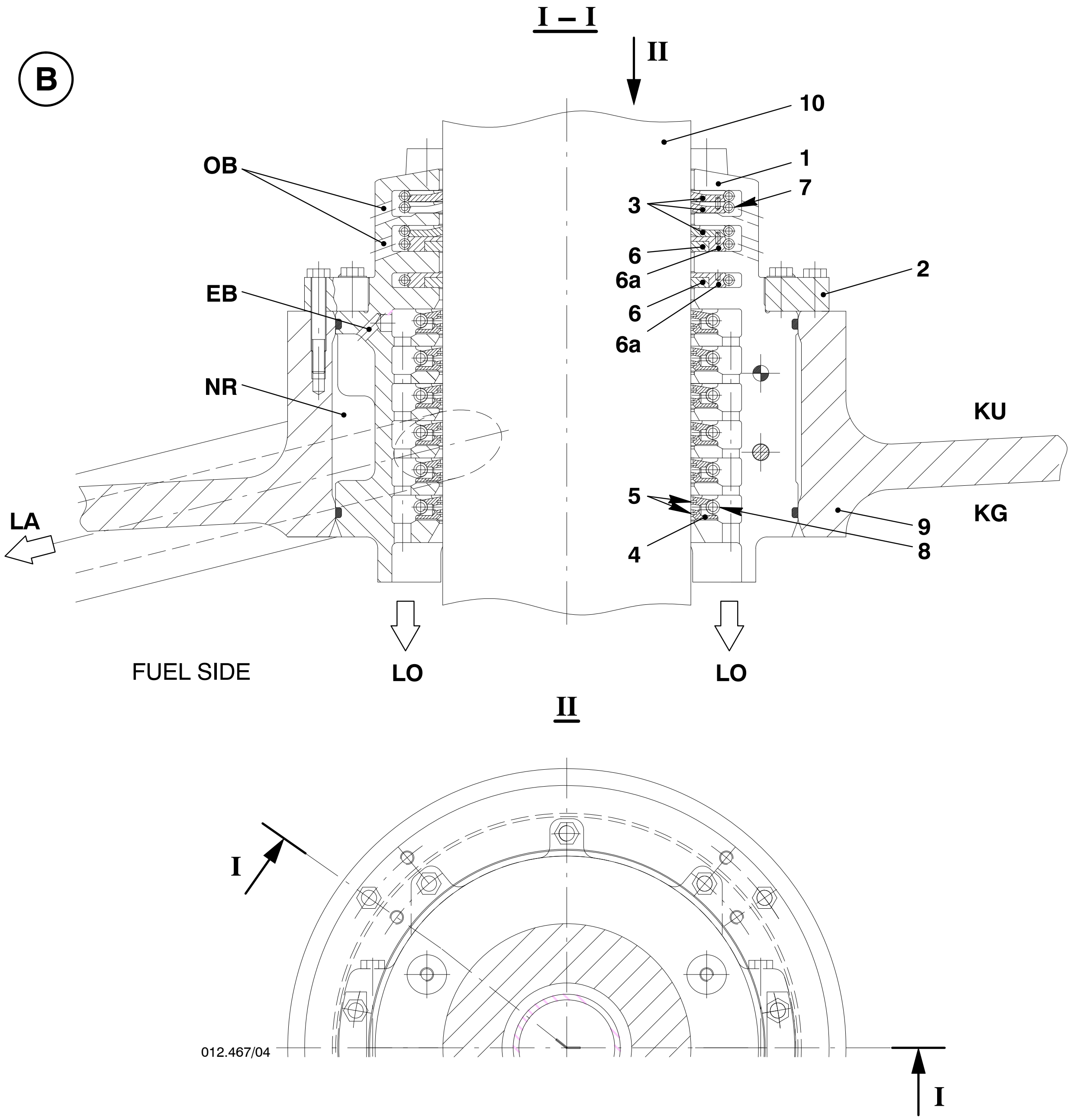
Oil that accumulates through relief bores 'EB' in the neutral space 'NR' flows back through the oil leakage drain 'LA' and the oil leakage pipe 'AB' (see Fig. 'A' and 'B').

Remark: An increase in the quantity of oil from the oil drain is a symptom of worn or damaged gaskets 6 and 6a.

Each of the six ring supports 4 has two scraper rings 5. The scraper rings 5 remove the bearing oil from the piston rod 10. The bearing oil flows back to the crankcase 'KU' through the bearing oil drain 'LO'.

The tension springs 7 and 8 keep all ring types against the piston rod.

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	Ring (2-part)	EB	Relief bore
3	Scraper ring (4-part)	KG	Crankcase
4	Ring support (3-part)	KU	Scavenge space (piston underside)
5	Scraper ring (3-part)	LA	Oil leakage drain
6, 6a	Gasket (4-part)		(air pressure relief from 'NR')
7	Tension spring	LO	Bearing oil drain
8	Tension spring	NR	Neutral space
9	Cylinder block	OB	Oil bore
10	Piston rod		

1. General

Two injection valves 1 are installed in each cylinder cover.

Fuel, which leaks due to the needle clearance, drains through the leakage fuel drain ’LA’ to the leakage fuel pipe 13. The leaked fuel then goes from the leakage fuel pipe 13 to the fuel return pipe 3.48 back to plant (see Fig. ’B’ and Fuel Oil System 8019–1).

Fuel, which can leak between the nozzle body 3 and nozzle holder 2, rises and appears at the upper edge of the cylinder cover at the leakage fuel outlet ’LB’.

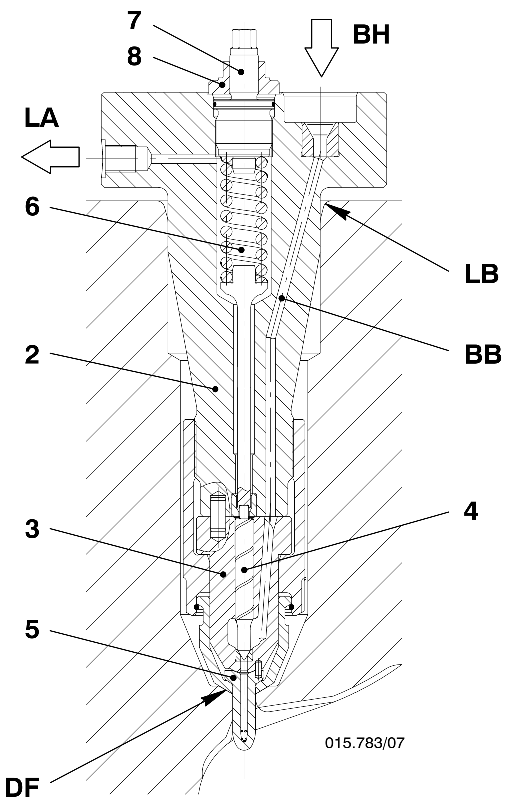
Remark: If fuel leaks between the nozzle body 3 and the nozzle holder 2, overhaul these parts at the next opportunity. If the sealing face ’DF’ leaks, exhaust gas flows through the leakage fuel outlet ’LB’.

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

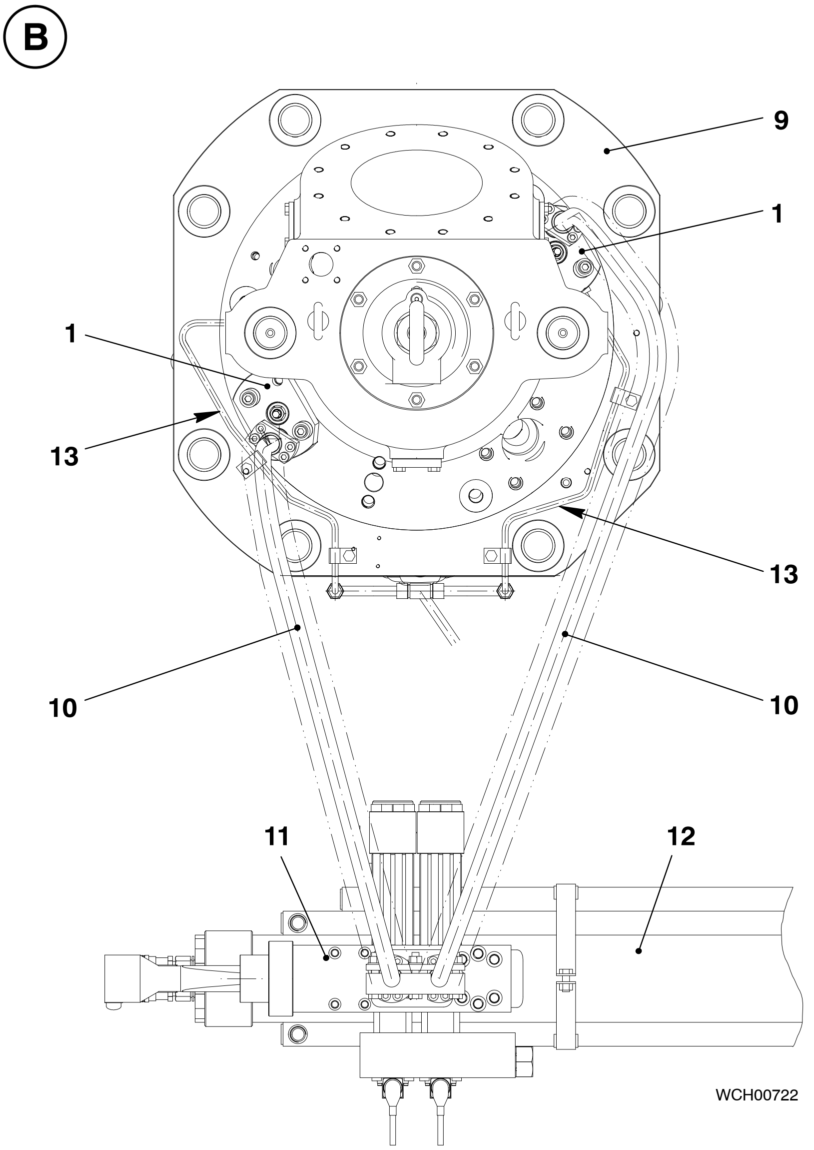
2. Function

The injection control unit 11 supplies fuel at high pressure to the two injection valves 1. The required fuel quantity for injection flows through fuel feed ’BH’ and the fuel bore ’BB’ to the nozzle body 3. The pressure of the fuel lifts the needle 4 against the compression spring 6 and fuel is injected and equally sprayed into the combustion chamber. When the fuel pressure decreases, the compression spring 6 pushes the needle 4 down and the fuel injection stops.

A



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	Leakage fuel pipe 3.49
4	Needle		
5	Nozzle tip		
6	Compression spring	BB	Fuel bore
7	Spring tensioner	BH	Fuel feed (high pressure)
8	Collar nut	DF	Sealing face
9	Cylinder cover	LA	Leakage fuel drain
10	Injection pipe 3.47	LB	Leakage fuel outlet (gap)

1. General

Each cylinder cover has a starting valve. The function of the starting valve is to start the engine, slow the engine down and reverse the direction of rotation of the engine. An FCM−20 module controls each starting valve electronically. At a given piston position, starting air enters the cylinder during the slow-down or reversing procedures (see also Maneuvering 0260−1).

The parameter settings, i.e. opening and closing of the starting valve relative to the crank position, are adjusted in the remote control (WECS−9520).

In the schematic diagram 4003−2, the number 2.07 identifies the starting valve.

2. Function

Ready for operation:

The starting air bore ’AL’ is pressurized with starting air pressure, which flows through the bores ’EB’ to pressurize the air space ’P_3’. This helps the compression spring 5 close the starting valve. The control air connection ’SL’ is pressurized from the starting air piping. Control air flows to the space ’P_2’ through the 5/2 way solenoid valve 8. The starting valve is closed.

Starting:

The FCM−20 module controls the 5/2-way solenoid valve 8. Space ’P_1’ pressurizes and space ’P_2’ vents. The pressure in space ’P_1’ moves the valve spindle 6 down against the compression spring 5 and the starting valve opens. Starting air then flows into the cylinder space from from the starting air bore ’AL’. The piston moves downwards and the engine begins to turn.

When the engine begins firing, the higher pressure (firing pressure) in the cylinder space closes the starting valve. The starting valve remains closed during the high pressure phase.

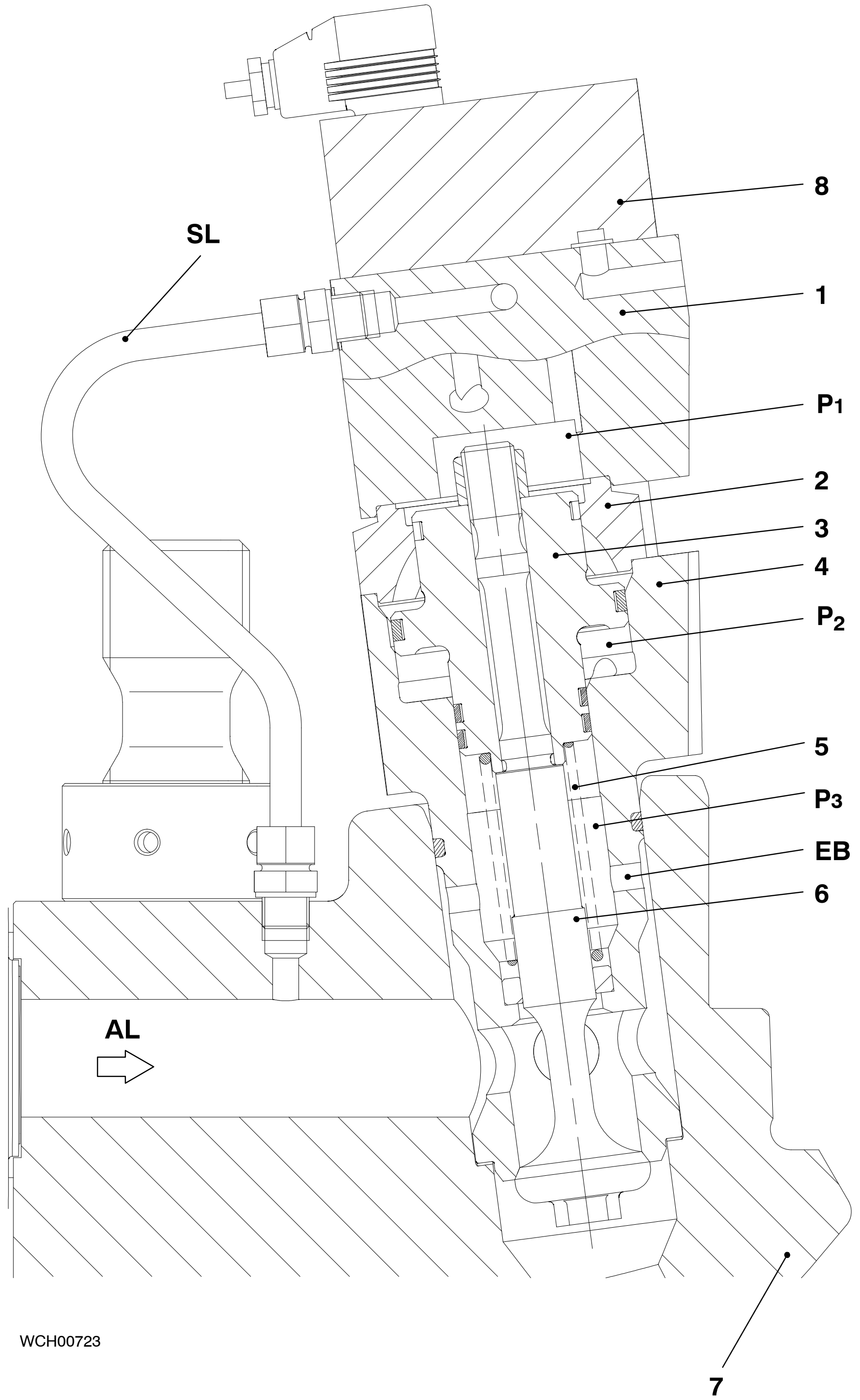
Slow-down of the engine for reversing:

The engine reversing procedure must be delayed until the engine speed falls below the set limit to prevent too much drag on the engine from the propeller. This can take several minutes. When the engine speed falls below the set limit, the engine control system operates the starting valve to release starting air / braking air into the cylinder space.

During the engine reversing procedure (when the ship is still in motion), the force of the water acts on the propeller and ’drags’ the engine in the wrong direction of rotation.

When the piston is approximately 100° before TDC, the starting valve opens and starting air enters the cylinder space. The piston compresses the air and the engine stops (is braked). The engine is then started in the new direction of rotation.

Starting Valve



Key:

1 Cover
2 Ring
3 Piston
4 Housing
5 Compression spring
6 Valve spindle
7 Cylinder cover
8 5/2-way solenoid valve

AL Starting air bore
EB Connecting bore
P_1–P_3 Air spaces
SL Control air connection (from starting air piping)

1. General

The exhaust valve is installed in the centre of the cylinder cover 19 (see Fig. ’A’). The exhaust valve has the parts that follow: Upper housing 3, lower housing 2, valve cage 1, valve spindle 6 and valve seat 18. The air spring ’LF’ is below the air spring piston 10 (see Fig. ’B’).

The valve stroke sensor 17 monitors and transmits the open and closed positions of the valve spindle 6 to the WECS−9520 engine control system.

If the balance of the valve opening and the force of the air spring is disturbed, damage can occur to the exhaust valve. For safety reasons, the cup springs 14 are installed to prevent damage to the exhaust valve.

The thrust piece 20 prevents damage to the inside piston 5 and the top of the valve spindle 6 when the exhaust valve operates.

Remark: The engine cannot be started if the exhaust valves are not fully closed. The air spring must have an air supply and the exhaust valves must be closed before the lubricating oil pump and the servo-oil service pump are switched on.

2. Function

Opening:

When the piston in the exhaust valve control unit operates, hydraulic oil ’HO’ flows through the hydraulic oil connection 12 into the upper housing 3. The inside piston 5 and the outside piston 4 move down. The air spring piston 10, which is attached to the valve spindle 6, moves down against the pressure in the air spring ’LF’ and the exhaust valve opens. The force of the exhaust gas on the rotation wing 15 turns the valve spindle 6.

Closing:

When the hydraulic oil pressure from the exhaust valve control unit decreases (i.e. when the slide rod in the exhaust valve control unit opens the related relief passages), the air spring ’LF’ pushes the air spring piston 10 up. The valve spindle 6 then pushes the outside piston 4 and the inside piston 5 up and the exhaust valve closes. The hydraulic oil in the upper housing 3 flows back to the exhaust valve control unit.

2.1 **Venting of hydraulic system** (see Fig. ’B’ and ’D’)

Hydraulic oil and air in the system flow continuously from the upper housing 3 and the outside and inside pistons 4, 5 into the leakage oil collection space ’LS’. This leakage oil / air then drains through the leakage oil drain ’LO’. The hydraulic oil that flows through the internal bores of the valve control unit continuously makes up the oil loss to the hydraulic system.

2.2 **Air supply to air spring** (see Fig. ’D’)

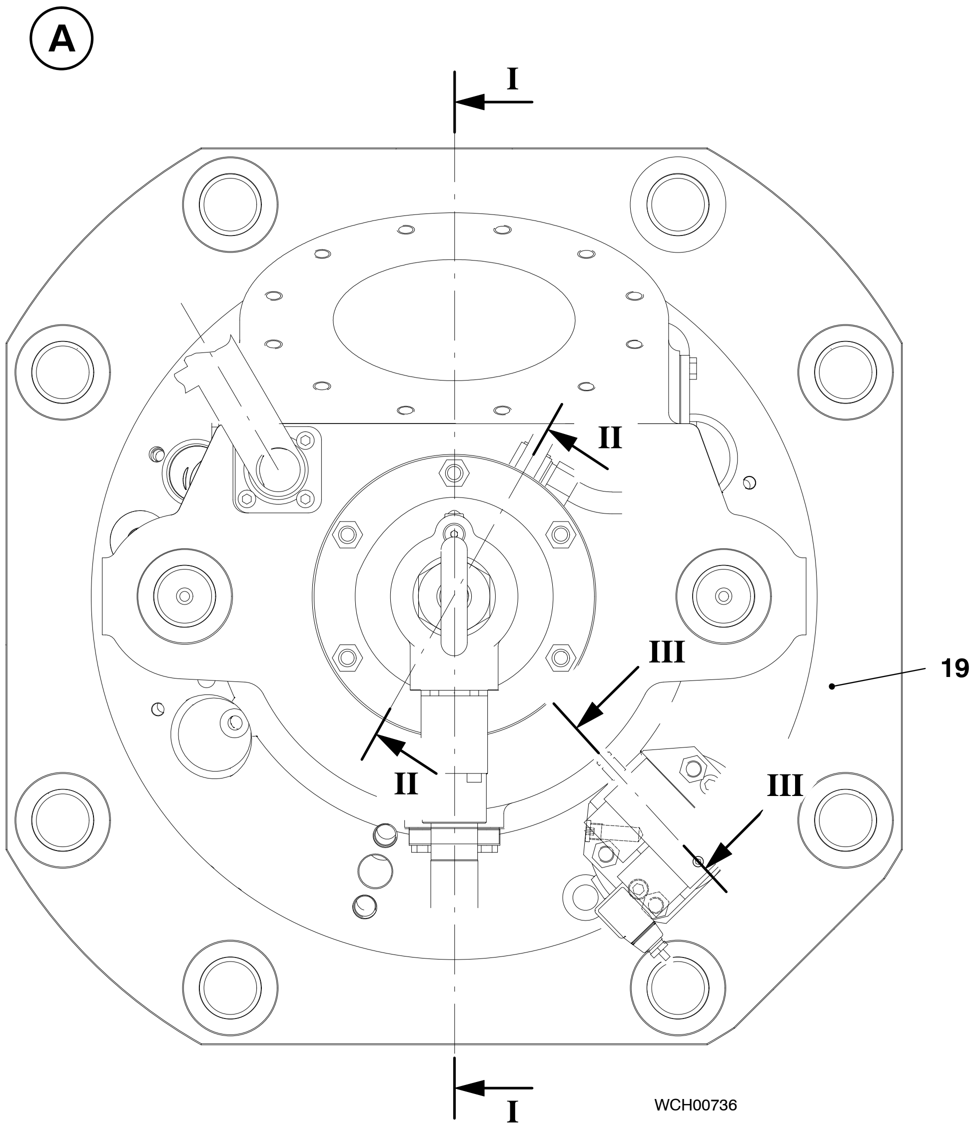
Compressed air enters the air inlet connection ’LE’ and flows through the non-return valve 16 to the inlet bore ’EB’. The compressed air then enters the air spring ’LF’. When the exhaust valve opens, the air spring piston 10 moves downwards, which compresses the air in the air spring ’LF’. Some of the compressed air flows back through inlet bore ’EB’. After the exhaust valve closes, compressed air flows into the air spring ’LF’ again.

3. Lubrication (see Fig. 'B' to 'D')

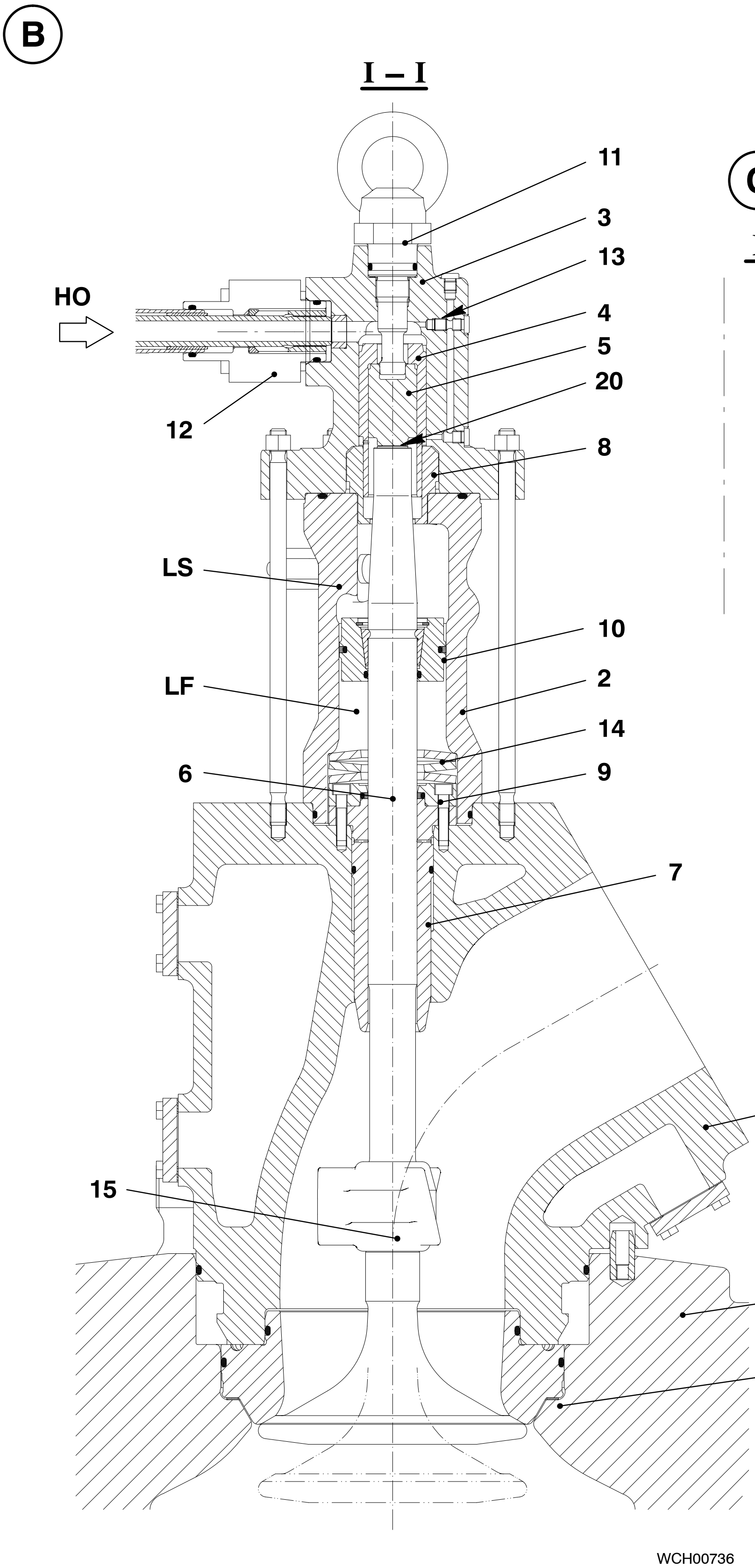
Leak oil from the outside and inside pistons 4, 5 lubricates the air spring piston 10. Surplus oil in the leakage oil collection space 'LS' drains to the leakage oil drain 'LO'. When the exhaust valve closes, oil flows through the air spring piston 10 and enters the air spring 'LF'. The air from the air inlet 'LE' turns the oil that accumulates at the bottom of the air spring 'LF' (inlet bore 'EB') into an oil mist. This oil mist lubricates the top part of the valve spindle 6. When the exhaust valve opens, excess oil is forced out of the air spring 'LF' and flows through the air spring pipe to an accumulator. The oil in the accumulator automatically drains through the leakage oil pipe at the driving end and into the crankcase.

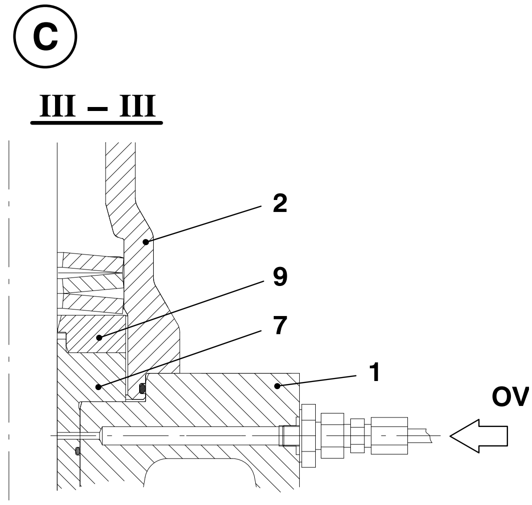
Oil from the oil bath 'OB' lubricates the valve spindle 6.

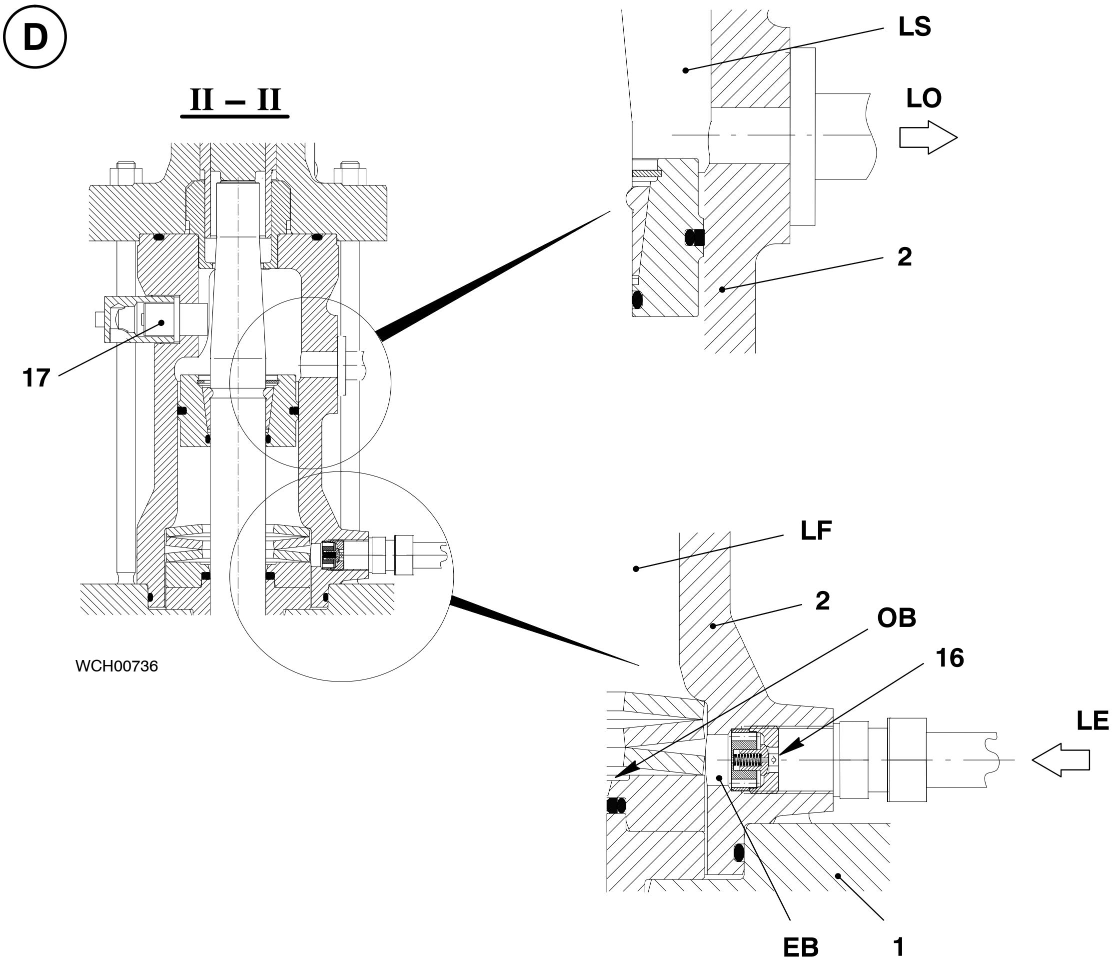
Remark: The oil supply 'OV' to the guide bush 7 ensures additional lubrication to the valve spindle 6 during the initial operating hours, or after an exhaust valve overhaul. For data about additional lubrication and the initial operating hours / hours after exhaust valve overhaul, see 7218−1 'Additional lubrication of exhaust valve spindle'.



Exhaust Valve







Key to Illustrations: 'A' **Arrangement in cylinder cover**
'B' **Exhaust valve**
'C' **Oil supply to valve guide**
'D' **Leakage oil drain and air inlet to air spring**

1 Valve cage
2 Lower housing
3 Upper housing
4 Outside piston
5 Inside piston
6 Valve spindle
7 Guide bush
8 Piston guide
9 Distance ring
10 Air spring piston
11 Damper
12 Hydraulic oil connection
13 Orifice
14 Cup spring
15 Rotation wing
16 Non-return valve
17 Valve stroke sensor
18 Valve seat
19 Cylinder cover
20 Thrust piece

EB Inlet bore (to air spring)
HO Hydraulic oil (high pressure)
LE Air inlet (to air spring)
LF Air spring
LO Leakage oil drain
LS Leakage oil collection space
OB Oil bath
OV Oil supply (to guide bush)

Crankshaft, Connecting Rod and Piston Group 3

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Axial Damper

1. General

The engine has an integrated axial damper. The function of the axial damper is to reduce axial vibrations.

The top part of the the cylinder 1, and bottom part of the cylinder 2 are attached to the last bearing girder 10 enclosing the flange 13. The flange is part of the crankshaft 9.

2. Function

Bearing oil flows from the oil inlet 'OE', through the orifice 7 into the oil chambers 'OR' on each side of the flange 13. When the crankshaft turns, most of the bearing oil flows between the oil chambers 'OR' through the housing 3. The remaining oil drains through the radial and axial clearances of the gaskets 5, 6 and the vent screw 4.

STOP Do **not** operate the engine with the oil supply to the axial damper interrupted.

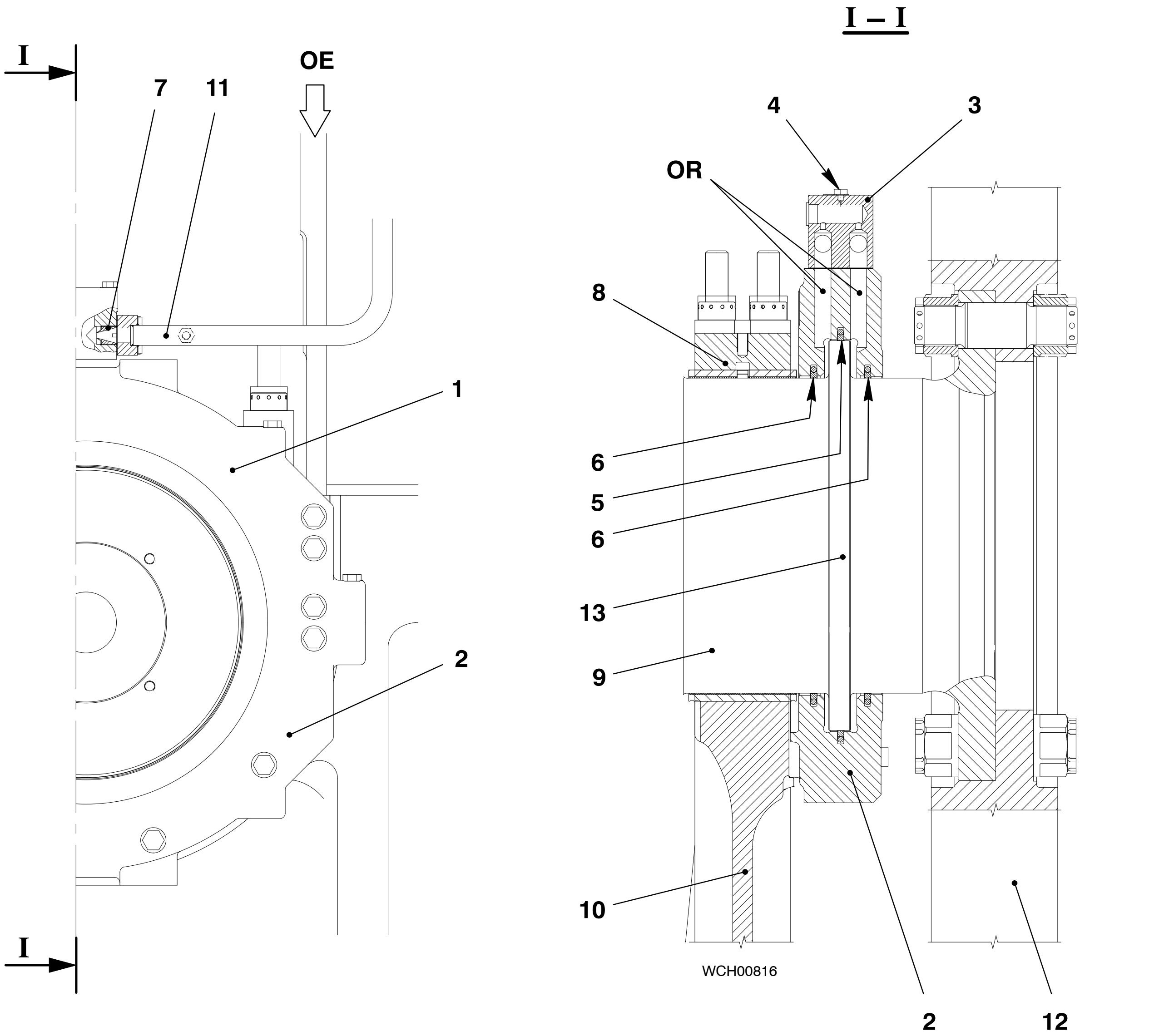
3. Monitoring system

The engine has an axial damper monitoring system installed above the end casing at the free end. This system monitors the oil pressure in the oil chambers 'OR' of the axial damper. If the oil pressure decreases below a set value, an alarm is triggered (for more data about the values, see Alarms and Safeguards at Continuous Service Power 0250–2).

The reason for this alarm must be investigated and resolved:

- 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.
- Excessive wear of the gaskets 5 and 6, e.g. caused by dirt particles (clearance too large).

Axial Damper



Key:

1 Top part of cylinder
2 Bottom part of cylinder
3 Housing
4 Vent screw
5 Gasket (and spring)
6 Gaskets (and springs)
7 Orifice
8 Bearing cover
9 Crankshaft
10 Bearing girder (part of bedplate)
11 Oil pipe
12 Damper (part of crankshaft)
13 Flange

OE Oil inlet
OR Oil chambers

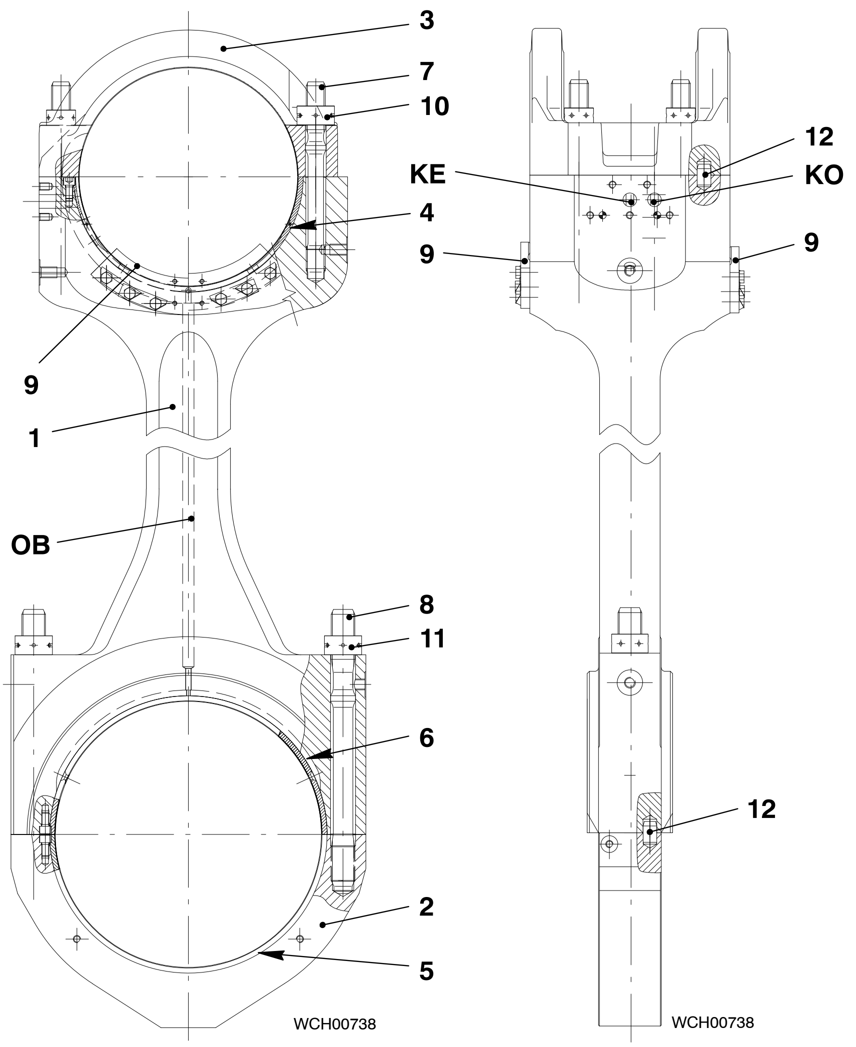
1. General

The connecting rod 1 connects the crosshead to the crankshaft and converts the linear stroke movement of the piston into a turning movement. Replaceable bearing shells 4, 5, and 6 are fitted to the top and bottom end bearings on the connecting rod 1. The top bearing cover 3 on the top end bearing is lined with white metal. The locking segments 9 prevent incorrect fitting of the crosshead pin.

2. Lubrication

Crosshead lubricating oil flows to the top end bearing through the oil inlet 'KE'. Oil bores in the crosshead pin let lubricating oil flow to the guide shoes. Crosshead lubricating oil flows to the bottom end bearing through the oil bore 'OB' in the connecting rod 1.

Bearing lubricating oil flows through the oil inlet 'KO' and through the related oil bores in the crosshead pin and piston rod to cool the piston.



Key:

- 1 Connecting rod
- 2 Bottom bearing cover
- 3 Top bearing cover
- 4 Bearing shell (for crosshead top end bearing)
- 5 Bottom bearing shell (for bottom end bearing)
- 6 Top bearing shell (for bottom end bearing)
- 7 Studs (top end bearing)
- 8 Studs (bottom end bearing)
- 9 Locking segment
- 10 Round nut
- 11 Round nut
- 12 Cylindrical pin

- KE Oil inlet (crosshead lube oil)
- KO Oil inlet (piston cooling oil)
- OB Oil bore (in connecting rod)

Intentionally blank

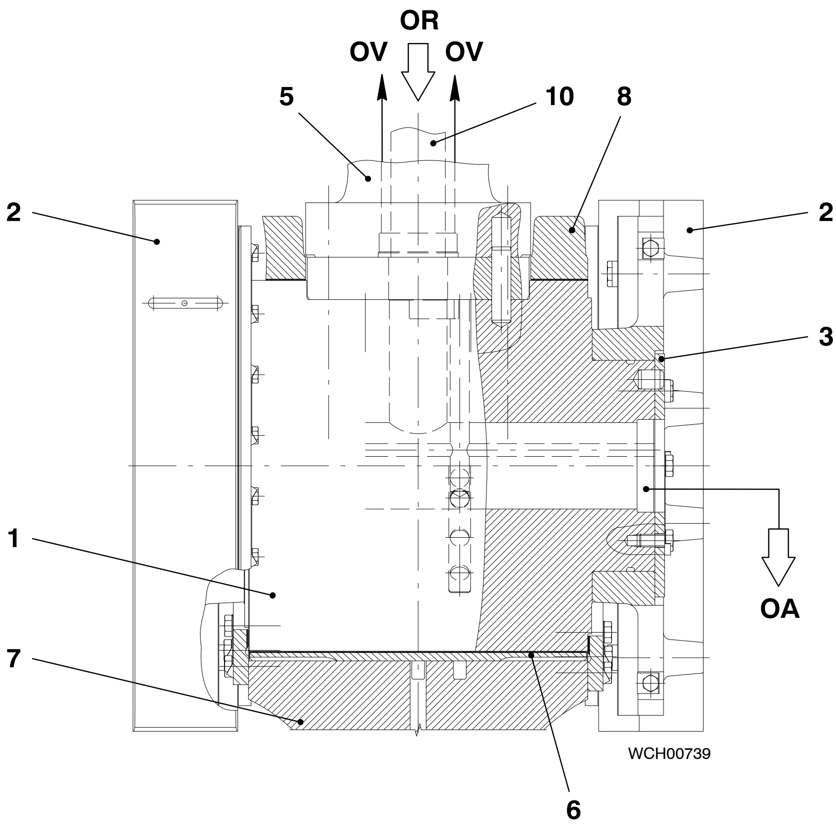
1. General

The crosshead guides the piston rod 5 and absorbs the lateral forces from the connecting rod 7.

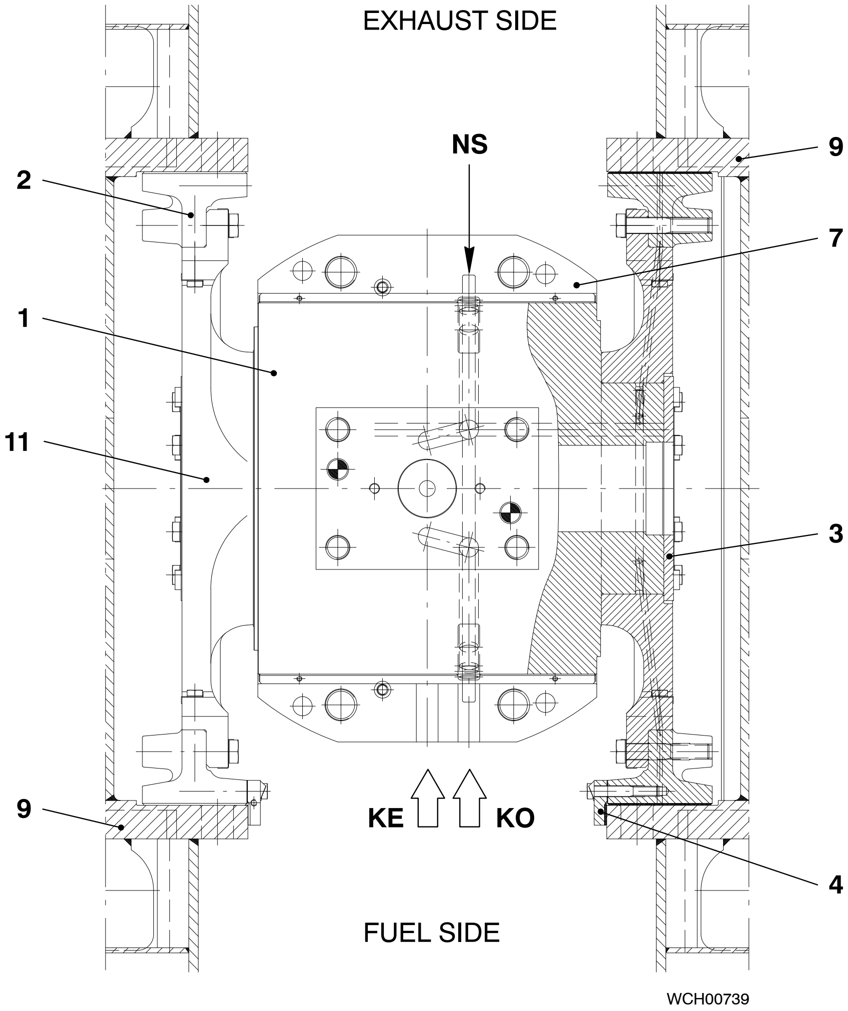
The piston rod 5 is attached to the crosshead pin 1. Piston cooling oil enters the oil inlet 'KO' and flows through the slot 'NS' and the oil inlet 'OV' to the piston. The oil flows back from the piston through the oil return 'OR' (in the oil pipe 10) to the crosshead pin 1 and returns to the crankcase through the oil drain 'OA'. Oil enters the oil inlet 'KE' and lubricates the crosshead.

The guide shoes 2 are attached to the middle parts 11. The middle parts 11 are fitted on to the round ends of the crosshead pin 1. The end covers 3 hold the middle parts 11 on the crosshead pin 1. The guide rails 4 keep the guide shoes 2 in the guides of the column 9.

The end covers 3 hold the middle parts 11 on to the crosshead pin 1 during removal of the crosshead pin. The end covers 3 let the crosshead pin 1 turn only a small distance.



Crosshead and Guide Shoe



Key to Illustrations:

1	Crosshead pin	10	Oil pipe (to piston)
2	Guide shoe	11	Middle part (guide shoe)
3	End cover		
4	Guide rail	KE	Oil inlet (crosshead lubrication)
5	Piston rod	KO	Oil inlet (piston cooling)
6	Bearing shell for top end bearing (crosshead)	NS	Slot (groove) in connecting rod
7	Connecting rod	OA	Oil drain (to crankcase)
8	Upper bearing half for top end bearing	OR	Oil return (from piston)
9	Column	OV	Oil inlet (in piston rod)

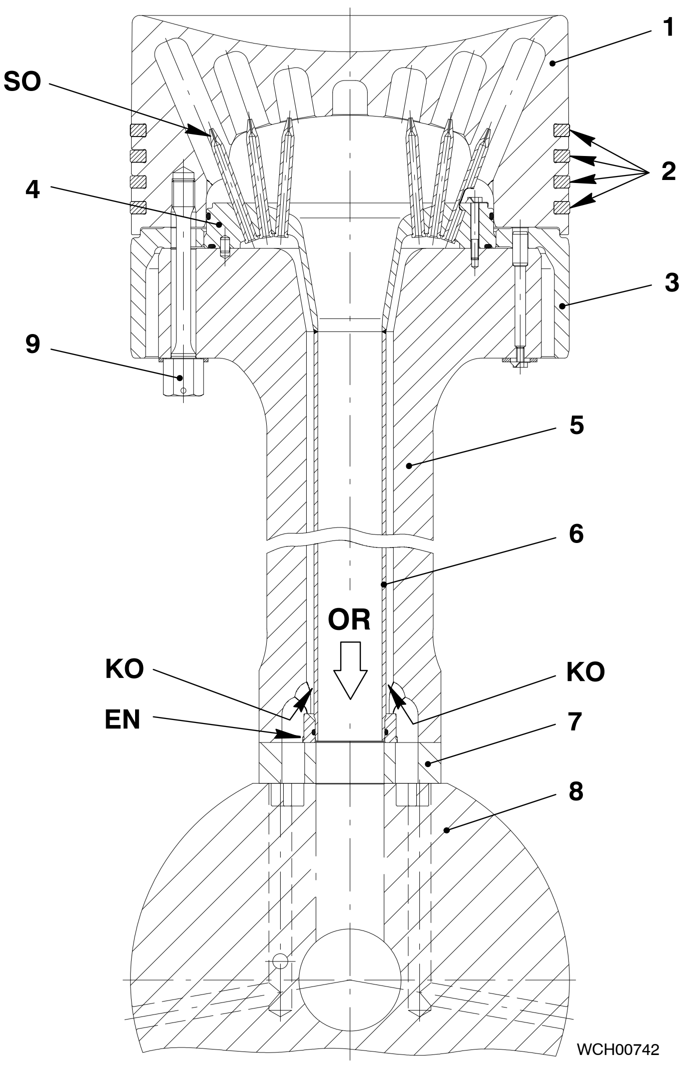
1. General

The piston has the parts that follow: Piston crown 1, piston skirt 3, piston rod 5, the oil cooling components and piston rings 2. Ten elastic screws attach the piston rod 5 to the piston crown 1. The piston skirt 3 is attached directly on to the piston rod 5. The piston rod 5 is attached to the crosshead pin 8 in a specific position. The compression shim 7 is installed between the piston rod 5 and the crosshead pin 8. The thickness of the compression shim 7 is related to the compression ratio.

Remark: All piston rings must be installed with the mark 'TOP' facing upwards. For more data about the piston rings, see the Maintenance Manual 3425–1.

2. Piston cooling

Lubricating oil is used to cool the piston crown 1. The piston cooling oil 'KO' flows from the crosshead pin 8 into the two inlet slots 'EN'. The piston cooling oil then flows through the space outside the oil pipe 6 (in the piston rod 5) to the spray plate 4. The piston cooling oil is sprayed into the cooling bores of the piston crown 1 through the nozzles in the spray plate 4. The oil then flows through the oil return 'OR', into the crosshead pin 8 and out through the oil bores to the crankcase.



Key:

1 Piston crown
2 Piston rings
3 Piston skirt
4 Spray plate
5 Piston rod
6 Oil pipe to spray plate
7 Compression shim
8 Crosshead pin
9 Elastic bolt

EN Inlet slot (groove)
KO Piston cooling oil
OR Oil return (from piston)
SO Spray oil

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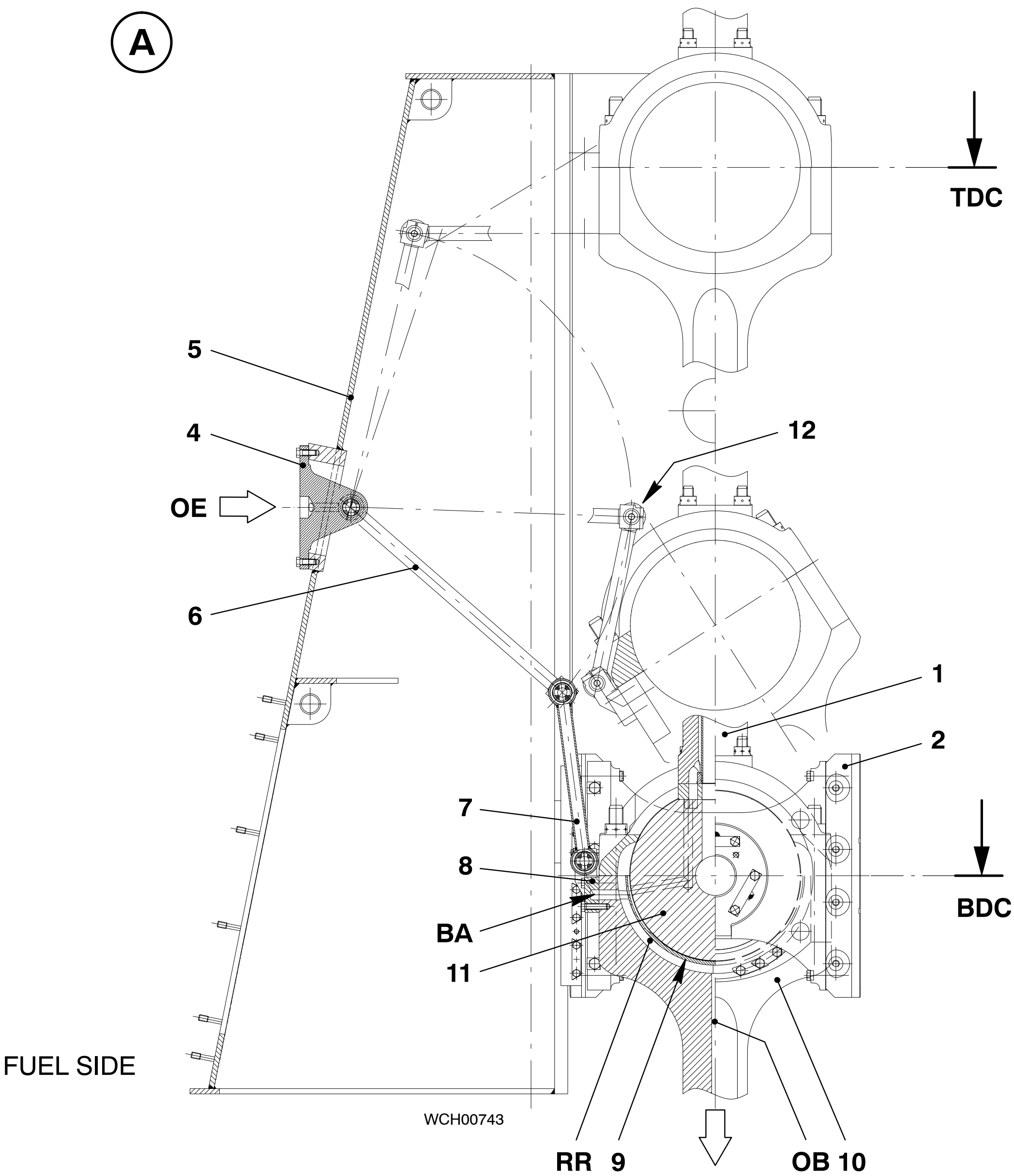
1. General

The oil system supplies oil to cool the pistons and to lubricate the crossheads. The support 4 is attached to the column 5. The oil enters the oil inlet ’OE’ and flows into the support 4, which has a bifurcated bore to give two separate oil supplies. The oil flows through the bifurcated bore into a double articulated lever. One side of the articulated lever is for crosshead lubrication, the other side is for piston cooling.

2. Crosshead lubrication

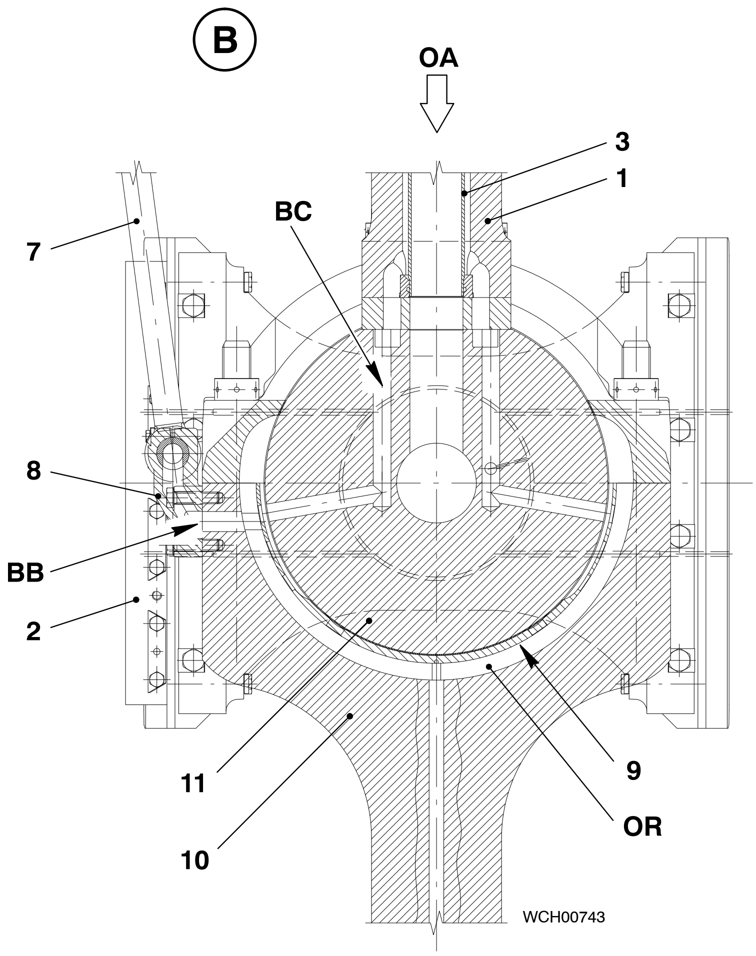
Crosshead lubrication oil flows from the support 4 through the lower lever 6 and upper lever 7 into the connection piece 8. The oil then flows through the bore ’BA’ into the ring space ’RR’. Holes in the top end bearing shell 9 let the oil flow through to lubricate the crosshead pin 11. The bore ’OB’ in the connecting rod 10 lets the oil flow to the bottom end bearing.



3. Piston cooling

Piston cooling oil flows from the support 4, through the related lower lever 6 and the upper lever 7 into the connection piece 8. The oil flows through the bore ’BB’ to the ring space ’OR’. Holes in the top end bearing shell 9 let the oil flow through the bores ’BC’ to the annular space around the oil pipe 3. The oil then flows to the piston.

After piston cooling, the oil flows through the oil return ’OA’ in the oil pipe 3 through the central bore in the crosshead pin 11 to the crankcase. Some of this oil is used to lubricate the guide shoes 2 (see also 3326−1).



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 Connection piece
9 Top end bearing shell
10 Connecting rod
11 Crosshead pin
12 Toggle lever (parts 6 and 7)

BA Bore (crosshead lubricating oil)
BB Bore (piston cooling oil)
BC Bore (in crosshead pin)
OE Inlet (piston cooling and crosshead lubricating oil)
OA Oil return (piston cooling)
OB Bore (crosshead lubricating oil to bottom end bearing)
OR Ring space (piston cooling oil)
RR Ring space (crosshead lubricating oil)

Engine Control and Control Elements — Group 4

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Overview

1. General

The WECS−9520 (**W**ärtsilä **E**ngine **C**ontrol **S**ystem) is specially designed for two-stroke engines with Common Rail technology, and is applicable to engine-related control functions (paragraph 3) and cylinder-related control functions (paragraph 4).

Engine-related control functions:

- Fuel rail pressure
- Servo oil pressure for the 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 (see paragraph 5). They serve as interface between operator and engine control.

2. Components

Fig. 'A' is a schematic diagram of the related components and their interconnections.

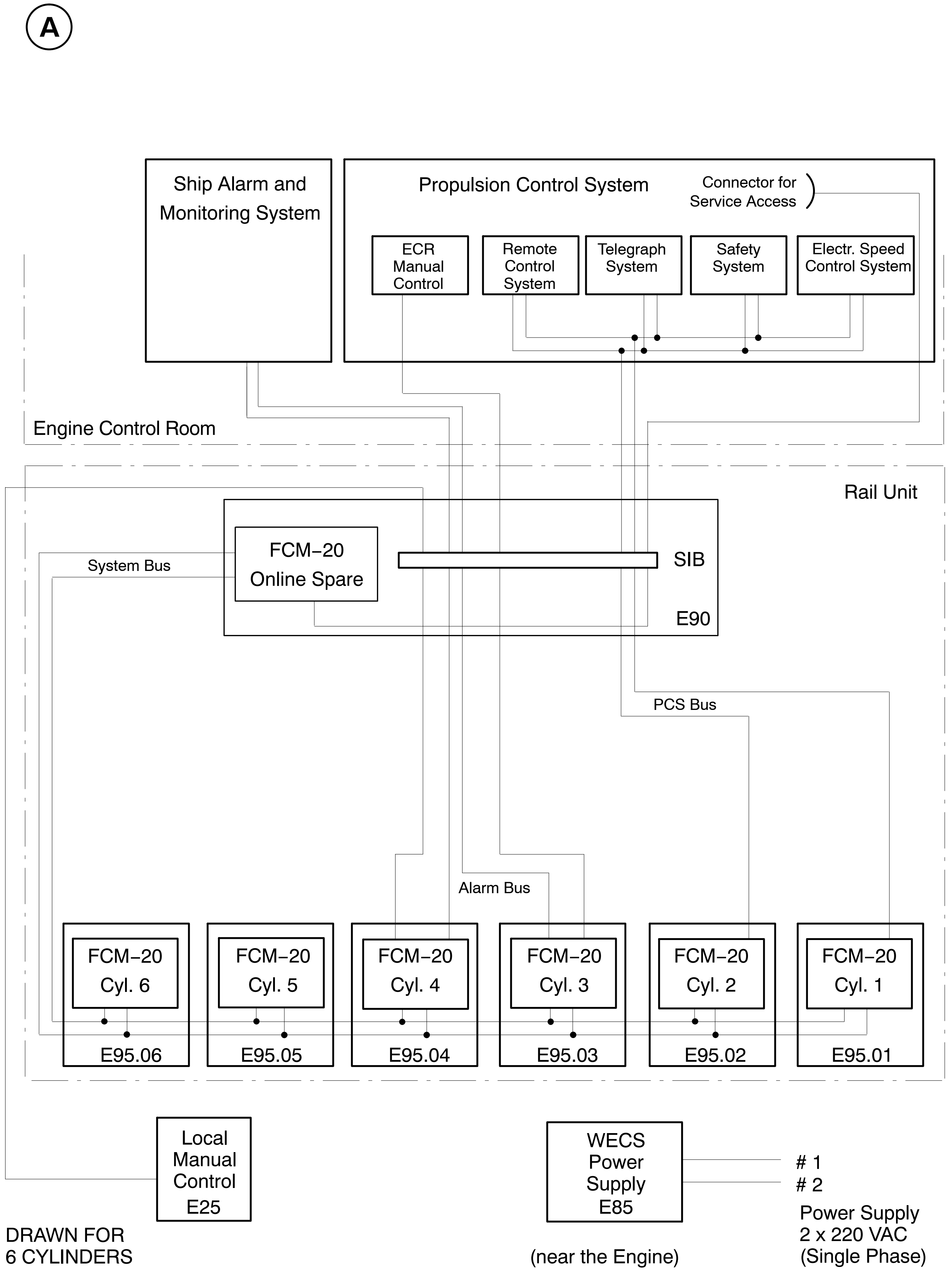
The main components of the WECS−9520 are as follows:

- Control box E90 Shipyard Interface Box (SIB) for communication to the external systems, includes an FCM−20 module as an online spare.
- Each cylinder has a control box E95.xx, which includes an FCM−20 module for engine and cylinder-related control functions.

The system bus connects all the modules.

All control boxes (E90, E95.xx) are installed on the rail unit. The power supply box (E85) is installed near the engine.

Engine Control System WECS−9520



3. Engine-related control functions

3.1 General

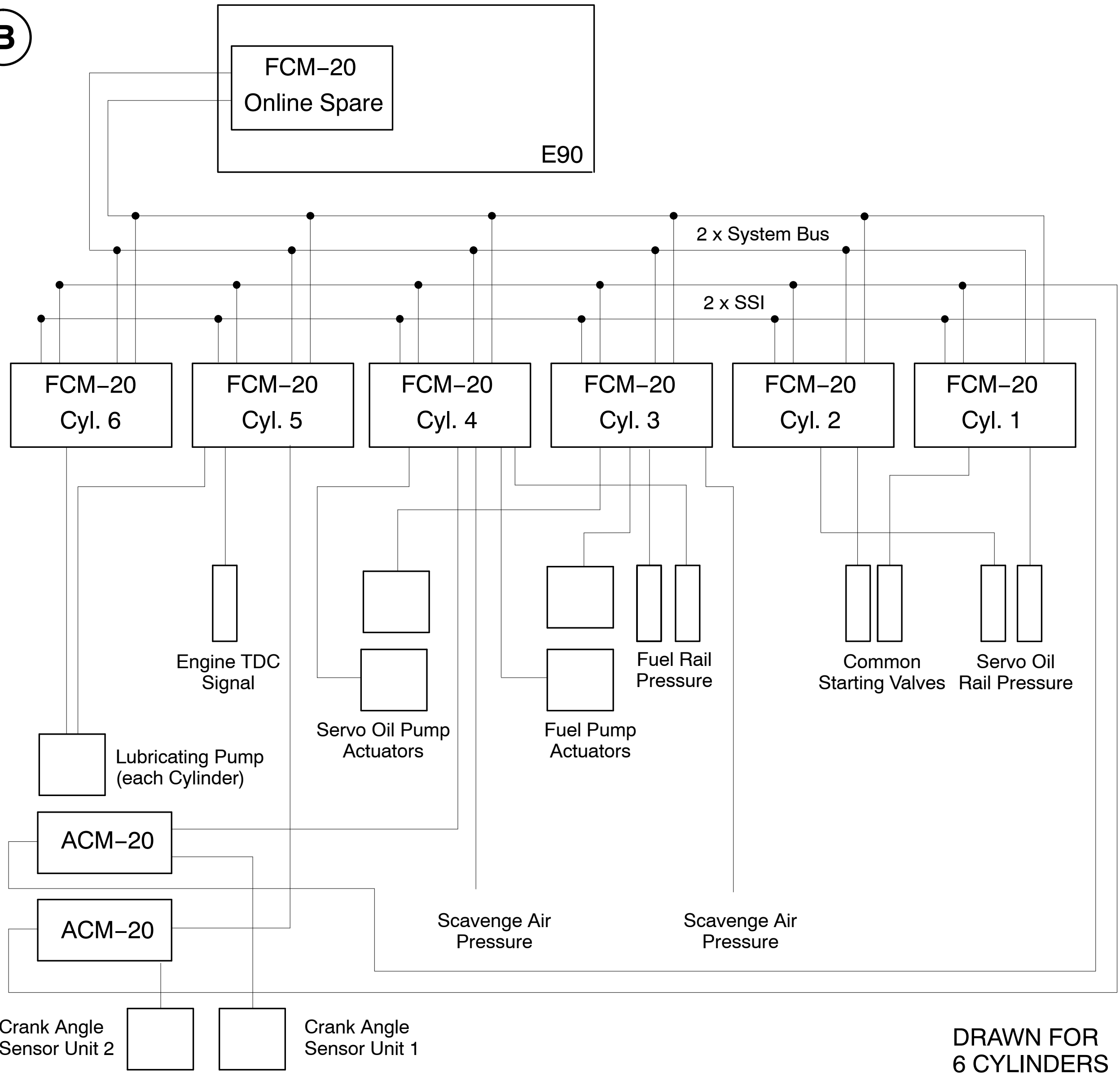
All engine-related control functions go to five FCM−20 modules (cylinders 1 to 5). The last and second last FCM−20 modules are for the control functions of the cylinder lubricating system.

For safety, all important functions, input and output signals of the modules are redundant. The engine continues to operate if one module has a failure. The power supply is also redundant (see Fig. 'B').

A defective module must be replaced with the online spare.

If the online spare is used to replace an unserviceable FCM-20 module, a new FCM-20 module must be installed in control box E90. This new module will receive a download of all application data.

B

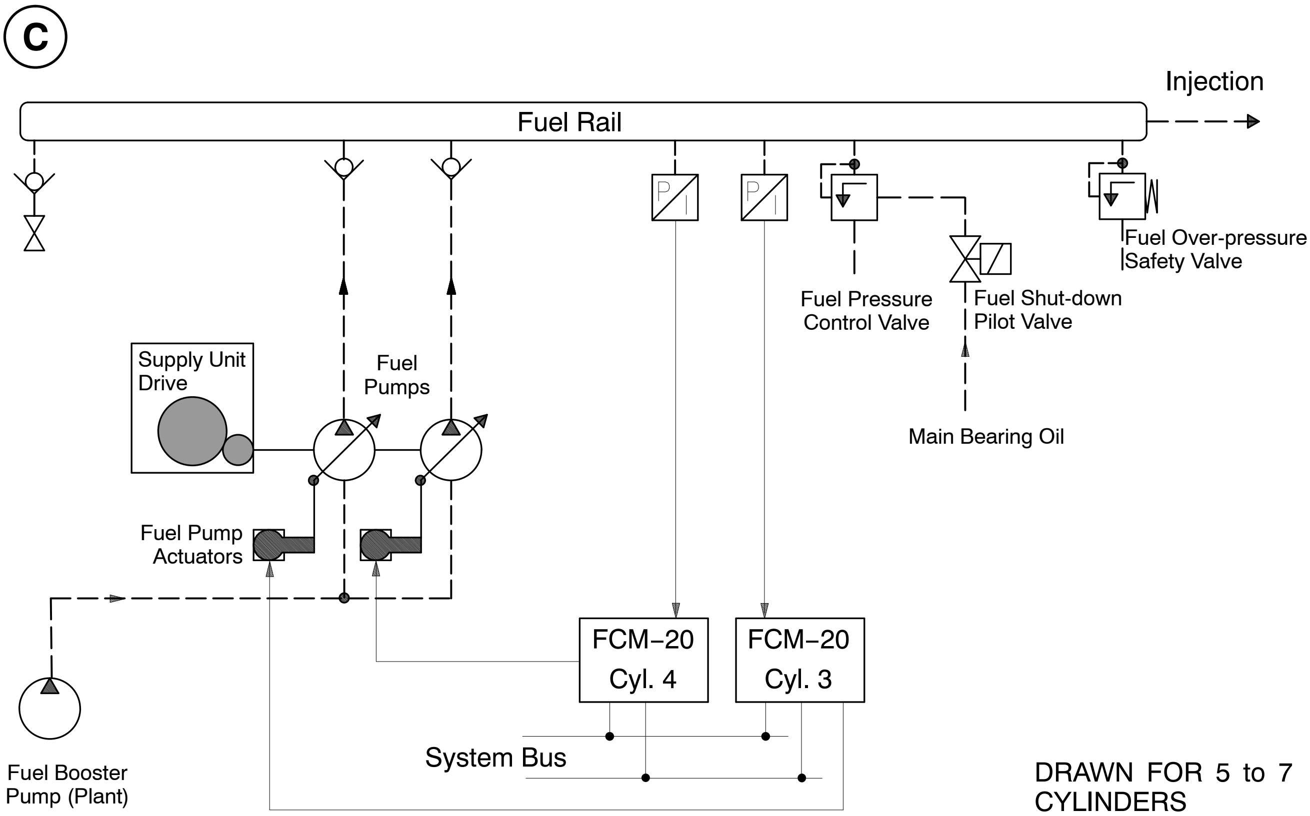


DRAWN FOR
6 CYLINDERS

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



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 is as follows:

- WECS−9520 generates a control signal based on engine speed and fuel command.
- Signals from the FCM−20 modules control the fuel pump actuators. Each fuel pump has one actuator.
- Two pressure transmitters measure the fuel rail pressure. The pressure transmitters send feedback signals to the FCM−20 modules of cylinders 3 and 4.

Shut-down:

At shut-down, the fuel pump actuators are set to position zero and the safety system operates the fuel shut-down pilot valve.

3.2.1 Emergency mode

One actuator defective:

If an actuator is defective, its regulating output stays in position or turns slowly to zero delivery.

The other actuator continues to control the fuel pressure. At less than medium load, the fuel pressure control valve releases unwanted fuel.

3.2.2 Monitoring

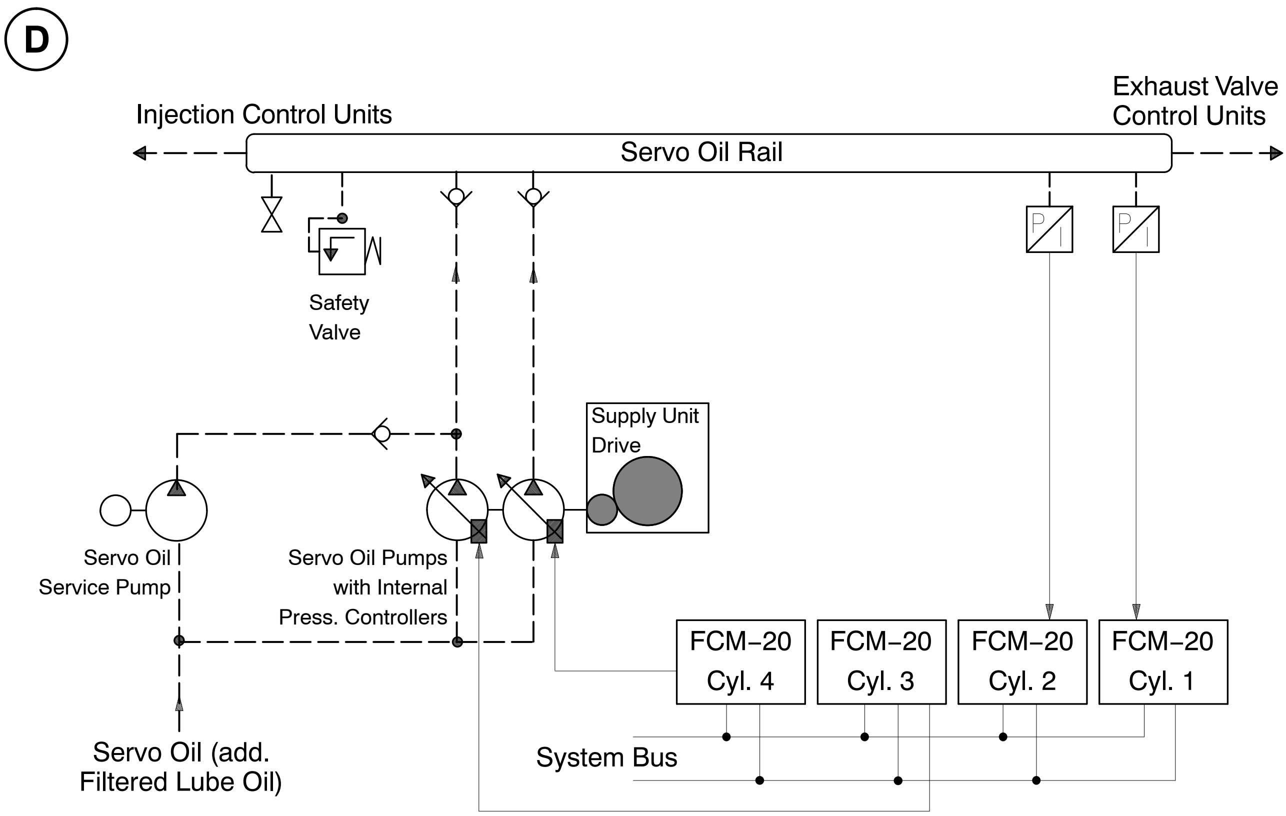
Pressure:

The fuel pressure is monitored. If the fuel pressure is out of tolerance, a failure indication shows.

Sensors:

The sensors are monitored. If the sensors are out of range, a failure indication shows. This failure indication is also shown with LEDs that flash on the FCM–20 modules on cylinders 3 and 4 (see 0850–1 'Failures and Defects of WECS Components').

3.3 Servo oil pressure setpoint



3.3.1 Pressure setpoint

Each servo servo oil pump has an internal mechanical pressure controller with an electrical setpoint. The pulse width modulation signal (PWM) gives the setpoint.

The FCM−20 module gives the setpoint and is a result of the engine load.

A closed loop control compensates for a pressure decrease in the pipes between the servo oil pumps and the servo oil rail.

Each pressure controller of the two pumps is connected to an FCM−20 module (cylinders 3 & 4). This decentralization increases the availability of the servo oil system.

3.3.2 Emergency mode

If one servo oil pump has a failure, the system will continue to operate. The other servo oil pump will continue to take the load.

3.3.3 Sensor monitoring

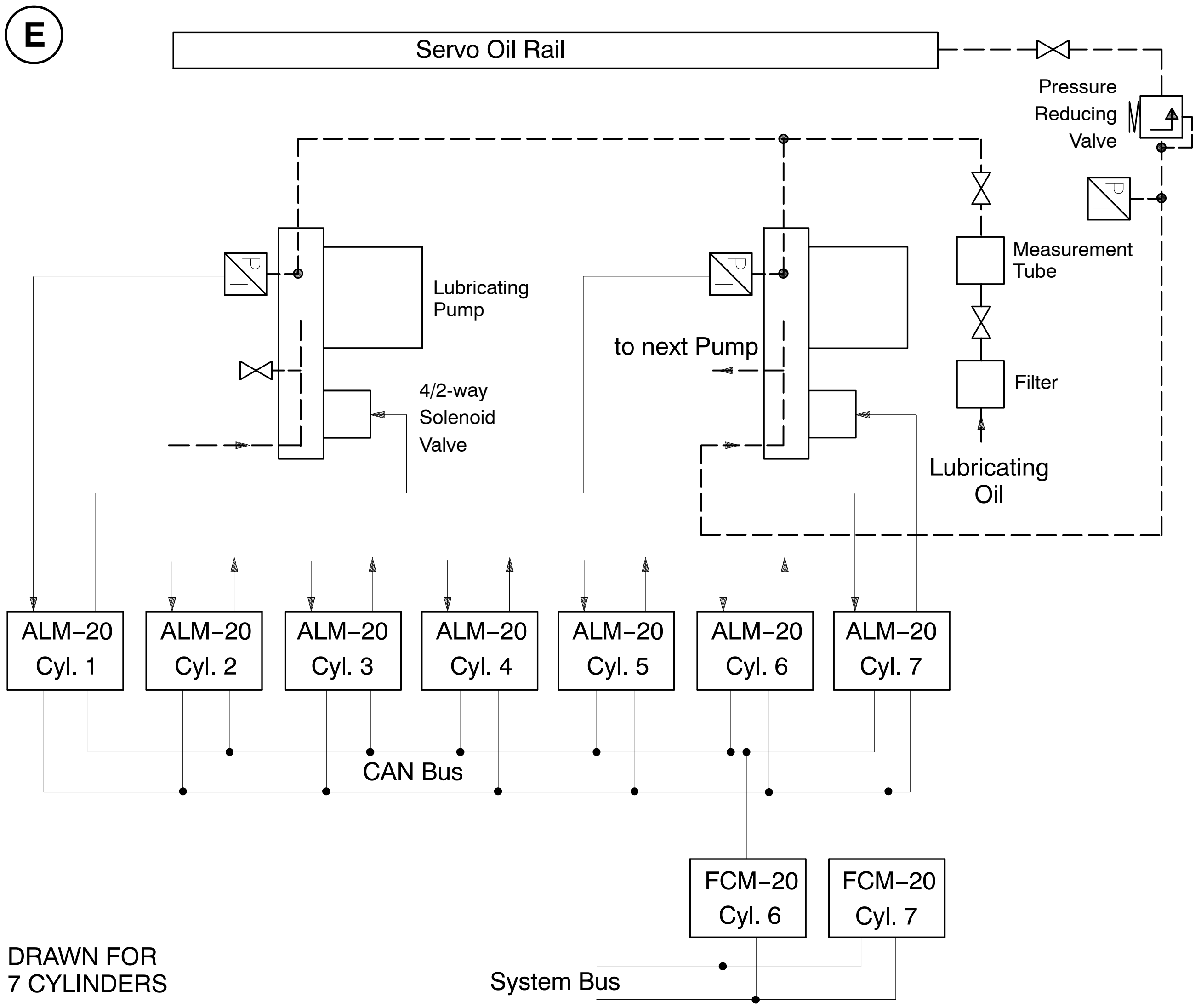
Pressure:

The pressure is monitored. If the pressure is out of tolerance, a failure indication shows.

Sensors:

The sensors are monitored. If the sensors are out of range or more than the difference, a failure indication shows. This failure indication is also shown with LEDs that flash on the FCM−20 modules on cylinders 1 and 2 (see 0850−1 ’Failures and Defects of WECS Components’).

3.4 Cylinder lubricating system control



3.4.1 General

The last and penultimate FCM−20 modules give the control functions of the cylinder lubricating system. Each ALM−20 module (control unit) starts a lubricating pump when the related control signal from the FCM−20 module is received. The dual execution of the system bus, CAN bus and power supply makes sure of the redundancy.

3.4.2 Emergency mode

If an FCM−20 module or bus has a failure, the other FCM−20 module or bus controls the cylinder lubricating system. A passive failure indication is shown in the WECS−9520 (see also 0850−1).

4. Cylinder-related control functions

4.1 General

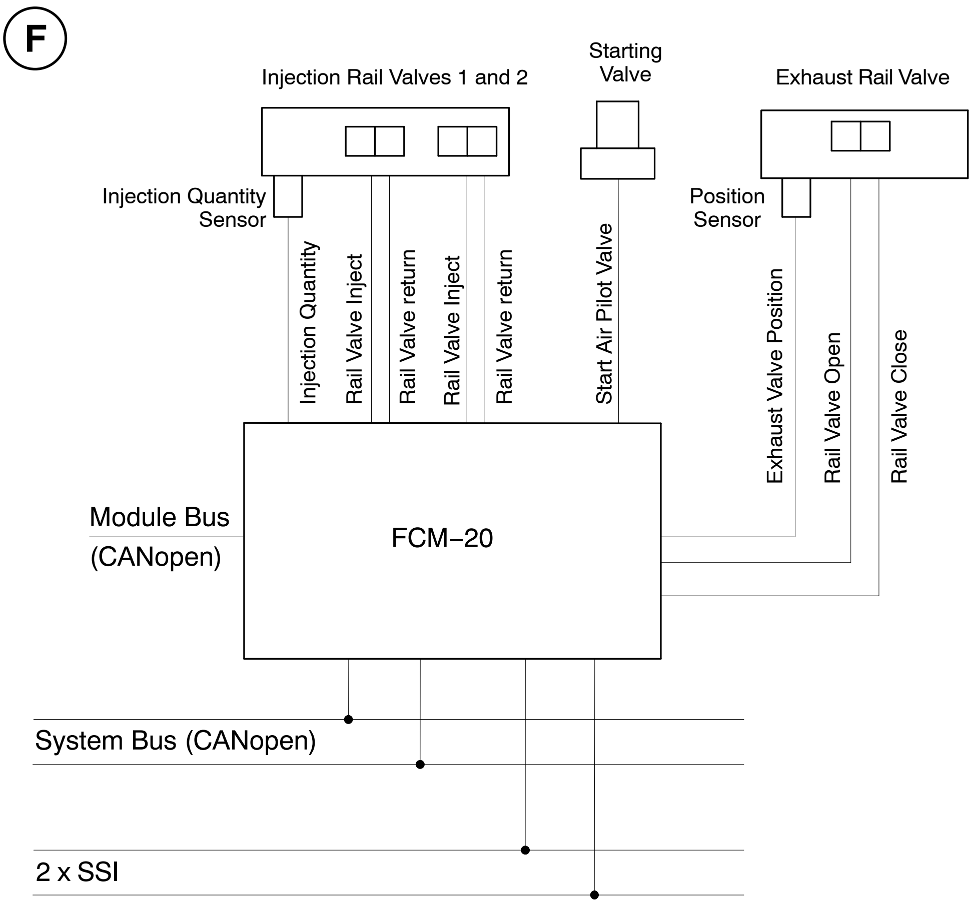
Each cylinder has an FCM−20 module. A redundant CANopen bus gives communication between the FCM−20 modules (system bus).

The FCM−20 modules receive the crank angle signal through a redundant SSI bus.

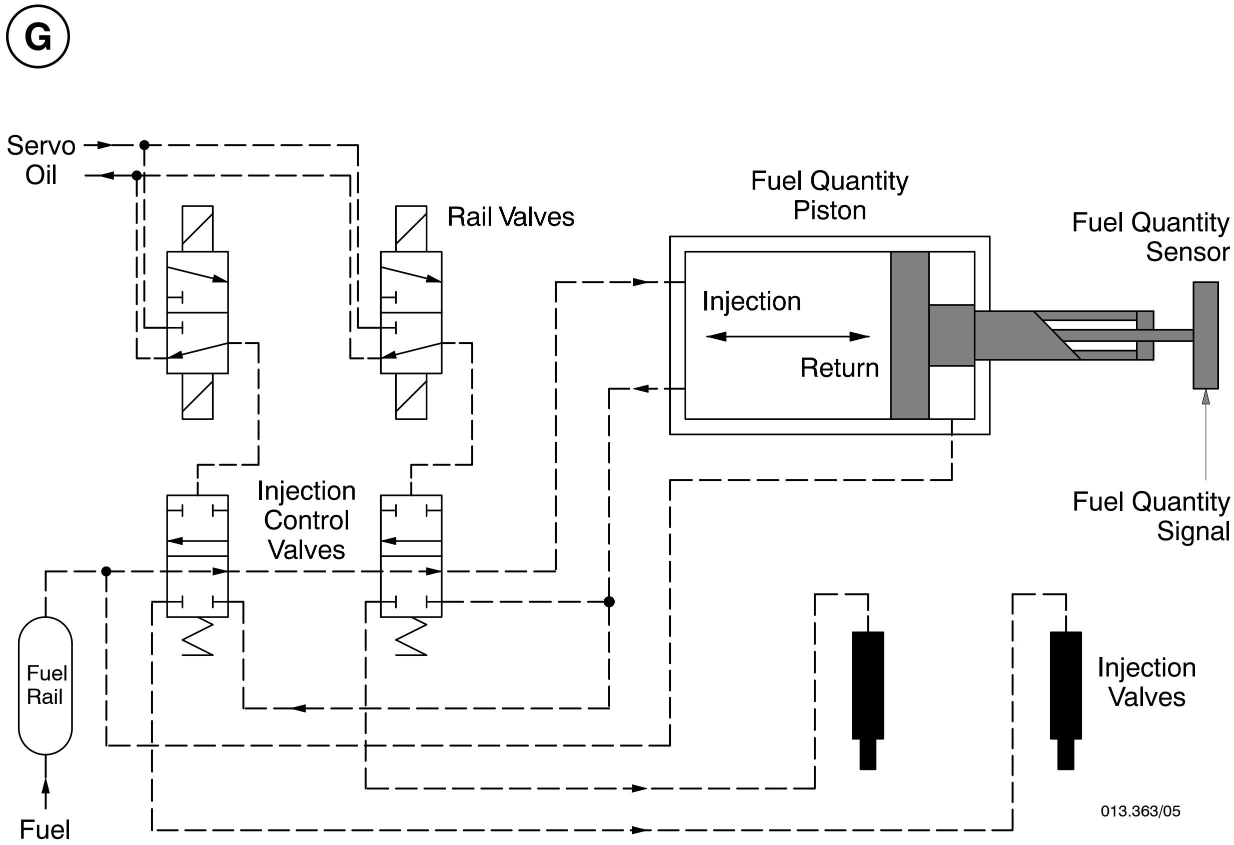
If an FCM−20 module has a failure, the related cylinder is cut out. The other FCM−20 modules continue to operate.

Functions:

- Volumetric injection control (including VIT)
- Exhaust valve control (including VEO/VEC)
- Starting valve control



4.2 Injection control



All components are shown in the NO INJECTION position

Injection valve control function:

All injection valves, related to the injection rail valves of a cylinder, are controlled independently, but with one common feedback signal for the injected fuel quantity.

Usually, all injection valves are started at the same time. Special operation modes enable injection with only one injection valve or with spray interruption (multi-shoot patterns), (see also 0280−1 'WECS−9520 Injection control').

To improve the fuel spray at low load, one injection valve is cut out automatically.

The FCM−20 module is used to amplify control outputs up to the necessary signal level for the rail valves.

Rail valve ON-time measurement:

The supply to the rail valve is cut off as soon as the valve piston has moved. This is measured ON-time and is shown in the remote control.

The On-time measurement lets you know the condition of the rail valve .

Initial setpulse:

Because the rail valves are bistable, their initial position is not known. Therefore, at engine standstill setpulses are applied at intervals to the rail valves to get a specified position.

Injection control:

Fuel injection is controlled as follows:

- Calculation of injection start with reference to the crank angle and VIT.
- When the rail valves operate, the injection is released.
- The time difference between the injection start signal and the injection start is called the Injection Deadtime. When the fuel quantity piston moves, the system senses injection start.
- The distance (stroke) that the fuel quantity piston moves is related to the quantity of fuel injected. The injection stops when the fuel quantity piston is at the calculated stroke.
- The governor calculates the injection quantity with reference to the control signal.
- On the next 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.

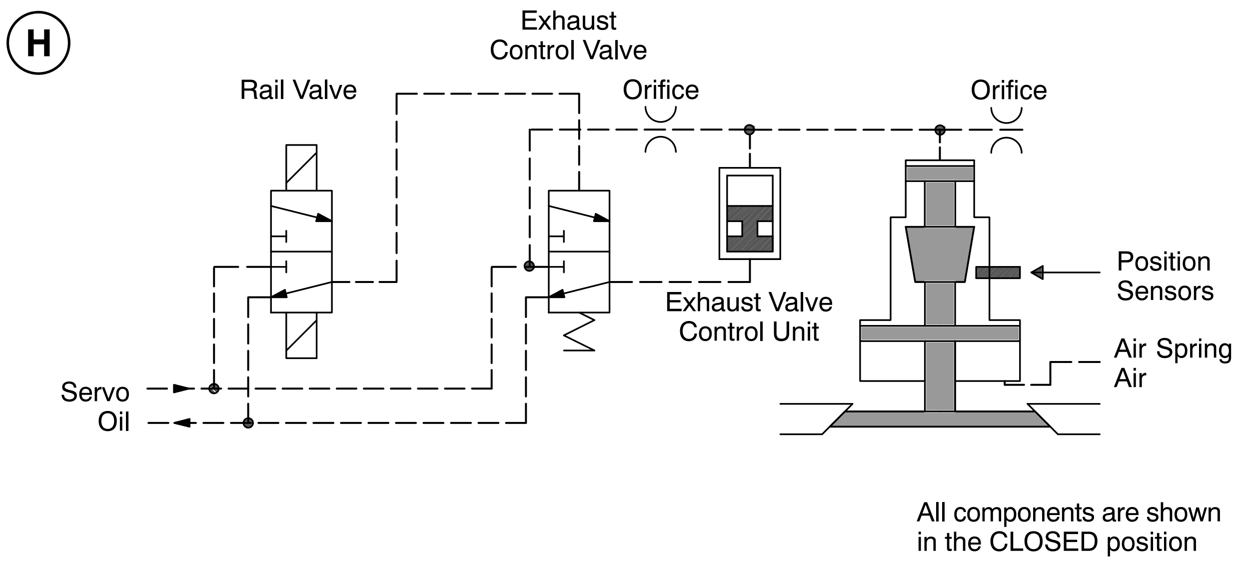
Reversing:

For running the engine ASTERN, the crank angle is mirrored.

Emergency mode:

If the fuel quantity sensor is unserviceable, the control system converts the fuel command signal from the related FCM−20 module into a time period. This cylinder is then controlled with timed injection.

4.3 Exhaust valve control



Exhaust valve function:

The exhaust valve opens and closes once for each crankshaft revolution.

The position sensor measures the exhaust valve movement.

The FCM−20 module is used to amplify control outputs up to the necessary signals for the rail valves.

Rail valve ON-time measurement:

The time between the start signal and valve piston movement is measured and shown in the remote control.

Initial setpulse:

Because the rail valves are bistable, their initial position is not known. Therefore, at engine standstill, setpulses are periodically applied to the rail valves to get a specified position.

Exhaust valve control:

The exhaust valve movement is controlled as follows:

- The command to open the exhaust valve is calculated with reference to the crank angle and VEO.
- The rail valve opens.
- Measurement of the opening deadtime: Displacement time from 0% to 15% valve stroke.
- The command to close the exhaust valve is calculated with reference to crank angle and VEC.
- The rail valve closes.
- Measurement of the closing deadtime: Displacement time from 100% to 15% valve stroke.
- After one full crankshaft revolution, the timing for the next cycle is corrected in accordance with the deadtime of the previous revolution.

Reversing:

For running the engine ASTERN, the crank angle is mirrored.

Emergency mode:

If a position sensor has a failure, the process continues with time control for the related cylinder.

4.4 Starting valve control

The FCM−20 module sends a signal to open and close the starting valve for each crankshaft revolution at a specified crank angle until the engine operates.

Reversing:

For starting the engine ASTERN, the crank angle is mirrored.

5

4.5 Crank angle sensor

Two measurement systems that operate independently are installed at the driving end. Each crank angle sensor unit has three position sensors for position measurement of the gear wheel on the crankshaft. The fourth sensor finds the related crank angle reference mark (TDC or BDC). The sensors are connected to the ACM−20 modules (see Fig. 'I').

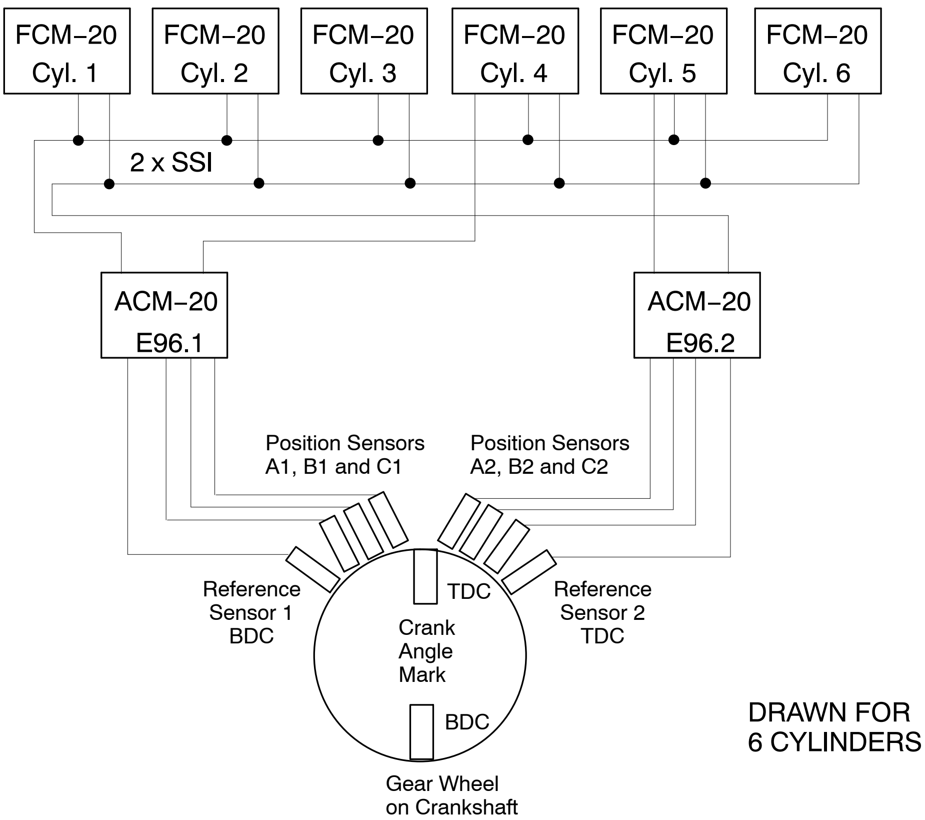
The ACM−20 modules calculate the absolute crank angle based on signals from the related position sensors. One ACM−20 module communicates with FCM−20 module #04 of WECS−9520 through CAN bus M#4, the other with FCM−20 module #05 through CAN bus M#5. The two ACM-20 modules send the crank angle data to all FCM−20 modules through the SSI bus.

Crank angle signal monitoring:

The signals and the power supply for the sensors are monitored. Malfunctions will be indicated on flex View (see 0850−1 'Failures and Defects of WECS Components). In addition, LEDs on the ACM−20 modules indicate the status of the measurement unit (sensors and modules) (see 9223−1 'Crank Angle Sensor Unit').

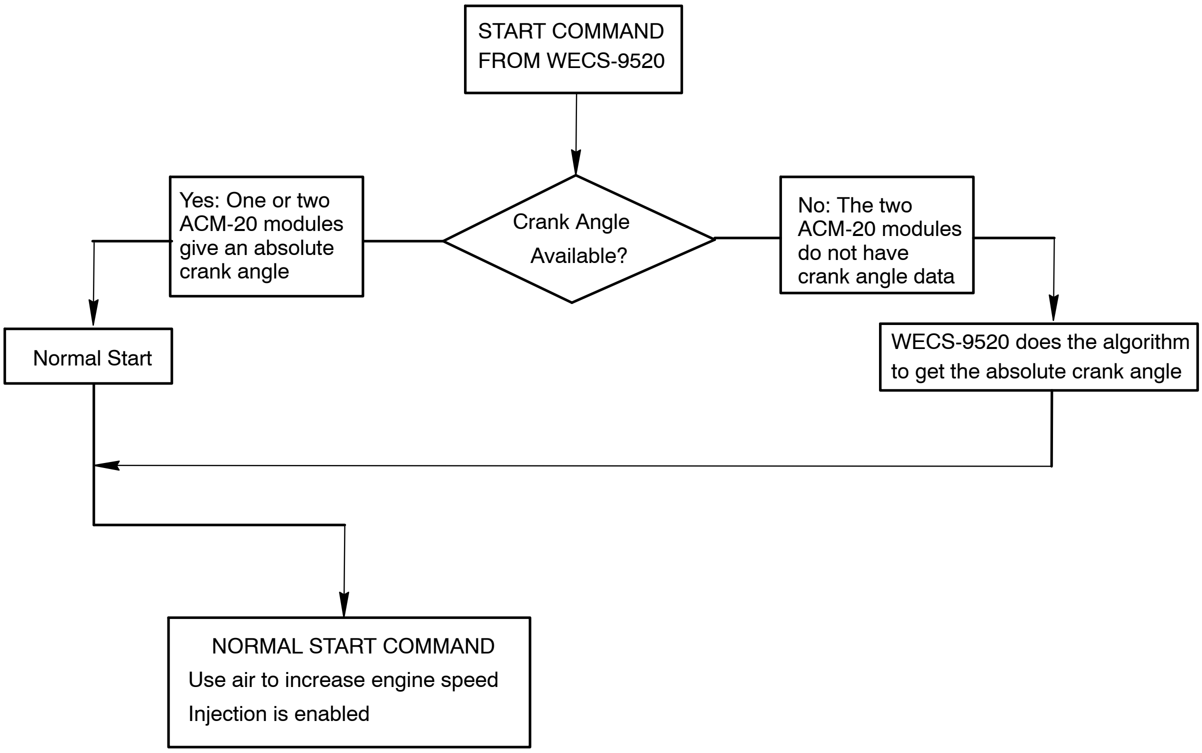
An alarm, slow-down or shut-down is indicated.

I



4.6 Crank angle algorithm

The ACM-20 module gives the absolute crank angle position based on the incremental measurement principle. Therefore, after power-up of an ACM-20 module, the crank angle data are only available when the engine turns the crankshaft to a position after the related reference mark.



4.6.1 Function

If a power loss affects each of the two ACM-20 modules, it is still possible to start the engine. The WECS–9520 does the crank angle calculation algorithm given below.

The crank angle algorithm starts automatically when:

- The WECS-9520 sends a signal to start the engine and
- The two ACM-20 modules do not have the correct crank angle data (no absolute angle).

The WECS-9520 selects a cylinder at random and start-air flows into this cylinder. The position of the crankshaft means that the engine will start to turn slowly ahead, astern or stay in position.

The algorithm selects the next applicable cylinder. Start-air flows into this cylinder and the engine turns slowly in the necessary direction.

When the engine turns the crankshaft to a position after TDC or BDC (on the first cylinder), one of the reference flags is found. The related ACM-20 module sends the absolute crank angle signal to the WECS-9520. The engine start-up sequence is correct.

4.6.2 Summary

A summary of the sequence is as follows:

- The WECS-9520 sends a signal to start the engine.
- The crank angle algorithm data goes to the WECS-9520.
- The WECS-9520 selects the cylinders (from the received algorithm data) that the start-air will flow to.
- The crankshaft starts to turn in the slow-turning mode.
- The engine starts correctly.

5. Communication between WECS−9520 and external systems

WECS−9520 supplies communications data to the:

- 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 includes 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 in the BACKUP control box of the remote control to connect a notebook for service personnel.

For the schematic diagrams, see Fig. 'J' and 'A'.

Remark: The communications between the systems can be different. See the related documentation of the approved system manufacturer.

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 system and telegraph system operate independently and are also fully operational if there is a failure of the remote control functions.

gle calculation algorithm

5.2 Remote control system

Main functions:

- Start, stop, reversing
- Automatic slow turning
- Auxiliary blower control
- Transfer control
- Speed setting
- Automatic speed setting program

Data about the WECS−9520 status are available in the remote control.

This includes measured values of sensors, alarm indications, parameter settings and trend lines (see the documentation of remote control manufacturer).

The engine operator can adjust the user parameters e.g. maximum fuel limit, running-in mode and FQS.

All commands to operate the engine, e.g. AHEAD or ASTERN, are given in the RCS.

As an alternative, the related FCM−20 module gives a load signal to the RCS out of the average from the measured fuel quantity signals.

Two charge (scavenge) air signals are transmitted to the RCS through WECS−9520, therefore the signal is redundant.

If the WECS−9520 finds a failure it sends an alarm signal to the ship alarm and monitoring 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

The engine operator can adjust the user parameters e.g. maximum fuel limit, running-in mode and FQS.

Expert parameters are changed only by service personnel, usually during commissioning. A typical expert parameter is the firing order of the engine, which is set only once. A connector for service access is installed in the engine control room.

5.3 BACKUP control box

The BACKUP control box is part of the propulsion control system and installed in the ECR console. The control functions of the BACKUP control box are the same as those for the local control panel (see also 4618−1).

5.4 Electronic speed control system

- Keeps engine speed at the necessary value from the remote control
- Transfers the 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 independently operated electronic device and is not part of the WECS−9520.

The WECS–9520 receives a fuel command signal from the speed governor.

This signal is sent to all FCM–20 modules. This is the setpoint for the fuel quantity to be injected.

If there is a speed control system failure, the engine can be operated in:

- LOCAL mode: manually adjusted fuel quantity at the local control panel, or
- ECR BACKUP mode from the BACKUP control box in the control room.

Attention! In BACKUP mode, an engine with a controllable pitch propeller (CPP) must be operated with the propeller pitch locked to prevent overspeed.

5.5 Safety system

Main functions:

- Emergency stop
- Overspeed protection
- Automatic shut-down
- Automatic slow-down

Each unusual WECS–9520 a request to the safety system.

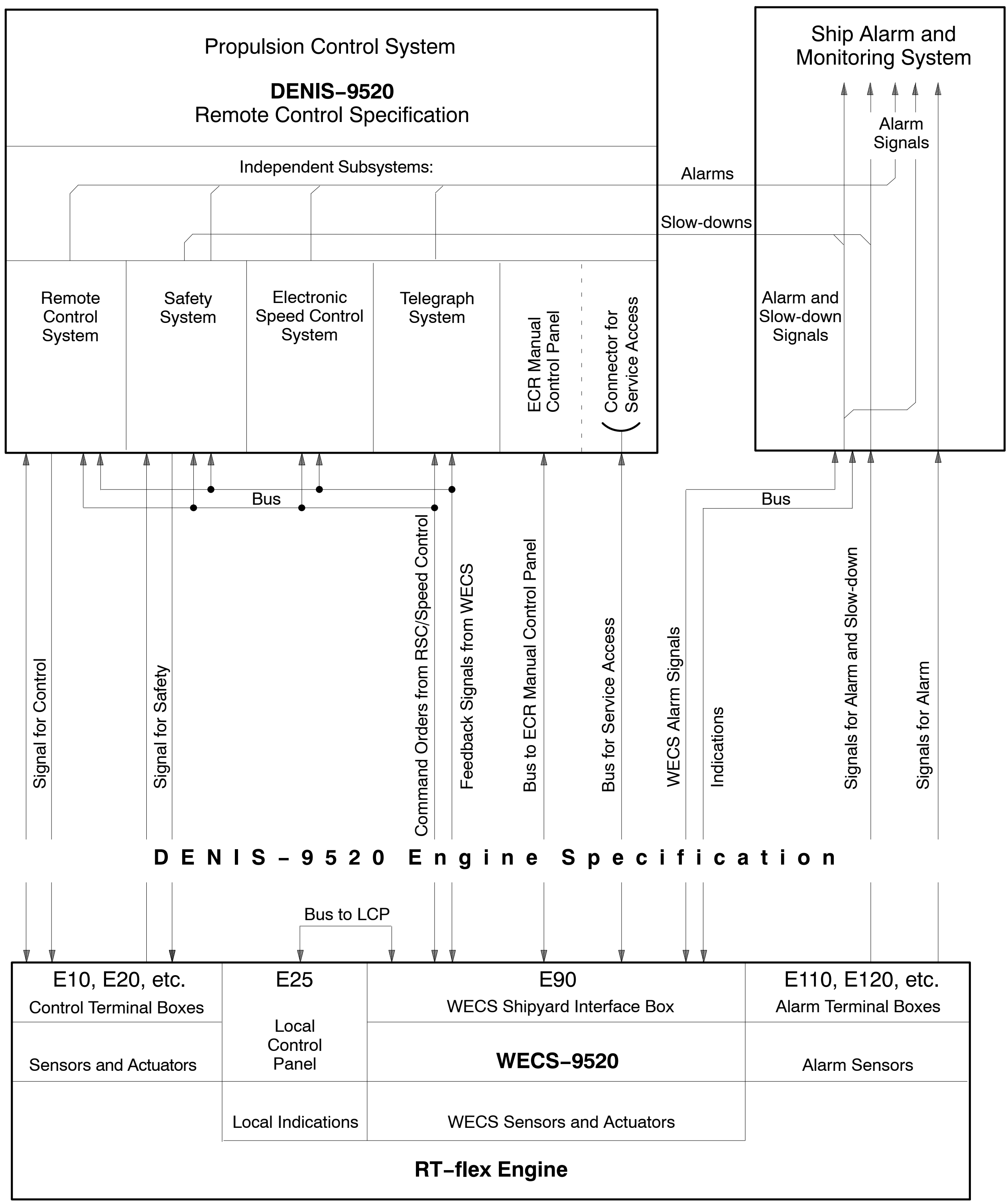
See the failure data in 0850–1 'Failures and Defects of WECS Components'.

5.6 Telegraph system

- Used to transmit the manoeuvring signals from the bridge to the control room and local control panel.

Engine Control System WECS−9520

J



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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
FQS (Fuel quality setting)	FQS can be set to adjust maximum firing pressure to nominal value. A negative correction angle will **advance** the injection begin and increase max. pressure. A positive correction angle will **retard** the injection begin and reduce max. pressure.
VIT on/off	VIT is normally switched on (shown as ON). It can be switched off (shown as OFF) for running-in. OFF means injection begins at nominal angle independent of the engine power.
Inj. cut off (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.
Inj. venting (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. This should be done preferably before every engine start after a stop of some hours.
Exv. A/M Cmd (Exhaust valve auto/manual command)	Use it to manually open and close single exhaust valve at **stopped engine**. Useful for testing and venting, e.g. after maintenance works. Preconditions: Servo oil service pump must be switched on, building up some pressure in servo oil rail. Air spring pressure must be up.
Start Valves Checking (Common start valves 1/2, enable/disable)	For function checks of control valves on shut-off valve for starting air. Switch off a valve in order to check the other one.
Heavy Sea Mode	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.
Lubrication (Feed rate)	Adjusting desired feed rate in steps of 0.1 g/kWh.

1.2 Overview of maintenance settings

Parameter	Purpose and effect
Crank Angle Crank angle offset, engine TDC offset	Crank angle settings and checks after maintenance or replacement of sensors in crank angle unit. Input of crank angle deviations (mean values) and checking of measured values.
Exv. closing offset (Exhaust valve closing offset)	Cylinder pressure fine tuning in service: Permits adjusting of compression pressure.
Inj. begin offset (Injection begin offset)	Cylinder pressure fine tuning in service: Permits adjusting of maximum firing pressure.
Inj. correction factor (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.
Servo oil pump, Pr. setp. tun. (Servo oil pump, pressure setpoint tuning)	Should be done at initial adjusting of engine at shop trial. 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

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'.

6. Recommendations for replacing ACM−20 modules

- Carry out at engine standstill if possible.
- Cut out the power supply to the module concerned in power supply box E85.
- Replace defective ACM−20 module.
- Check function of new ACM−20 module.

Overview

1. General

The DENIS−9520 (Diesel Engine CoNtrol and OptImizing Specification) and the WECS−9520 (Wärtsilä Engine Control System) 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.

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 section 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 [1)]
Starting air from starting air bottle	max. 25 / 30 bar
Main bearing, crosshead bearing and piston cooling oil	3.6 – 5.0 bar
Servo oil	100 – 200 bar

1) Adjusted to 6.5 bar with pressure reducing valve 23HA

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.

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 8 bar feed from board supply system to control air supply unit using shut-off cock 36HB at connection A1.

⇒ Adjust air for stand-by 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.

⇒ 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 air is fed to automatic filter 4.20 and blocking valve on turning gear 2.13.

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	2.9 bar	Stop	10 sec.
Air spring	PS4341S	4.5 bar	Stop	0 sec.
Piston cooling oil	PS2541–48S	0.4 bar	Stop	15 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

The value of the resistors depends on the remote control supplier:

Supplier	Resistor [kOhm]	Power [W]
KONGSBERG Maritime	10	0.6
NABTESCO	5.6	0.6
SAM / Lyngsø	8.2	0.6

⇒ 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 drain unit. 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 control air at the automatic filter. Check whether stop valve 4.37 is open in oil pipe after automatic filter, and stop valve is closed in 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	8

⇒ Bring selector switch in the control box back to 'Operation' (I).

⇒ Touch 'Flushing' button on the display. A flushing cycle of 8 seconds duration must now be initiated.

⇒ Observe whether the motor of the rotating device turns in the indicated direction (clockwise viewed from top).

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.

- 1st auxiliary blower must start immediately.
- 2nd auxiliary blower must start with a delay of approx. 2−3 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 TIER I or 0−6 bar TIER II). 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 TIER I or 0−6 bar TIER II). If necessary adjust or replace transmitter(s). Reconnect cables to terminals after test. Auxiliary blower start/stop hysteresis (0.45/0.65 bar) is adjusted in remote control.

⇒ Remove compressed air pump.

Test of auxiliary blowers in ECR manual control panel:

⇒ Switch off power supply of FCM−20 module #4.

- Command and feedback of auxiliary blowers shall still be working.

⇒ If not, check cabling to starter box(es).

Test of auxiliary blowers in ECR manual control panel:

⇒ Switch off power supply of FCM−20 module #3.

- Command and feedback of auxiliary blowers shall still be working.

⇒ If not, check cabling to starter box(es).

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 Crank angle sensor

Replacement ACM−20 Module:

⇒ Switch off circuit breakers in E85 for the corresponding FCM−20 module #04 and #05.

⇒ Replace the faulty ACM−20 module in E96.1 respective in E96.2.

⇒ Switch on circuit breakers in E85 one by one. FCM−20 module #04 and #05 are rebooted and supply the ACM−20 modules.

● The software download, if required (CRC uneven) takes automatically place.

⇒ Check on flexView card SW−Info the CRC state. The state must be ’CRC OK’ for ACM−20 module #1 and #2.

Replacement proximity sensor (pick-up):

⇒ Disconnect cable to concerned sensor and screw the sensor out.

⇒ Screw in the new sensor until the sensor touches the tooth or marker head. Use no force!

⇒ Screw the sensor out four whole turns (4 x 360 ° = 4mm).

⇒ Secure the sensor with nut and connect the cable.

⇒ Turn clockwise the engine by turning gear device. The pickup signal sequence on the ACM−20 module has to be in the correct order: ’A’, ’B’, ’C’. When passing the reference flag the LED ’REF’ lights up.

4.9 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 values (mA) in remote control, EXV of fields ’Open position sensor 1/2’.

Remark: These values 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 values (mA) in remote control, EXV of fields ’Open position sensor 1/2’.

⇒ 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’).

4.10 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 valve 4.30−5.

⇒ Check servo oil pressure of 60 bar. If necessary adjust it by means of pressure reducing valve 8.11−1. The value can be read off on pressure gauge PI2041L.

⇒ Ensure lubricating oil supply and cleanness of piping filter 8.17.

⇒ Check whether ball valve is open in the oil pipe after measurement tube 8.19.

⇒ Put shut-off valve in the lubricating pumps to operating position (to stop fully turned out).

⇒ Vent lubricating oil filter 8.17, measurement tube 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. 20 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').

4.11 Regulating linkage

⇒ Verify if the regulating linkages to the fuel pumps have been fitted according to Maintenance Manual 5801−1 'Adjusting the regulating linkage'.

⇒ Ensure that the regulating linkage moves freely over the entire stroke.

Never switch on actuators which are disconnected from the regulating linkage, or disconnect the regulating linkage of already powered up actuators! This leads to actuator damage!

4.12 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).

⇒ 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.

4.13 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.

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.

4.14 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%.

4.15 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

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

1.	**Speed setting system**	39	Plug
01	Crank angle sensor unit	40	Stop valve
02	Crank angle sensor unit	41	Injection control valve
04	Speed pick-ups	42	Fuel quantity piston
		43	Actuator piston
2.	**Starting system**	46	Fuel leakage pipe
03	Shut-off valve for starting air	47	Injection pipe
04	Non-return valve	48	Fuel leakage pipe pressurized
05	Control valve	49	Fuel leakage pipe
06	Drain and test valve	52	Fuel overpressure safety valve
07	Starting valve	53	Pressure retaining valve
08	Flame arrester	55	Camshaft
09	Relief valve	67	Non-return valve
10	Handwheel for -off valve	76	Rail valve
13	Blocking valve on turning gear	77−1	Pressure transmitter
21	Venting valve	77−2	Pressure transmitter
27	Venting valve	81−1	Non-return valve
		81−2	Non-return valve
3.	**Fuel system**	81−3	Non-return valve
01	Injection valve	82	Drain screw
02	Injection control unit		
03	Fuel quantity sensor	**4.**	**Exhaust valve drive**
05	Fuel rail	01	Exhaust valve
06	Fuel pressure control valve	02	Air spring
08	Fuel shut-down pilot valve	03	Valve drive
10	Level switch	06	Non-return valve with throttle
14	Fuel pumps	08	Air spring venting
15	Fuel booster pump (plant)	10	Exhaust valve control unit
17	Leakage inspection point	11	Servo oil rail
19	Cut-out device (tool)	15	Servo oil pump
21	Fuel pump actuator	16	Pressure control valve
22	Non-return valve	17	Leakage inspection point
24	Fuel inlet pipe	18	Level switch
29	Fuel rising pipe	19	Throttle

Designations (Description to 4003–1, 4003–2 and 4003–3)

20	Automatic filter	76	Rail valve
22	Crankcase	77–1	Pressure transmitter
23	Safety valve	77–2	Pressure transmitter
24–1	Non-return valve	82	Drain screw
24–2	Non-return valve	88	Servo oil service pump
30–5	Stop valve		
37	Stop valve	**7.**	**Monitoring**
39	Gear wheel crankshaft	18	Collector for leakage oil from air spring
41	Intermediate wheel supply unit		
42	Gear wheel	**8.**	**Cylinder lubricating system**
44	Gear wheel	06	Cylinder lubricating pump
45	Pinion	11–1	Pressure reducing valve
50	Carrier with shearable overload protection	12	Lubricating quill with injection nozzle
51	Supply pipe	13	Non-return valve
53	Non-return valve	17	Cylinder lube oil filter
54	Flow sensor	19	Measurement tube
55	Servo oil rising pipe		
63	Servo oil return piping	**9.**	**Engine room**
66	Actuator pipe	01	Starting air bottles
68	Disc spring	02	Oil pump (low pressure)
69	Two-stage piston	04	Oil filter
70–1	Stroke sensor	05	Oil cooler
71	Stroke measuring device		

Designations (Description to 4003−1, 4003−2 and 4003−3)

	Sensors		**Actuators**
PS3121A	Cyl. lube oil filter difff. pres.	**CV**7231−33C	Fuel pump actuator No. 1−3
		CV7221−22C	Servo oil pump actuator No. 1−2
PT2041A	Cyl. lubr. servo oil free end		
PT2046A	Cyl. lubr. servo oil leakage	**ZV**7201−08A/B	Exhaust valve actuator Cyl. 1−8
PT2071C	Servo oil rail pressure	ZV7201−08C−H	Injection control unit Cyl. 1−8
PT2072C	Servo oil rail pressure	ZV7241−48C	Start air pilot valve Cyl. 1−8
PT3131−38C	Cyl. lube oil Cyl. 1−8	ZV7131−38C	Cylinder lubrication valve Cyl. 1−8
PT3421A	Fuel before supply unit	ZV7061S	EM. STOP (Fuel Shd pilot valve)
PT3461C	Fuel rail pressure	ZV7013C	Common start valve 1
PT3462C	Fuel rail pressure	ZV7014C	Common start valve 2
LS2055A	Servo oil supply unit, leak		
LS3426A	Fuel supply unit, leak		
LS3444A	Rail unit general leak		
LS3446A	Injection control unit, pipe for injection valve or fuel overpressure safety valve leak		
FS2061−62A	Servo oil pump 1−2 (flow)		**Local indications**
		PI2041L	Cylinder lubr. servo oil free end
ST5131−33C	Crank angle pickup A1−C1	PI2051L	Servo oil pumps inlet pressure
ST5134−36C	Crank angle pickup A2−C2	PI2071M	Servo oil rail pressure
		PI3421L	Fuel before pressure retaining valve
ZS5016C	Turning gear disengaged	PI3431L	Fuel after pressure retaining valve
ZS5018C	Start air shut-off valve man. closed	PI3462M	Fuel rail pressure
ZS5123C	Engine TDC signal		
ZS5124C	Engine BDC reference signal	**SI**5101M	Engine speed
ZS5125C	Engine TDC reference signal		
ZT5421−28C	Exhaust valve 1−8, open and close positions (driving end)	**XS**2053A	Servo oil filter, failure
ZT5461−68C	Fuel injection quantity cylinder 1−8		

Remark: Systems are drawn for engines in STOP position, reversed AHEAD with unpressurised circuits.

Circuits:

- Starting air and cooling water
- Control air
- Low pressure oil
- High pressure oil
- Low pressure fuel
- High pressure fuel
- Heating

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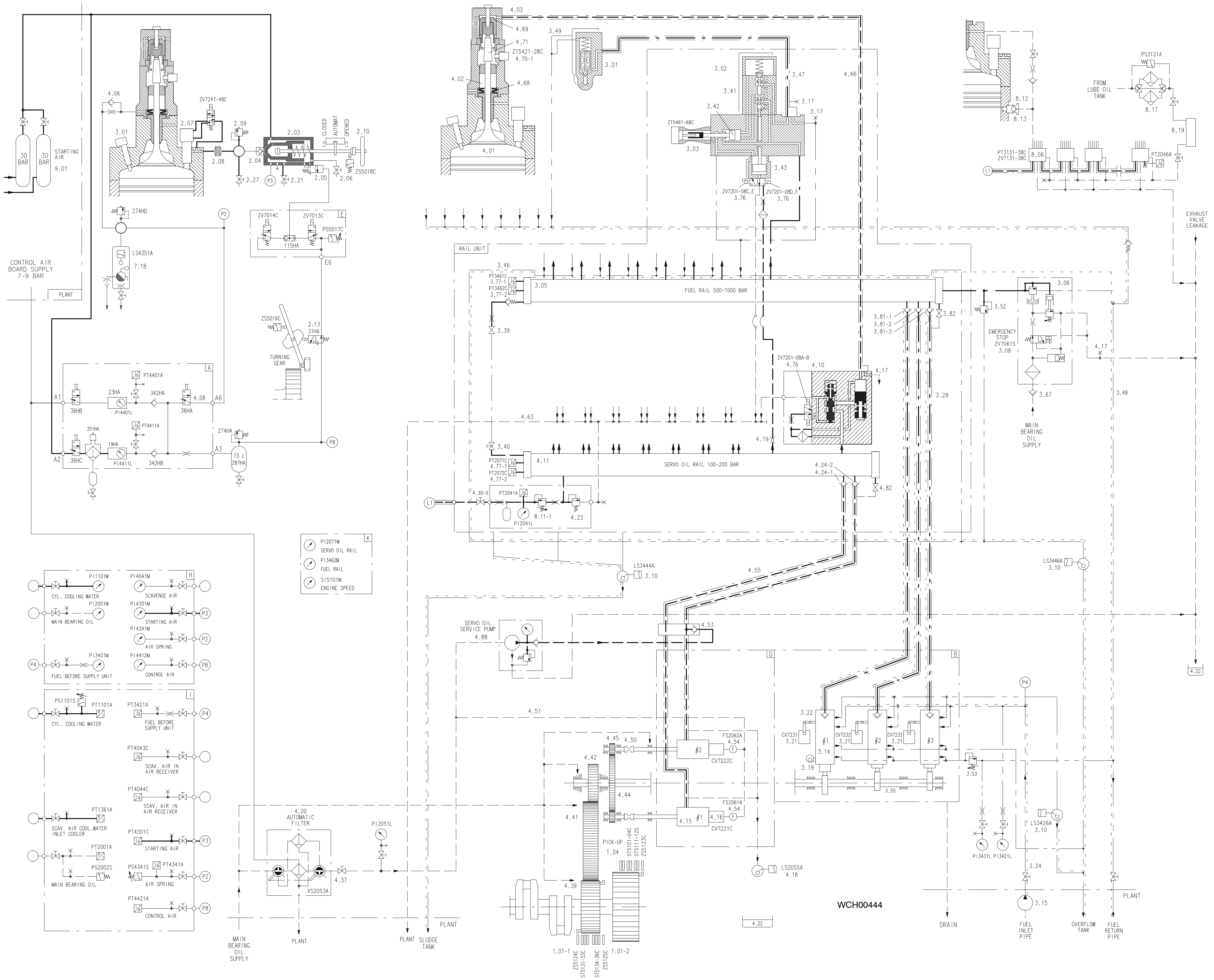
Control Diagram



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Control and Auxiliary Systems

Detailed Control Diagrams with Interfaces to the Plant

On the following pages 3 to 14 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. range	Page
Air supply	30	3
Bearing and cooling oil supply	40	4
Hydraulic and servo oil supply	50	5
Fuel supply	60	6
Starting system	110	7
Speed control and crank angle sensor unit	150	8
Cylinder lubrication pulse	170	9
Exhaust gas / turbocharger type TPL and MET / scavenge air / auxiliary blower (1-stage scavenge air cooler)*	300	10
Exhaust valve drive, air spring	310	11
Fuel injection	330	12
Cooling water (cylinder)	340	13
Main bearing & crosshead bearing lubrication, piston cooling, oil mist detector (OMD)	350	14

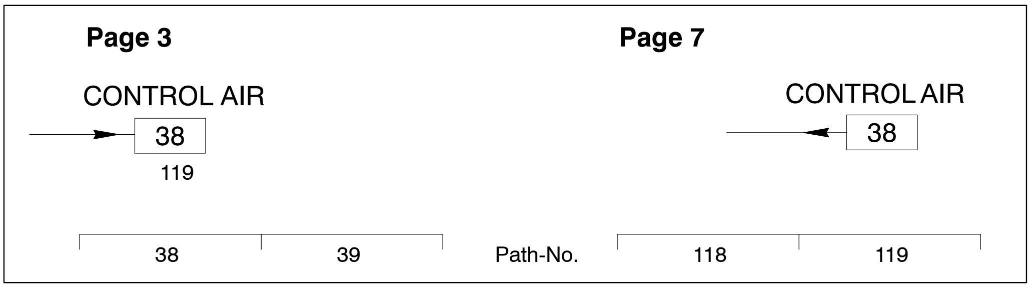
* Design execution alternative

(continuation on page 2)

Remarks for easier understanding of the individual diagrams:

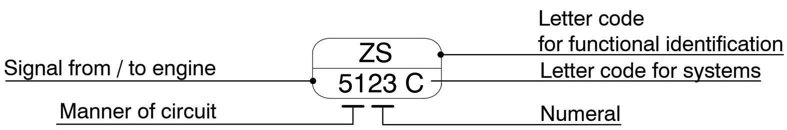
Each diagram has a path No. range allotted to the system part, which is subdivided at the page edge (on the right) into 10 sections. These **path numbers** designate the junctions from one diagram to the other.
One piping leading away in the direction of the arrow is marked with the path No. (framed) which lies above this No. in the section part. The number below the rectangle is the target path number.

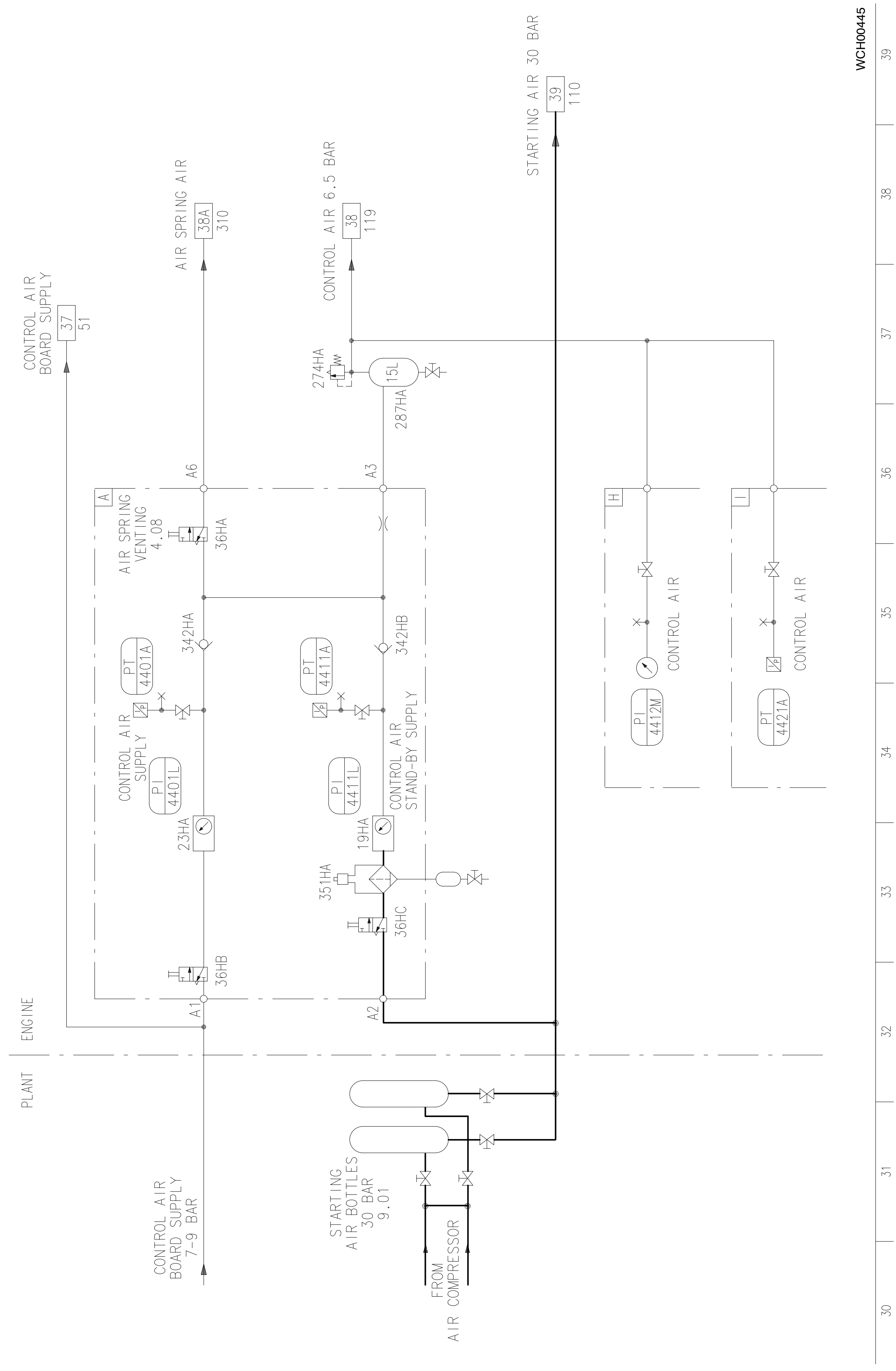
Example:



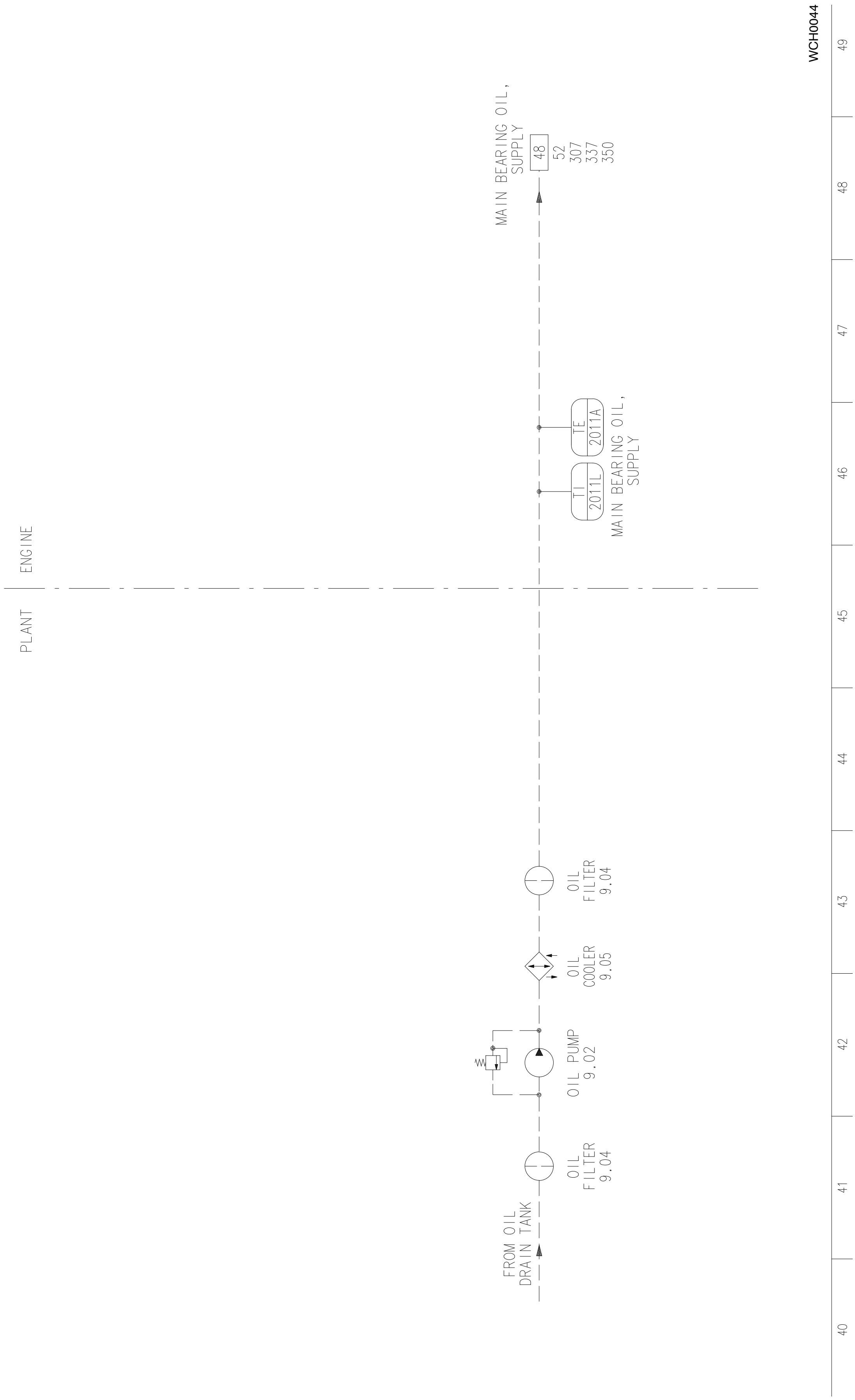
In this example the control air tube carrying number 38 (page 3) leads to target path No. 119 (page 7). Where two equal path numbers appear additional letter indications are used for identification, e.g. on page 3 No. 38 and 38A.

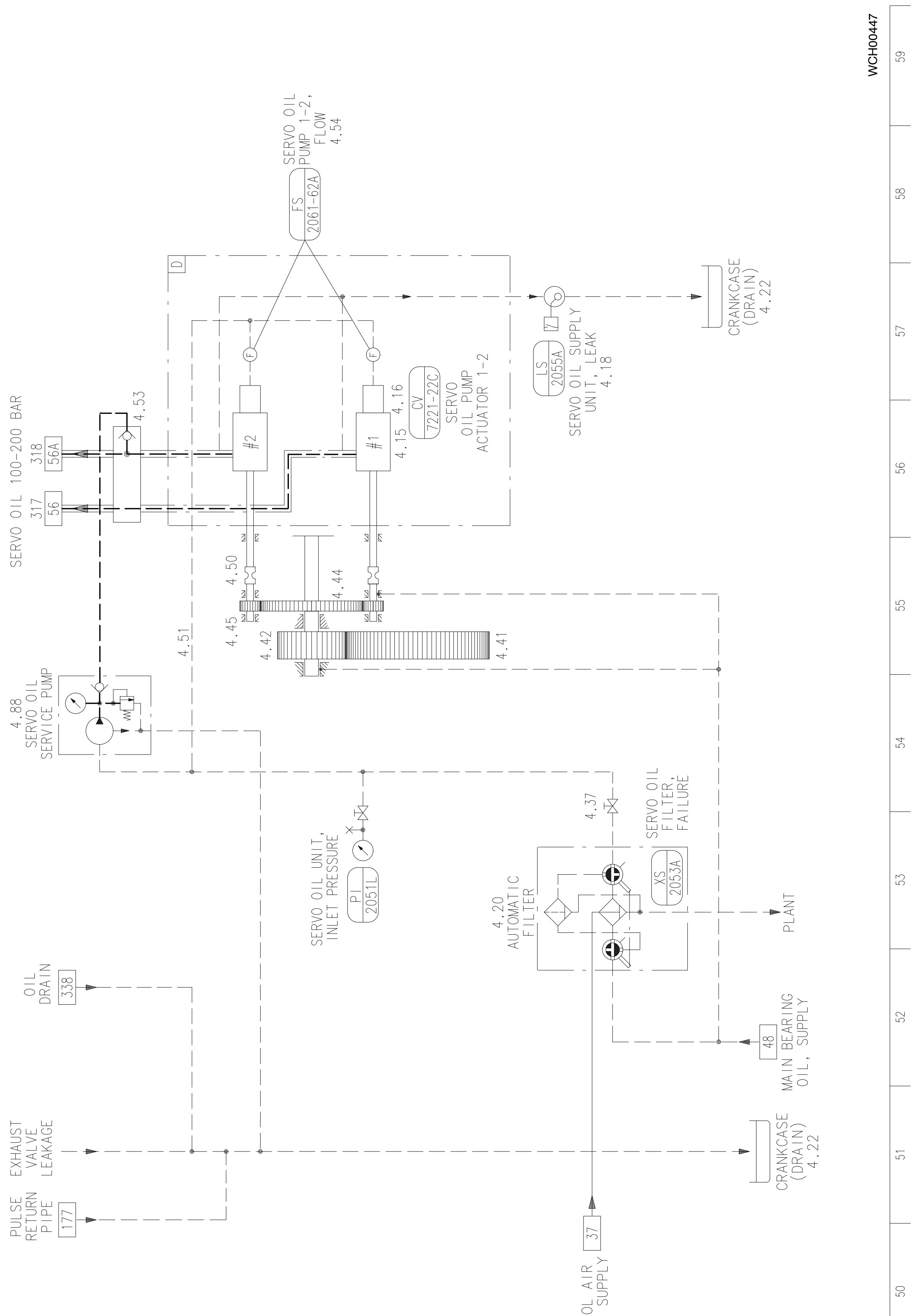
The **interfaces** to the remote control as well as local alarm and monitoring instruments have been designated by expressive symbols (box with rounded corners).



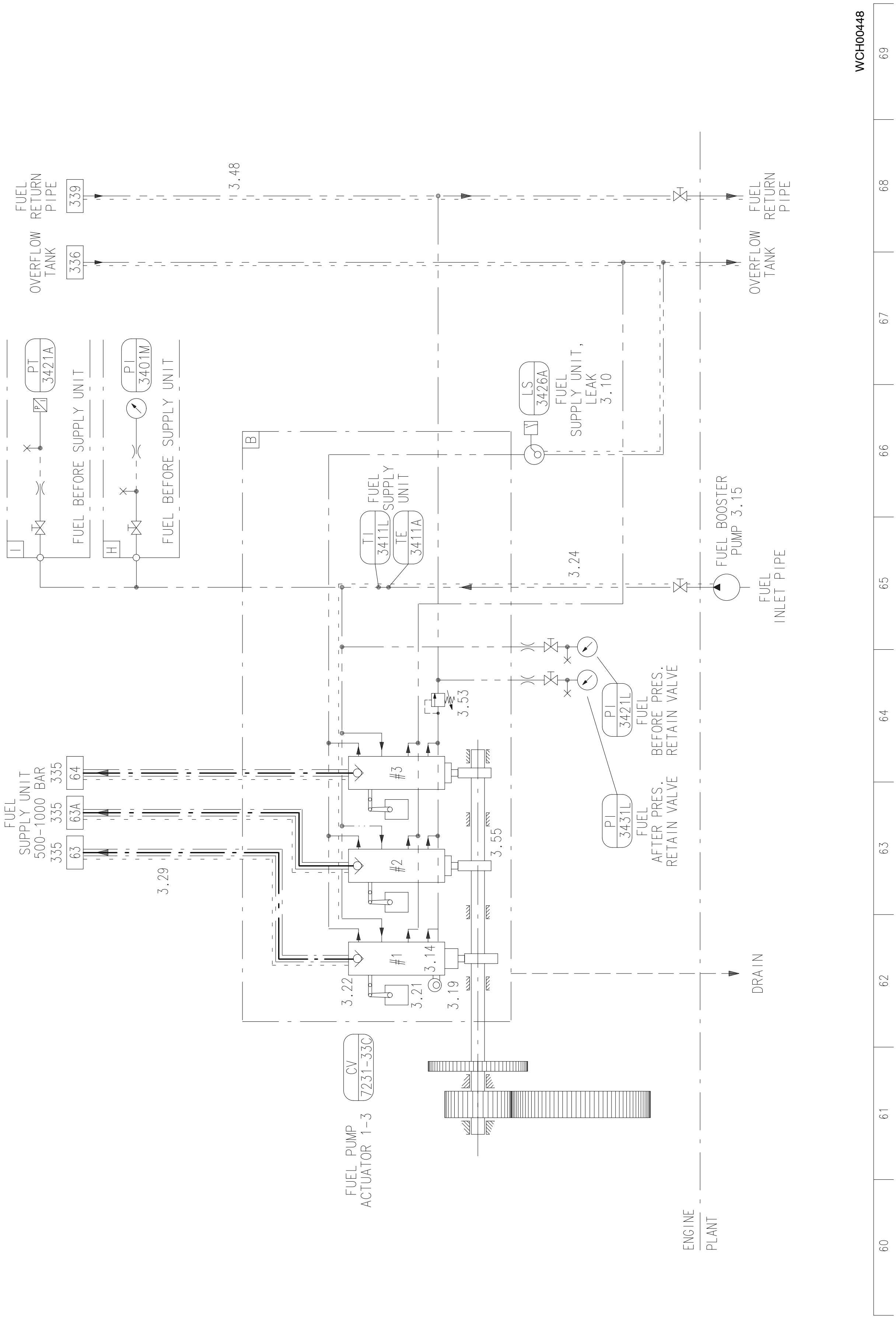

WCH00445
CONTROL AIR
BOARD SUPPLY
37
51
AIR SPRING AIR
38A
310
CONTROL AIR 6.5 BAR
38
119
STARTING AIR 30 BAR
39
110
274HA
15L
287HA
A6
A3
A
AIR SPRING
VENTING
4.08
36HA
342HA
342HB
PT
4401A
PT
4411A
CONTROL AIR
SUPPLY
PI
4401L
PI
4411L
CONTROL AIR
STAND-BY SUPPLY
23HA
19HA
351HA
36HC
36HB
A1
A2
ENGINE
PLANT
H
CONTROL AIR
PI
4412M
I
CONTROL AIR
PT
4421A
STARTING
AIR BOTTLES
30 BAR
9.01
CONTROL AIR
BOARD SUPPLY
7-9 BAR
FROM
AIR COMPRESSOR
30
31
32
33
34
35
36
37
38
39

Bearing and Cooling Oil Supply

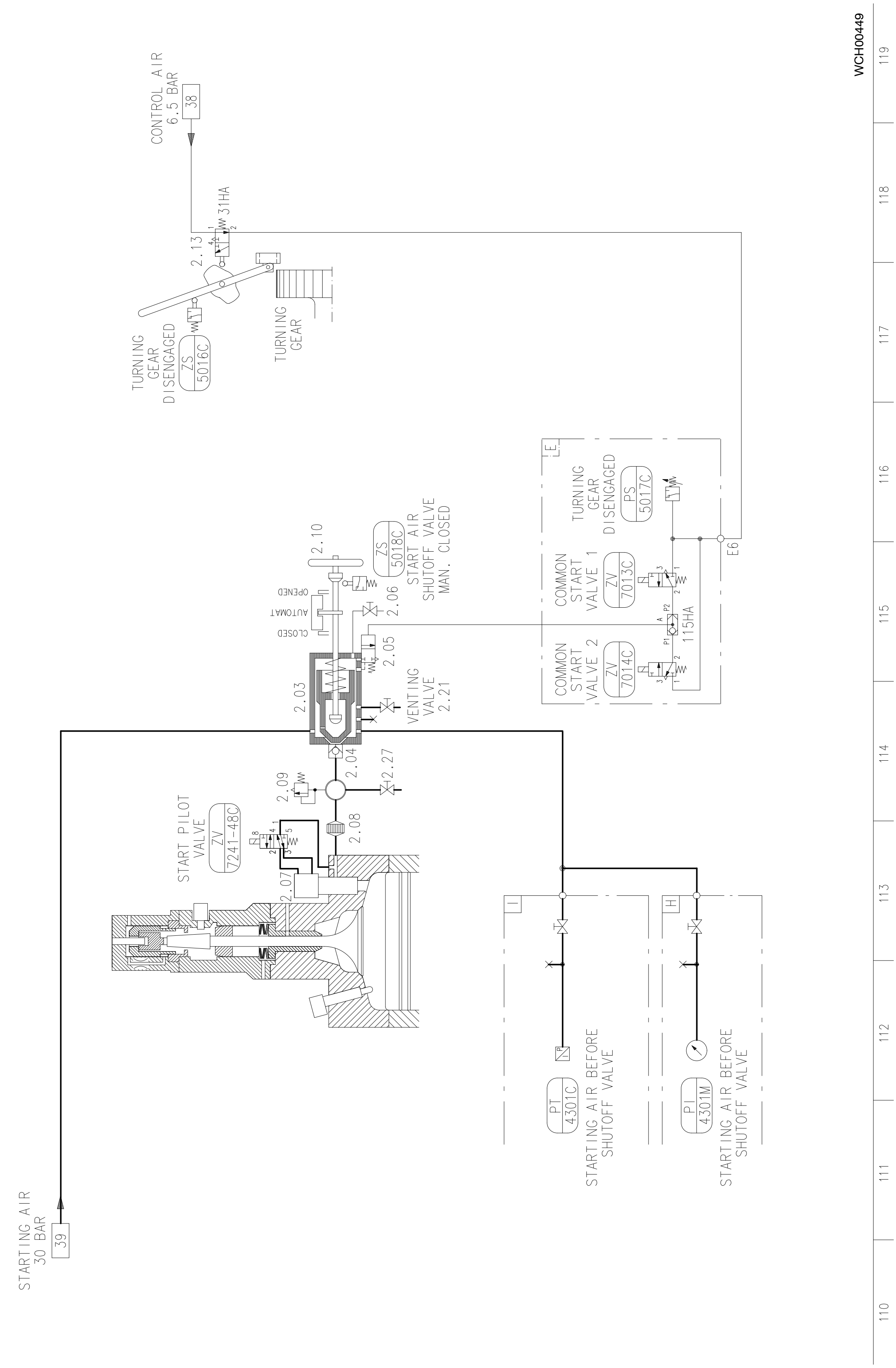



WCH00447
SERVO OIL 100-200 BAR
317
56
318
56A
4.53
SERVO OIL PUMP 1-2, FLOW 4.54
FS
2061-62A
D
F
F
#2
#1
4.16
4.15
CV
7221-22C
SERVO OIL PUMP ACTUATOR 1-2
LS
2055A
SERVO OIL SUPPLY UNIT, LEAK 4.18
CRANKCASE (DRAIN) 4.22
4.50
4.44
4.45
4.42
4.41
4.51
4.88 SERVO OIL SERVICE PUMP
SERVO OIL UNIT, INLET PRESSURE
PI
2051L
4.37
SERVO OIL FILTER, FAILURE
XS
2053A
4.20 AUTOMATIC FILTER
PLANT
OIL DRAIN
338
MAIN BEARING OIL, SUPPLY
48
EXHAUST VALVE LEAKAGE
CRANKCASE (DRAIN) 4.22
PULSE RETURN PIPE
177
CONTROL AIR BOARD SUPPLY
37
59
58
57
56
55
54
53
52
51
50

Fuel Supply

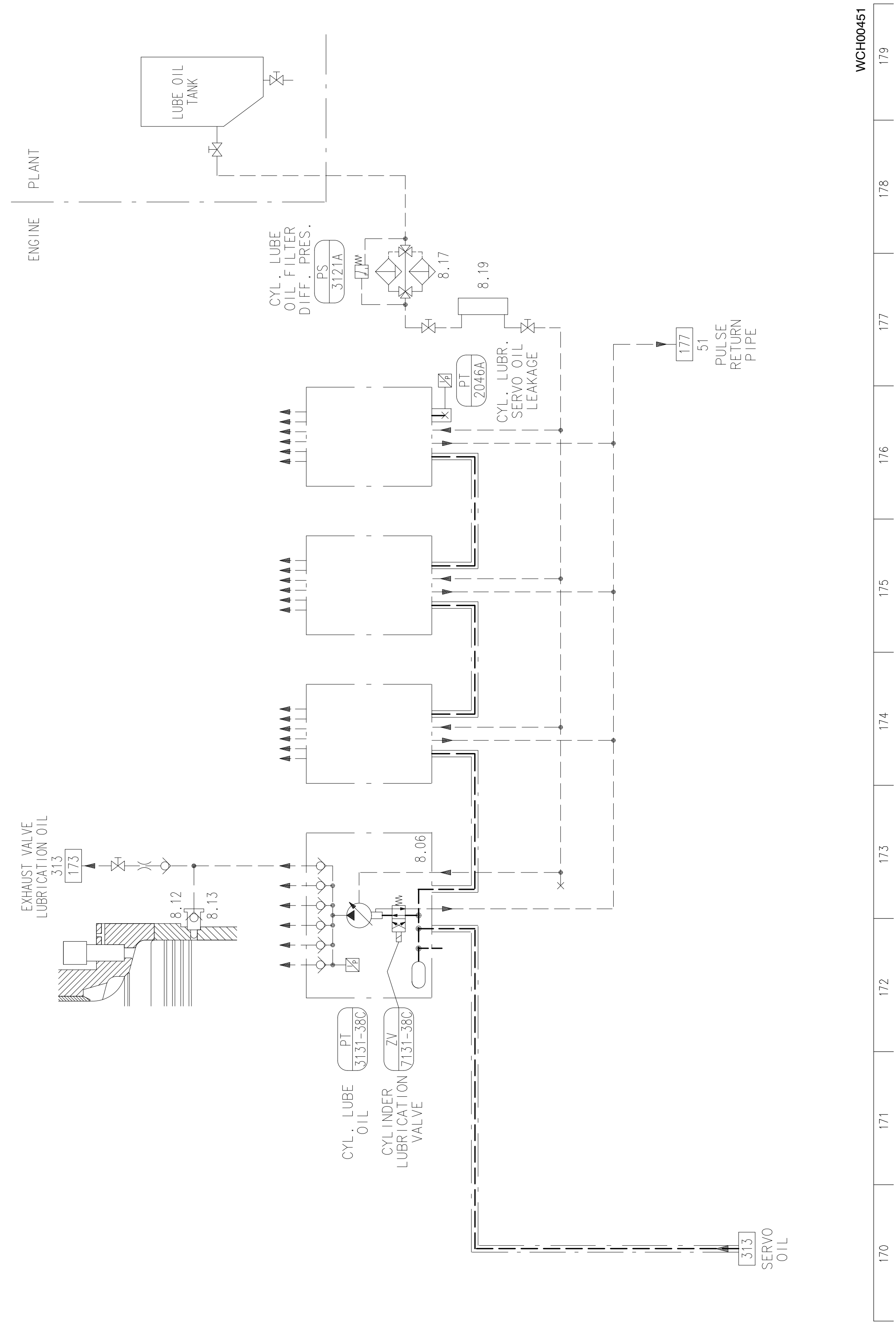

WCH00448
FUEL RETURN PIPE
339
3.48
OVERFLOW TANK
336
PT 3421A
PI 3401M
FUEL BEFORE SUPPLY UNIT
I
H
B
LS 3426A
FUEL SUPPLY UNIT, LEAK 3.10
FUEL SUPPLY UNIT
TI 3411L
TE 3411A
3.24
FUEL BOOSTER PUMP 3.15
FUEL INLET PIPE
3.53
PI 3421L
FUEL BEFORE PRES. RETAIN VALVE
PI 3431L
FUEL AFTER PRES. RETAIN VALVE
FUEL SUPPLY UNIT 500-1000 BAR
335
64
63A
63
3.29
#3
#2
#1
3.55
3.14
3.22
3.21
3.19
DRAIN
CV 7231-33C
FUEL PUMP ACTUATOR 1-3
ENGINE
PLANT
69
68
67
66
65
64
63
62
61
60

Starting System



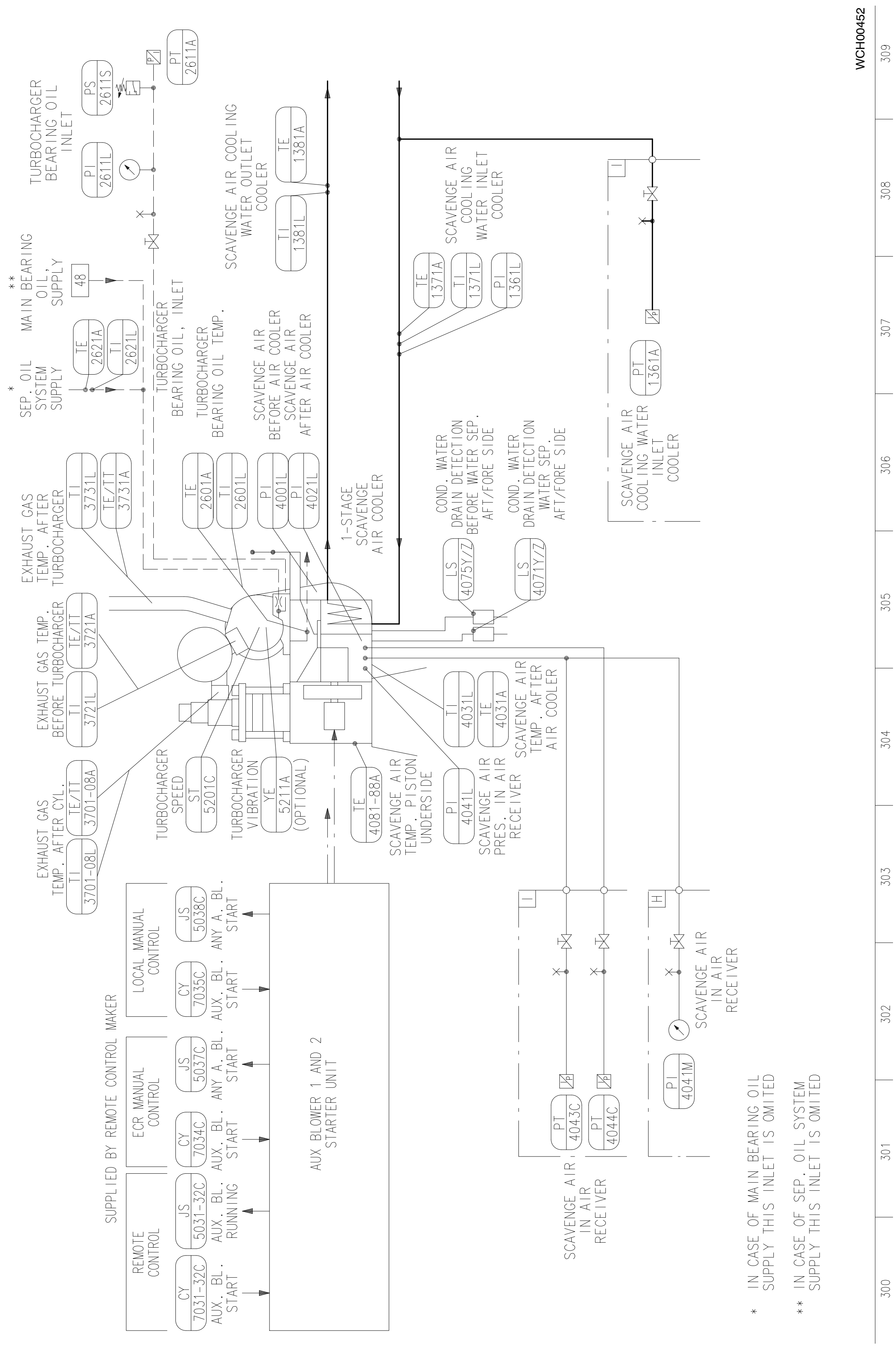

WCH00450
K
SI
5101M
ENGINE SPEED
ZS
5123C
ENGINE TDC SIGNAL
ST
5101-04C
ENGINE SPEED
ST
5111-12S
ENGINE SPEED
PICK UP
1.04
ZS
5125C
PICKUP TDC/REF
ST
5134-36C
PICKUPS
A2,B2,C2
CRANK ANGLE
SENSOR
UNIT 2
1.01-2
4.39
ZS
5124C
PICKUP BDC/REF
ST
5131-33C
PICKUPS
A1,B1,C1
CRANK ANGLE
SENSOR
UNIT 1
1.01-1
CRANKSHAFT
159
158
157
156
155
154
153
152
151
150

Cylinder Lubrication Pulse

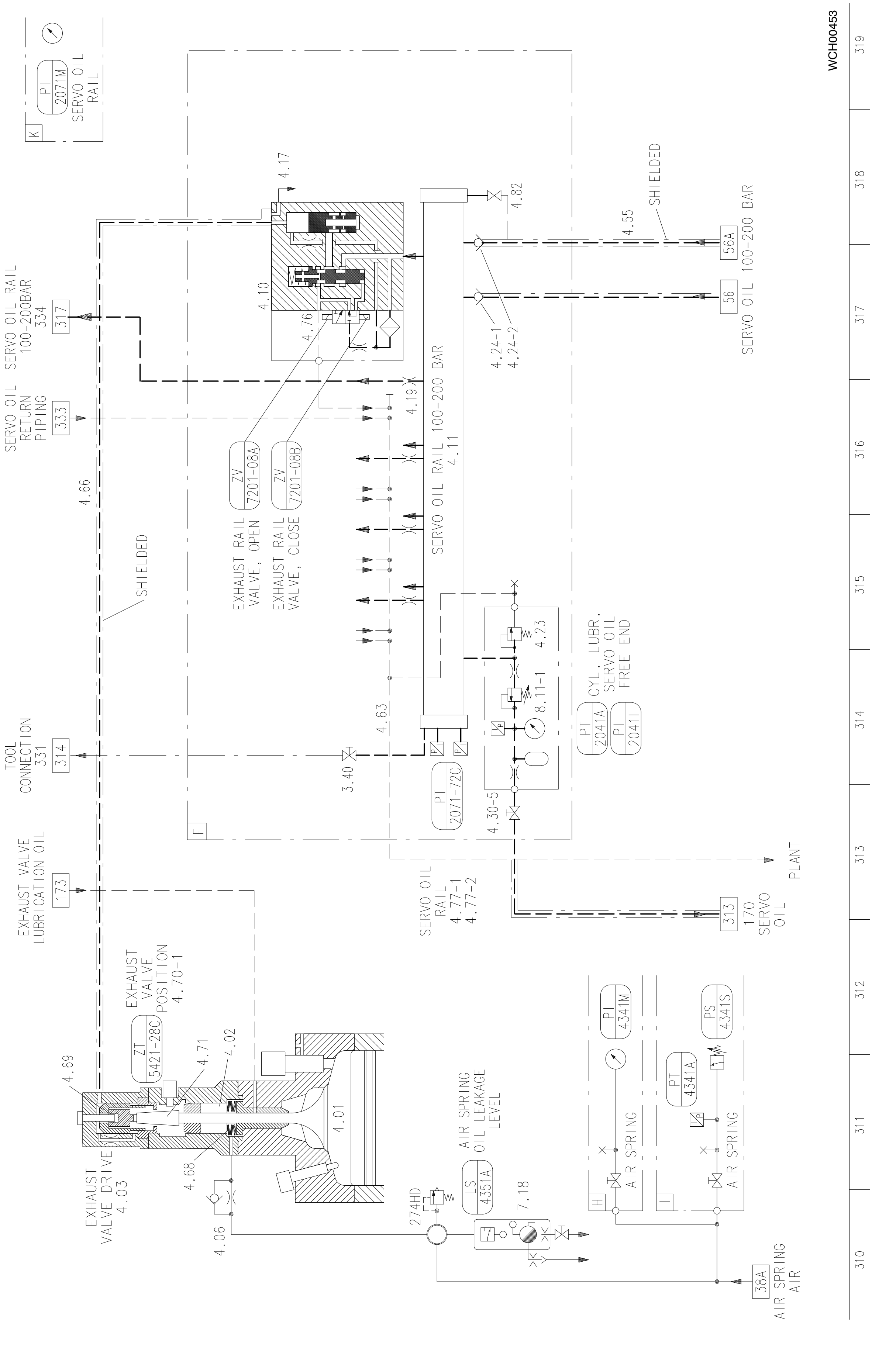


Exhaust Gas / Turbocharger Type TPL and MET / Scavenge Air / Auxiliary Blower

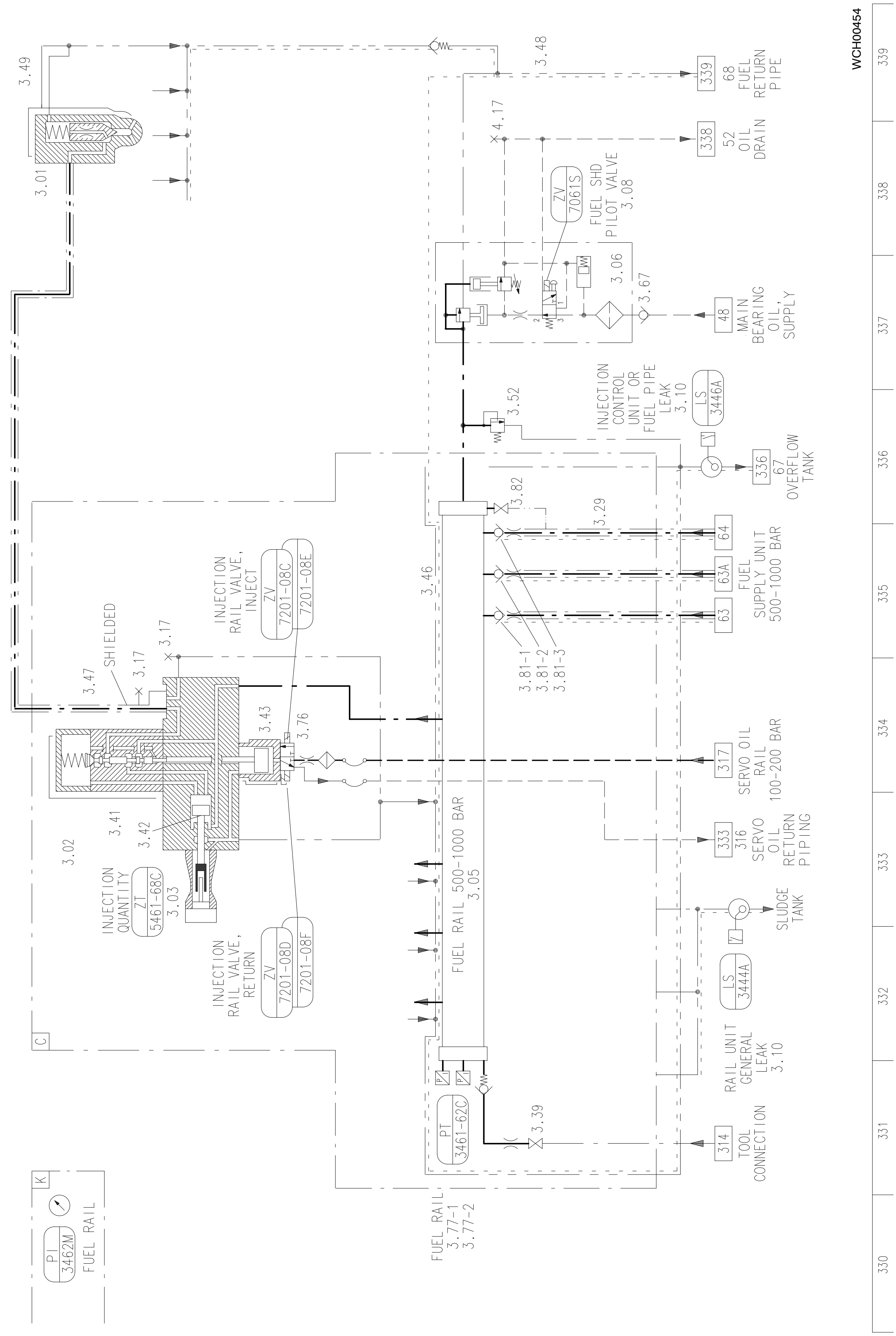
for 1-Stage Scavenge Air Cooler



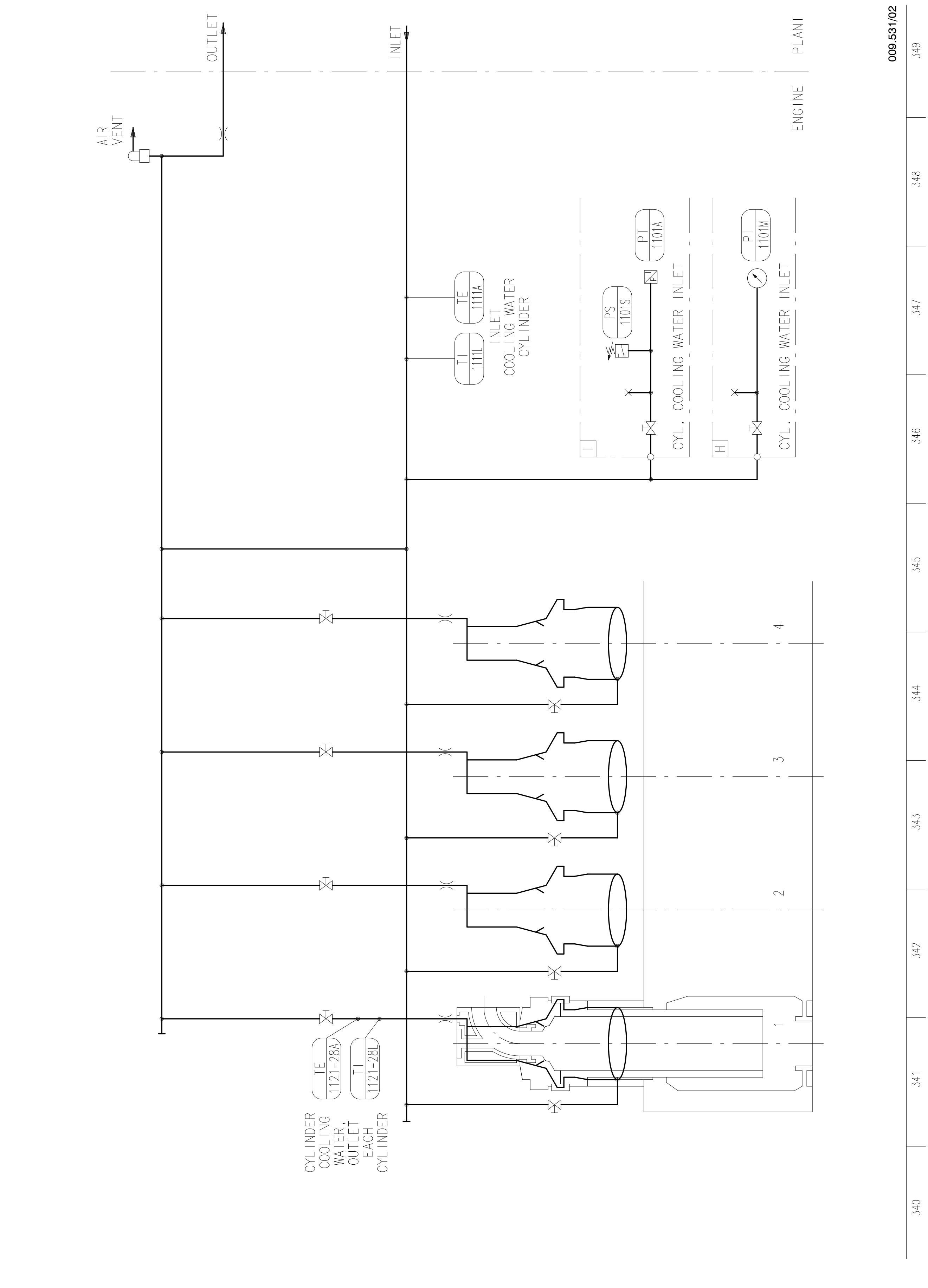
Exhaust Valve Drive / Air Spring



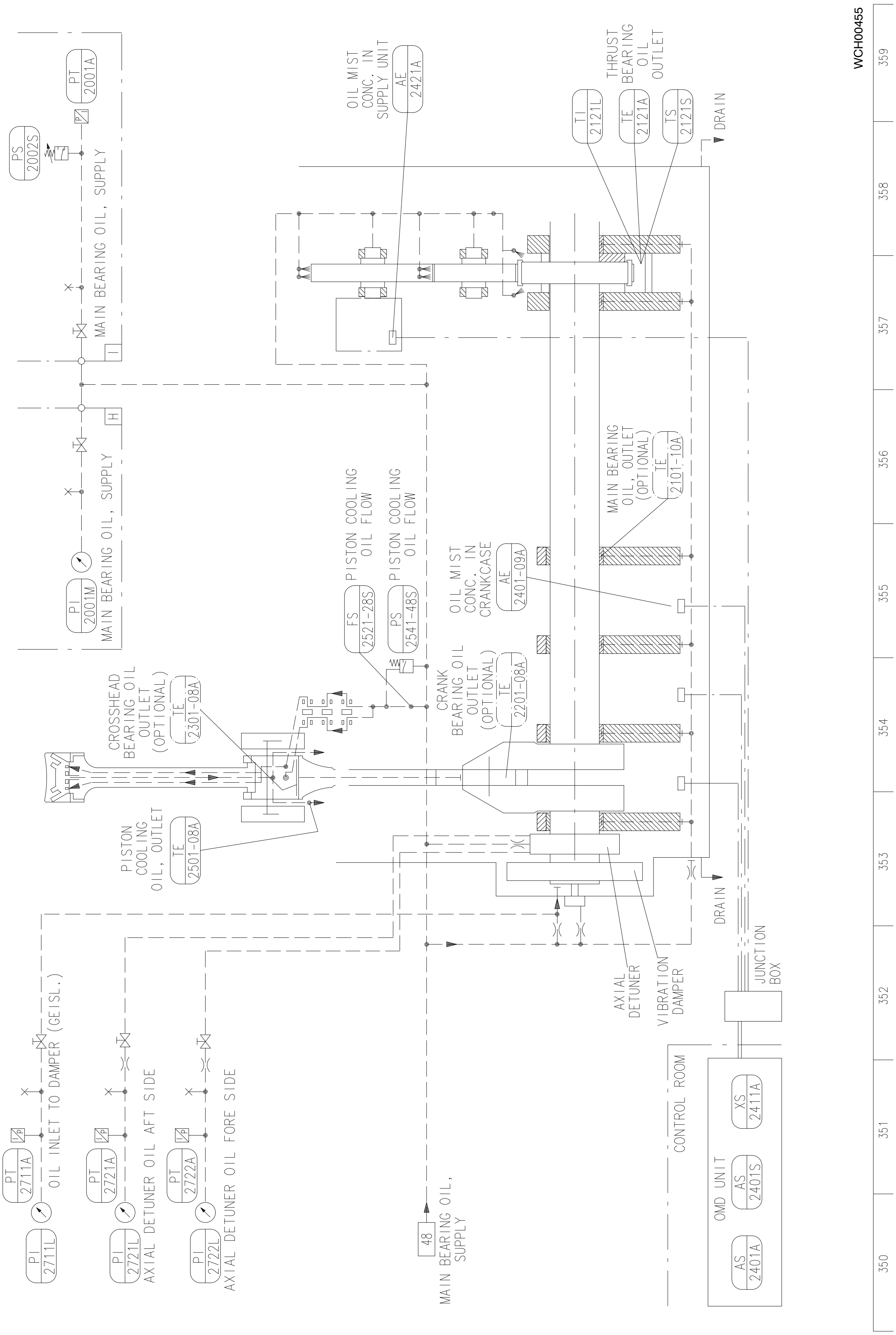
Fuel Injection



Cooling Water (Cylinder)



Main Bearing & Crosshead Bearing Lubrication / Piston Cooling / OMD



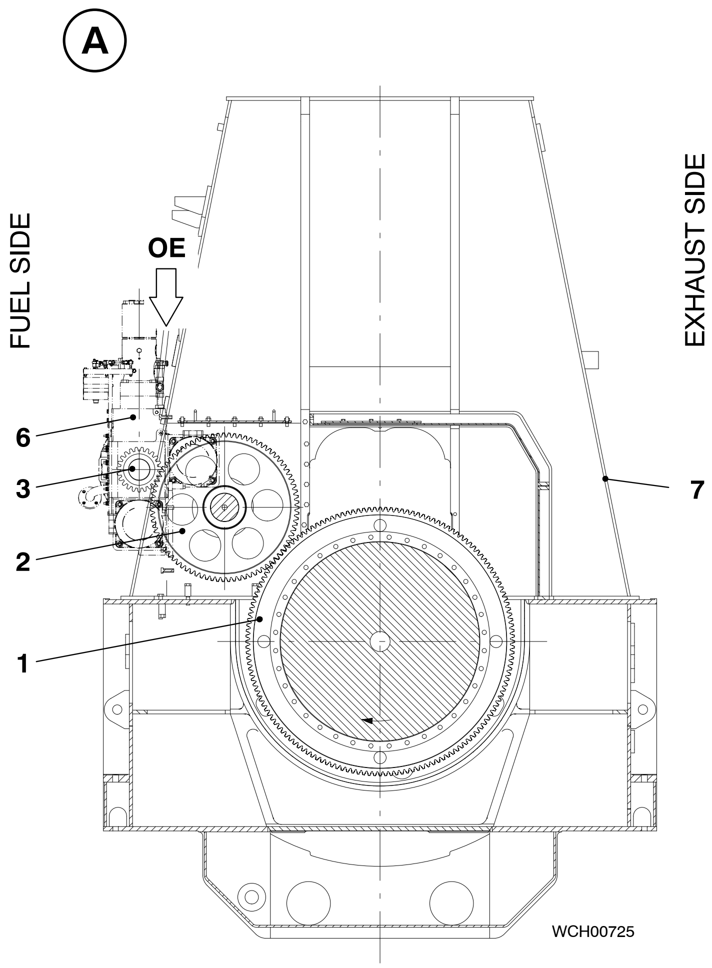
1. General

The drive of the supply unit 6 is arranged at the driving end of the engine. The camshaft of the supply unit is driven by the gear wheel 1 on the crankshaft 5 via intermediate wheel 2. The camshaft turns in the same running direction as the crankshaft (see also Supply Unit 5552−1).

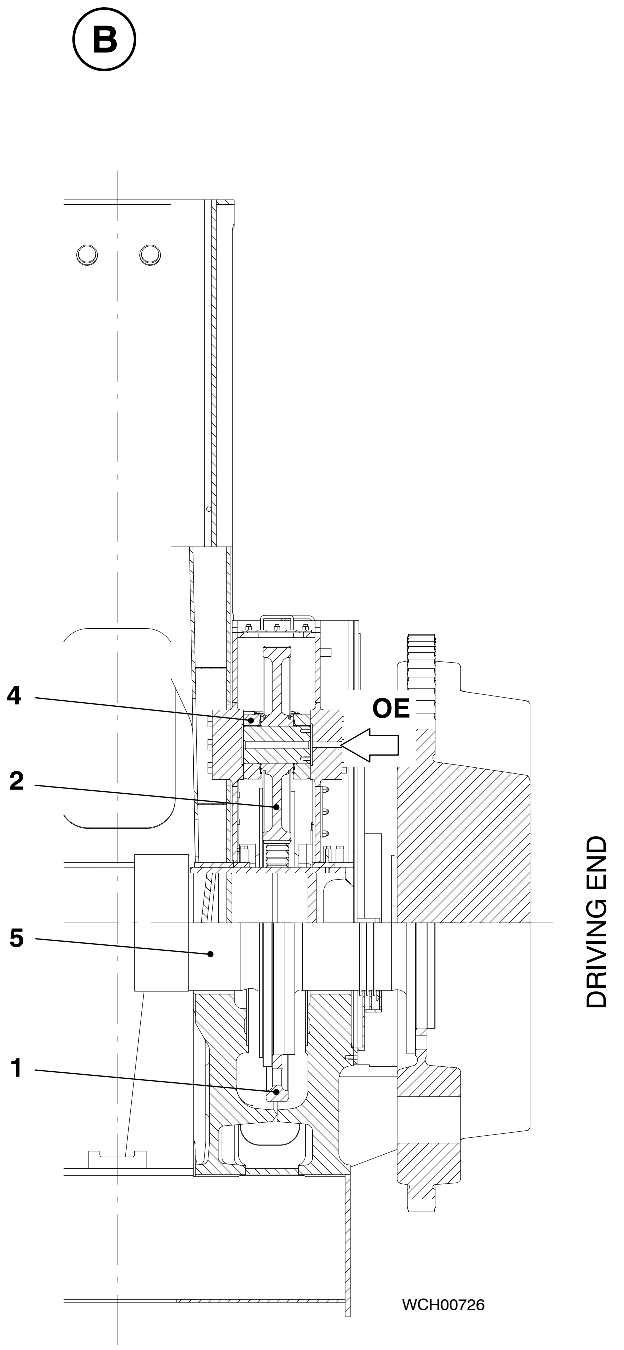
The condition of the tooth profile must be checked periodically. In particular new gear wheels must be checked frequently after a short running-in period (see Maintenance Manual 4103−1).
Should abnormal noises be heard from the area of the gear train, their cause must be established immediately.

2. Lubrication

The bearing 4 of the intermediate wheel 2 and the bearings for the camshaft are lubricated with bearing oil via connections 'OE'. The gear teeth are supplied with bearing oil through the spray nozzles (see Lubricating Oil Diagram 8016−1).



Drive Supply Unit



Key to Illustrations: 'A' Cross section
'B' Longitudinal section

1 Gear wheel on the crankshaft
2 Intermediate wheel
3 Gear wheel for supply unit
4 Bearing for intermediate wheel
5 Crankshaft
6 Supply unit
7 Column

OE Oil inlet

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 the starting air bottles 9.01.

⇒ Close the shut-off valve by means of the handwheel 5 (locking lever 6 in position CLOSED).

⇒ Open the venting valve 2.21 (by that the shut-off valve and the air feed pipes are vented).

⇒ Open the 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 the 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.

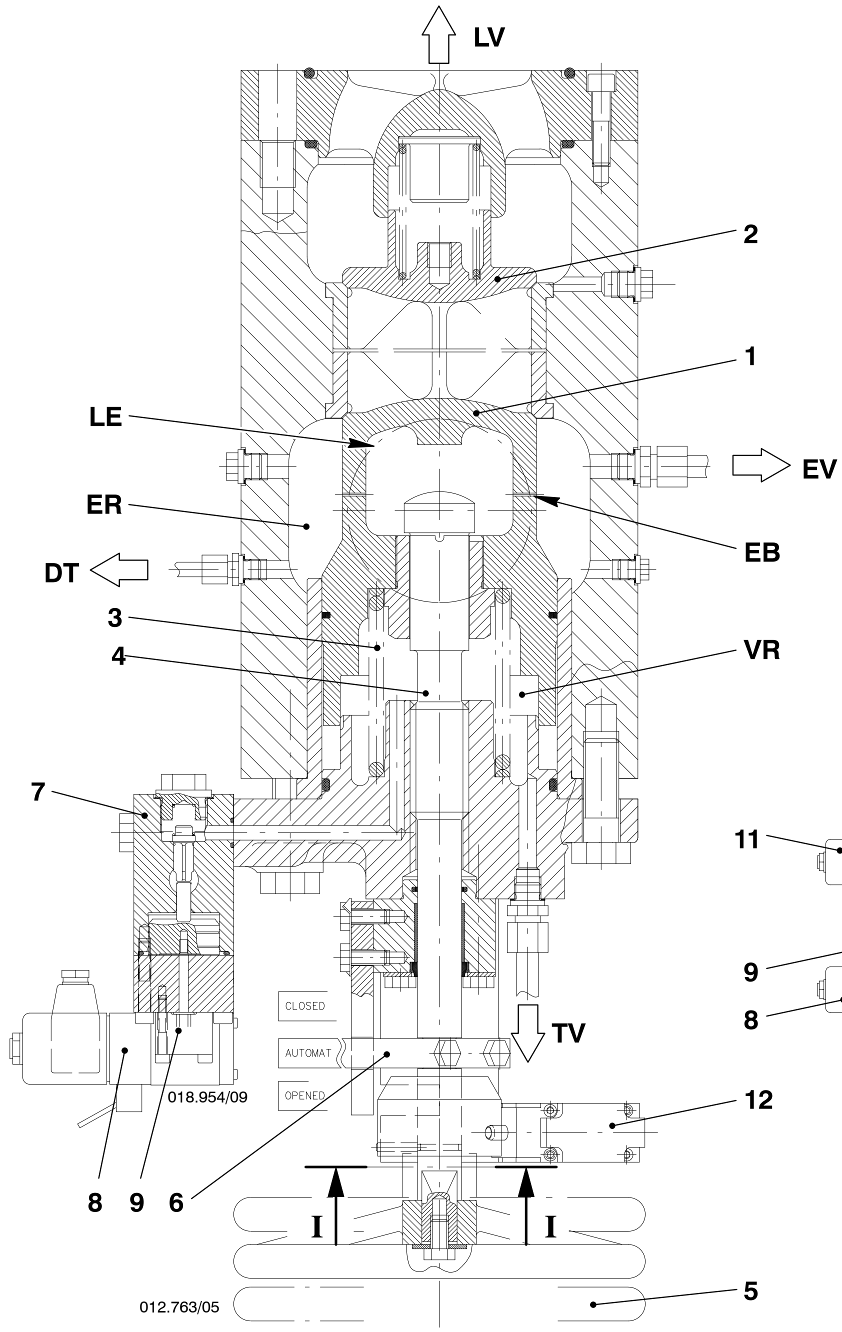
End of start:

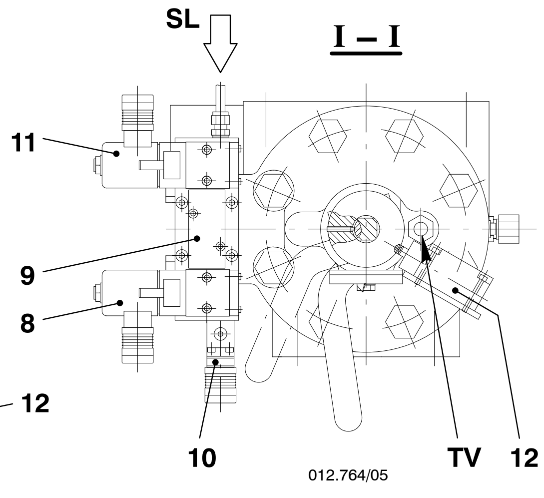
Control valve 7 closes space ’VR’ which again fills with starting air via the balancing bores ’EB’. Valve 1 shuts.

Function check:

When valve 2.06 is actuated on the ready-to-start engine, space ’VR’ is vented and valves 1 opens audibly.

Shut-off Valve for Starting Air





Key:

1	Valve	DT	To instrument panel and pressure transmitter PT4301C
2	Non-return valve	EB	Balancing bore
3	Spring	ER	Air inlet space
4	Spindle	EV	To venting valve 2.21
5	Handwheel	LE	Air inlet piping (drawn-in hidden)
6	Locking lever	LV	To starting air distributor piping and starting valves 2.07
7	Control valve 2.05	SL	Control air
8	Common start valve ZV7014C	TV	To test valve 2.06
9	Duplex non-return valve 115HA	VR	Valve space
10	Pressure switch PS5017C		
11	Common start valve ZV7013C		
12	Limit switch ZS5018C		

1. General

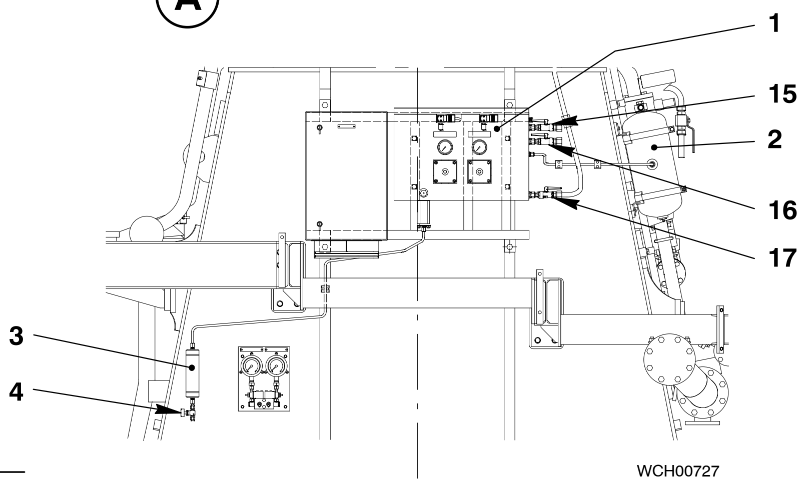
The compressed air required for the air spring of the exhaust valves and the turning gear interlock is primarily taken from the shipboard system. The air must be clean and dry in order to prevent blockages occurring in the control units.

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.

A



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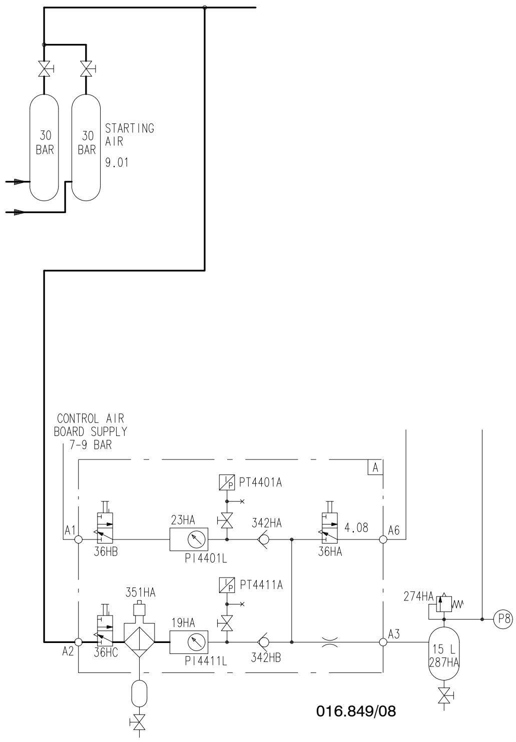
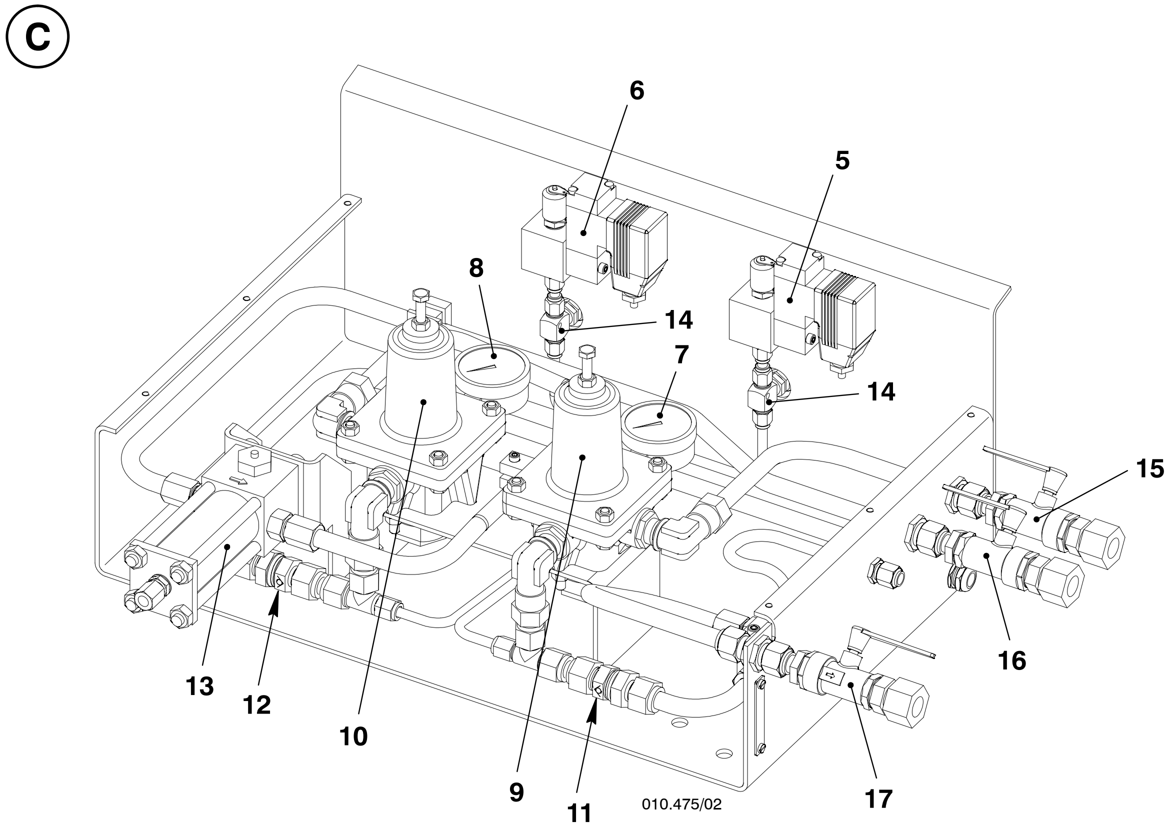


Control Air Supply



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 A
2 Air bottle 287HA
3 Condensate water container
4 Condensate water drain valve
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
12 Non-return valve 342HB
13 Filter 351HA

14 Control valve
15 Shut-off and venting cock 36HB for control air
16 Shut-off and venting cock 36HC for starting air
17 Shut-off and venting cock 36HA (4.08) for air spring

A1 Control air from board system
A2 Starting air from starting air system
A3 Connection to air bottle 287HA
A6 Air spring air supply

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

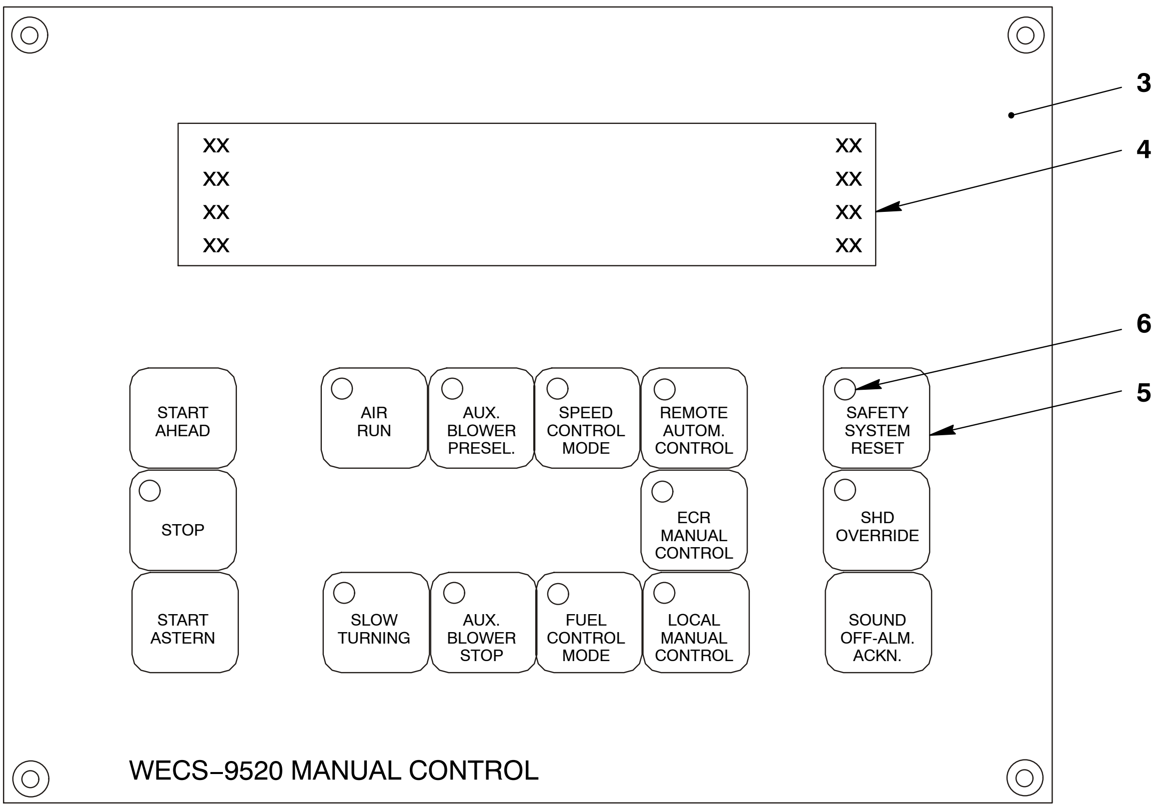
The WECS–9520 manual control panel, supplied by Winterthur Gas & Diesel Ltd. to the remote control manufacturers, contains buttons and indications necessary for running the engine from the local manoeuvring stand (in backup mode).

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 WinGD.

Operating buttons and their functions:

A



Local Control Panel

Button			Function	Purpose and action
Designation	**Colour**	**LED**		
START AHEAD	GREEN	none	Engine START AHEAD Interruption running ASTERN (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 Interruption running AHEAD (reversing from AHEAD - ASTERN)	Auxiliary blower preselect signal is generated automatically
AIR RUN	GREY	GREEN	Engine start with starting air only (fuel command adjusted to ’zero’) After a longer shut-down or maintenance works with opened indicator valves	LED lights up as long as button is pressed 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 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 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) Slow turning sequence can be stopped at any time by pressing button once again	LED blinks during SLOW TURNING 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)

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 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) Transfer from REMOTE AUTOM. CONTROL (Remote Control) to LOCAL MANUAL CONTROL (Local Control)	After takeover of control both green LEDs light up constantly 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 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 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) Information about version and check of software on display	(Shut-down) alarm indications change from blinking to constantly lighting up Pressing button for approx. 5 seconds

Display:

- Speed setting
- Fuel injection quantity (fuel command)
- Fuel rail pressure
- Servo oil rail pressure

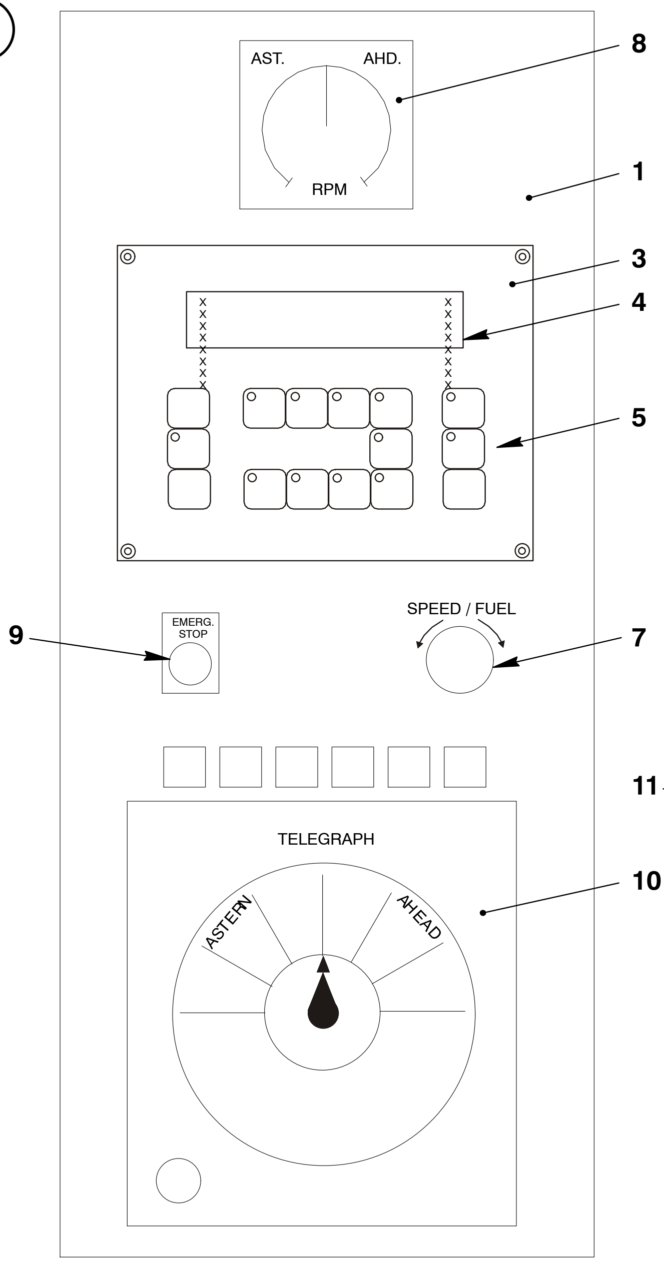
Furthermore, important conditions (statuses) are displayed in 3rd and 4th scanning line on the left as:

- 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 3rd scanning line)

2.2 Remote control

- Rotary knob for speed setting or fuel injection quantity adjustments
- Emergency stop
- Telegraph

B



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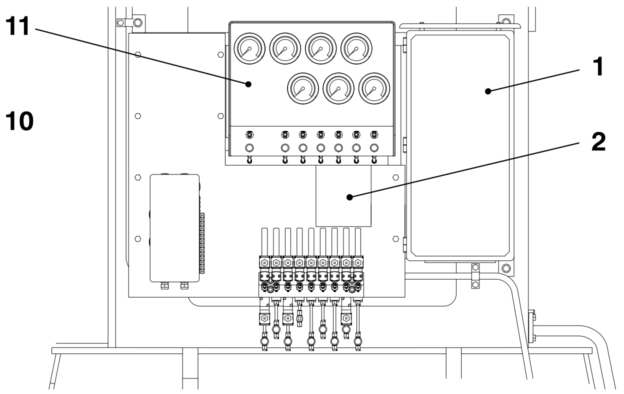


WCH00735

FREE END

Key to Illustrations:

’A’ **WECS−9520 Manual control panel**
’B’ **Front view of local control panel** (example)
’C’ **Arrangement of local control panel**

1 Control panel
2 Nameplate with brief instruction
3 WECS−9520 manual control panel
4 Display
5 Attendance buttons
6 LEDs
7 Rotary knob (speed / fuel)
8 ME tachometer
9 Emergency stop button
10 Telegraph
11 Instrument panel

1. General

To measure the engine speed (rpm), a proximity sensor is installed in a speed pick-up unit attached to the front face of the column.

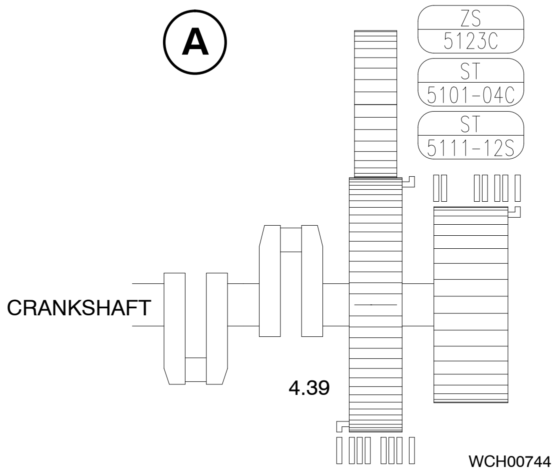
For safety, there are three electrically-isolated proximity sensor groups:

- Speed detection in the remote control system (RCS)
- Overspeed safety system
- Speed control system

2. Function

The proximity sensors 1 to 6 measure the speed of the flywheel 7. Each time a tooth passes the proximity sensor, a signal is sent through the DENIS−9520 to the RCS. he RCS monitors the load and speed-dependent functions and sends data to the speed indication instruments (see Fig. ’A’ and Fig. ’B’).

A



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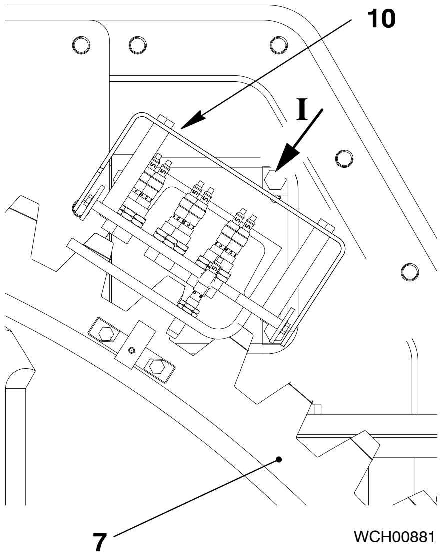
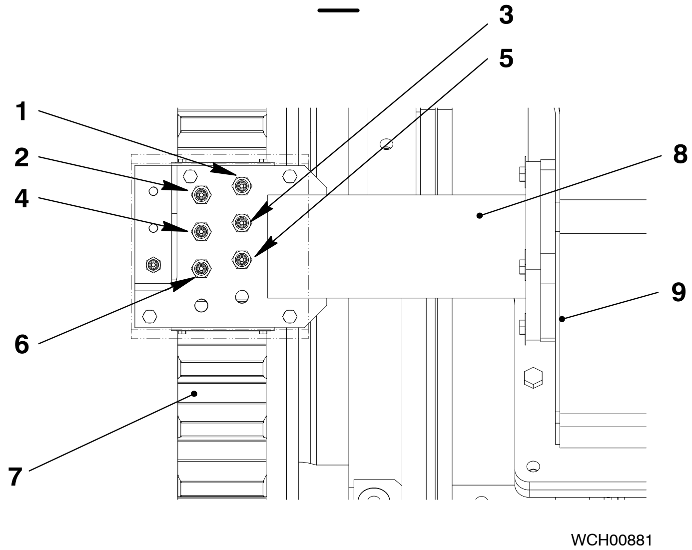


I



Key to Illustrations: **'A' Schematic Diagram**

'B' Speed Pick-up Proximity Sensors

1 Proximity sensor ST5101C
2 Proximity sensor ST5102C
3 Proximity sensor ST5103C
4 Proximity sensor ST5104C
5 Proximity sensor ST5111C
6 Proximity sensor ZS5112C
7 Flywheel
8 Pick-up holder
9 Column
10 Cover

Supply Unit, Servo Oil Pump and Fuel Pump Group 5

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1. General

The servo oil pumps 2 are integrated in the supply unit 1 (see Supply Unit 5552−1). These pumps supply servo oil to operate the exhaust valves and the injection valves. The servo oil flows from the main bearing oil supply, through the automatic filter 7 to the servo oil pumps 2 (see Fig. 'A').

2. Function

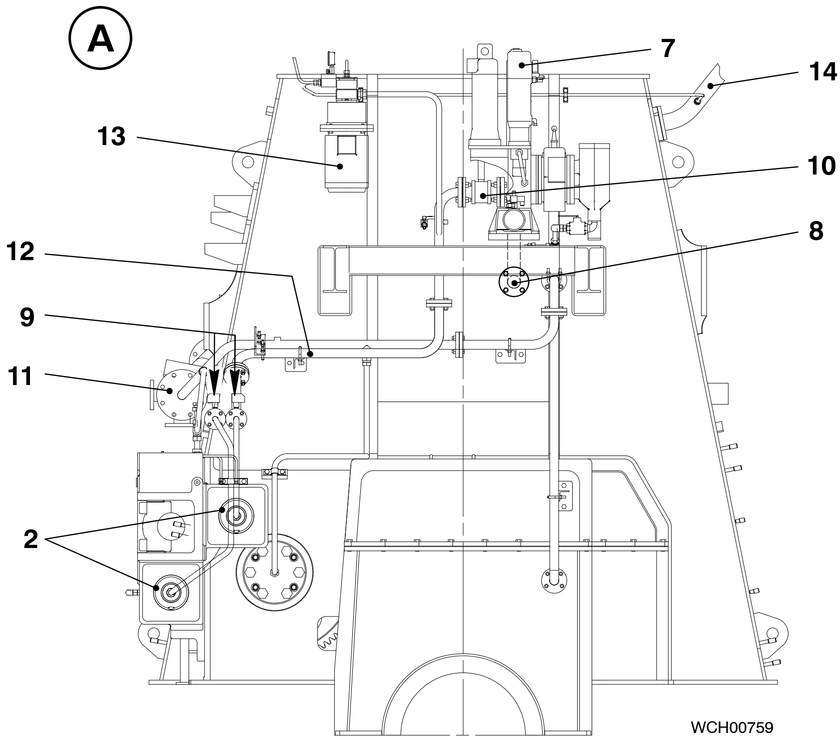
During normal operation, the servo oil pumps 2 equally distribute the load over the total load range.
The pressure regulating system is electrically controlled. The nominal pressure value is dependent on the engine load. The pressure regulating system adjusts the servo oil system pressure over the entire load range (i.e. approximately 200 bar at high engine load, and reduced pressures at low engine load).

The shaft 6 (see Fig. 'B') of each servo oil pump 2 has a waisted portion (shearable overload protection 'SB'). This waisted portion has a predetermined breaking point. If a servo oil pump 2 seizes, the shaft 6 shears at the waisted portion. This prevents the total loss of the gear wheel 4.

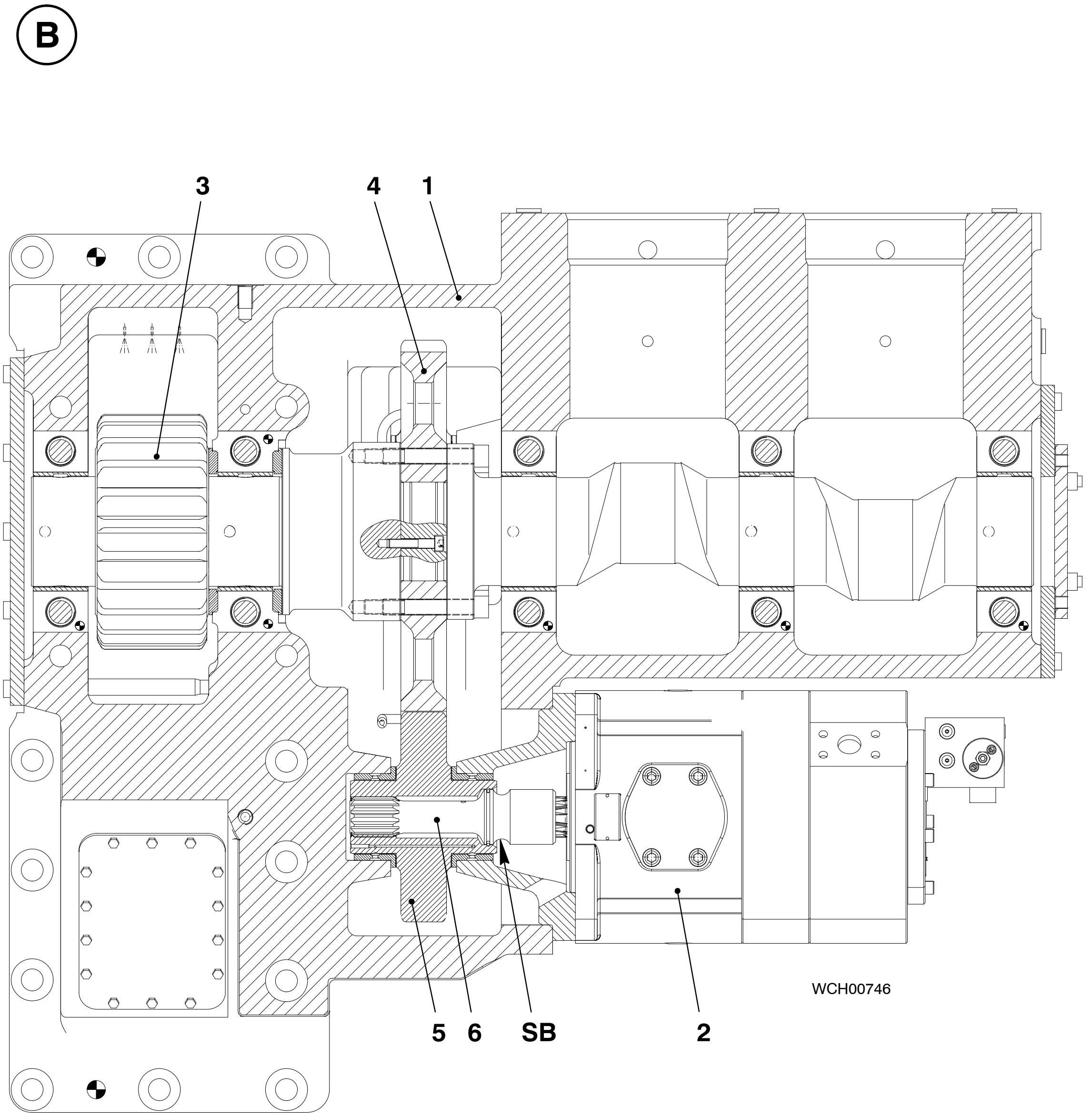
The flow sensors 9 monitor the oil supply in each of the inlet pipes to the servo oil pumps 2. A possible failure of a servo pump 2 is indicated in the alarm and monitoring system.

If one of the two servo oil pumps 2 fails, it is possible to operate the engine over the entire load range.

Attention! Do not operate the engine for an extended period if one of the servo oil pumps fails. If the other servo oil pump fails, the engine cannot operate. Replace a defective servo oil pump as soon as possible (see Maintenance Manual 5552−1).



Servo Oil Pump



Key to Illustrations: **'A' Arrangement of automatic filter**
'B' Arrangement of servo oil pump

1 Supply unit
2 Servo oil pump 4.15
3 Gear (driving) wheel 4.42
4 Gear wheel 4.44
5 Pinion 4.45
6 Shaft 4.50
7 Automatic filter 4.20
8 Flushing oil pipe
9 Flow sensor 4.54 (FS2061−62A)
10 Ball valve 4.37
11 Oil pipe
12 Supply pipe 4.51
13 Servo oil service pump 4.88
14 Collecting main for leakage oil from exhaust valves

SB Shearable overload protection (predetermined breaking point)

1. General

The supply unit is mounted on the column on the fuel side (see Drive Supply Unit 4104–1).
The supply unit comprises the servo oil supply, the fuel oil supply and their driving and regulating systems.
The following components are integrated in and mounted on the supply unit housing:

Camshaft:

The camshaft 2 has the gear wheel shaft 3, gear wheels 4 and 5 and pinion 6. The screws 7 attach the camshaft 2 to the gear wheel 5 and the gear wheel shaft 3. The bearing shell halves 8 and thrust bearing ring halves 9 make sure that the camshaft turns freely and stays in the correct alignment.

Servo oil pumps:

Two servo oil pumps 10 are mounted on the front of the supply unit. The gear wheel 5 turns the pinion 6 and shaft 11, which drives the servo oil pump 10.

- For the description of the servo oil pump, see Servo Oil Pump 5551–1.

Fuel pumps:

Two or three fuel pumps 12 are mounted in line on the supply unit. The number of fuel pumps is dependent on the number of cylinders on the engine.

- For the description of the fuel pump, see Fuel Pump 5556–1.

Regulating linkage:

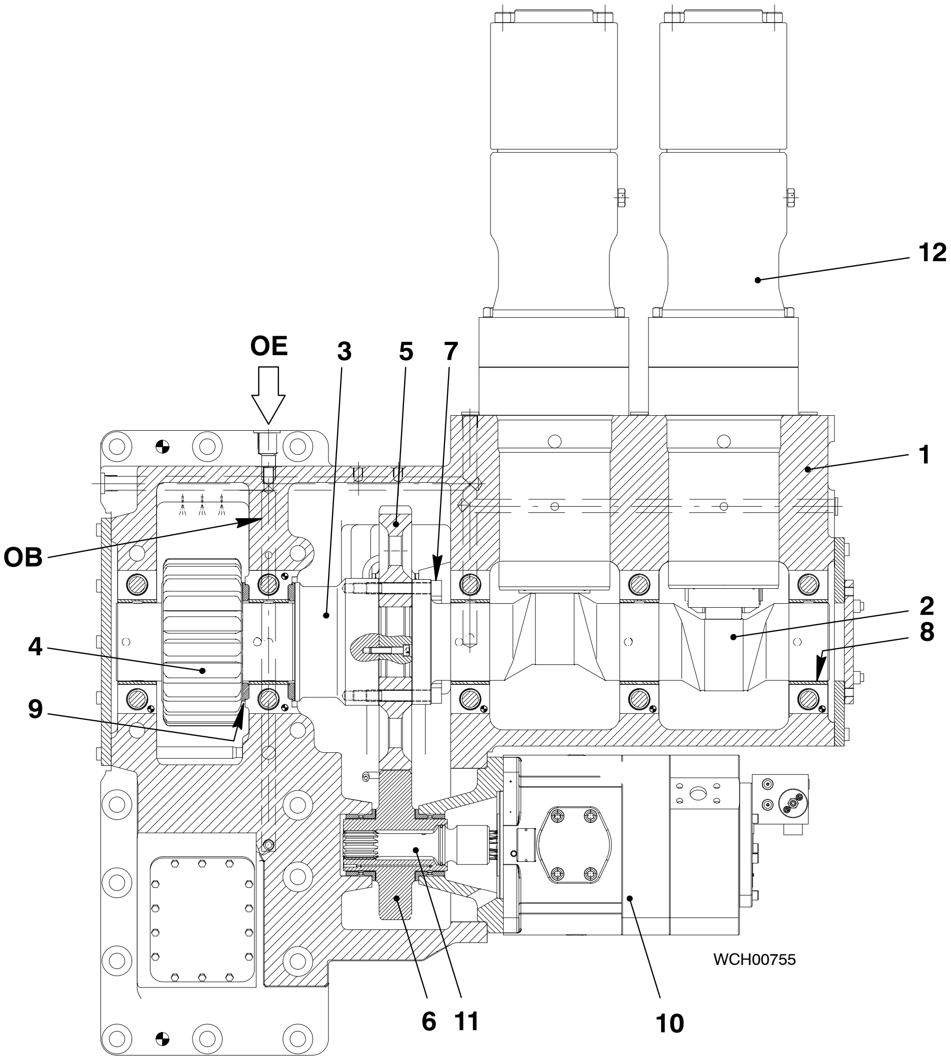
A fuel pump actuator 13 is mounted on each fuel pump 12. The actuators 13 (electrical control elements) control all fuel pumps simultaneously.

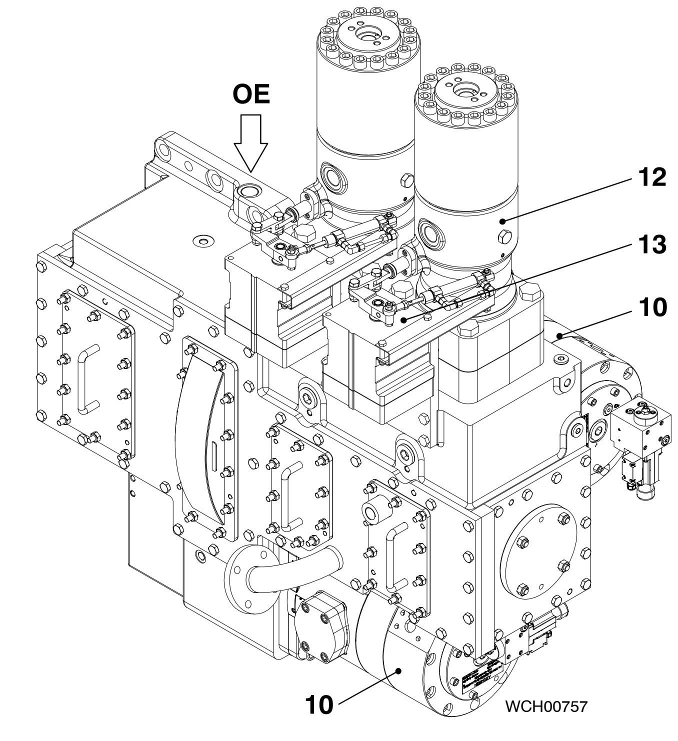
- For the description of the regulating linkage, see Regulating Linkage 5801–1.

2. Lubrication

Oil flows through the oil inlet 'OE' into the oil bores 'OB' and through the spray nozzles to lubricate the bearings and fuel pumps.

Supply Unit





Key:

1 Housing
2 Camshaft 3.55
3 Gear wheel shaft
4 Gear wheel 4.42
5 Gear wheel 4.44
6 Pinion 4.45
7 Head screw
8 Bearing shell half
9 Thrust bearing ring half
10 Servo oil pump 4.15
11 Shaft 4.50 (with shearable overload protection)
12 Fuel pump 3.14
13 Fuel pump actuator 3.21

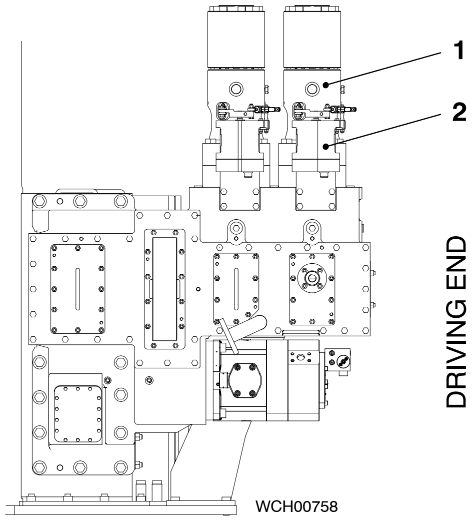
OB Oil bore
OE Oil inlet

1. General

Depending on the number of cylinders, two or three fuel pumps 1 are fitted in the supply unit (see Fig. 'A').
The fuel pumps supply high pressure fuel through the connection 'HD' into the rising pipes to the fuel rail.

The fuel pumps are controlled to supply the necessary quantity of fuel to keep the required pressure (load-dependent) in the fuel rail.

A



DRAWN FOR 5 to 7 CYLINDERS

2. Function

The compression spring 11 keeps the lower carrier 13 against the guide piston 12, which in turn keeps the roller 14 against the cam 16. When the cam 16 moves the roller 14 up, the guide piston 12 moves up and the lower spring carrier 13 compresses the compression spring 11. The pump plunger 18 then moves up. The control grooves 'ST' in the pump plunger 18 control the required fuel quantity.

When the toothed rack 9 moves, the teeth mesh with the teeth on the regulating sleeve 8 and the regulating sleeve turns. The regulating sleeve 8 turns the driver 'KM' and thus the pump plunger 18.

When the pump plunger passes the BDC, fuel flows through the two inlet bores 'ZB' and the two control grooves 'ST' into the plunger chamber 'PR' (see Fig. 'C'). The quantity of fuel that enters the plunger chamber 'PR' is dependent on the regulating position (between '0' for zero delivery and '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 9 is connected to the fuel pump actuator 2 (see Regulating Linkage 5801–1).

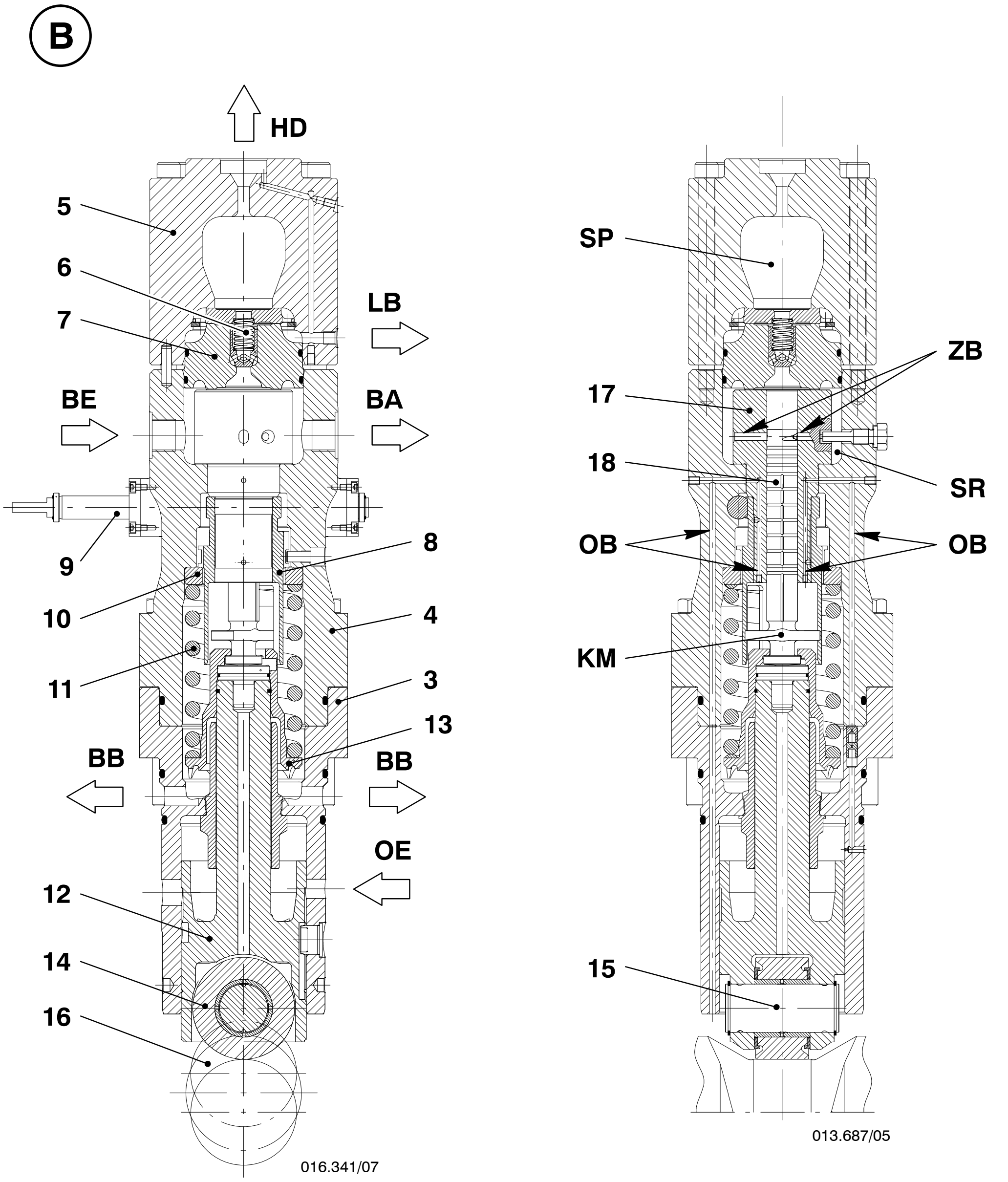
3. Lubrication

The fuel pump is lubricated with engine lube oil which enters the lower housing 3 through the inlet bore 'OE' from the supply unit housing.

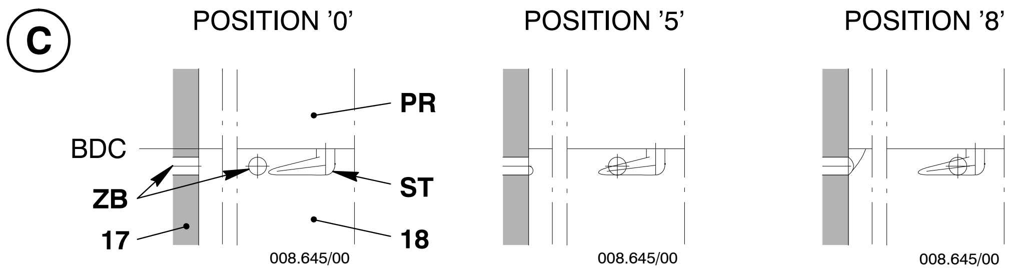
Some of the engine lube oil lubricates the guide piston 12, the roller pin 15 and roller 14 through spot faces, annular groove and bores in the guide piston. Engine lube oil that flows down lubricates the cam surface.

Engine lube oil also flows through the oil bores 'OB', in the upper housing 4 and the pump cylinder 17, to lubricate the regulating sleeve 8.

Leakage fuel lubricates the pump plunger 18. The leakage fuel, and the engine lube oil from the regulating sleeve 8, flows through the drain bores 'BB', into an internal bore in the supply unit housing.



Fuel Pump



Key to Illustrations: **'A' Arrangement of fuel pumps**
'B' Fuel pump
'C' Control groove of pump plunger

1	Fuel pump	17	Pump cylinder
2	Fuel pump actuator	18	Pump plunger
3	Lower housing		
4	Upper housing	BA	Fuel outlet
5	Pump cover	BB	Leakage fuel drain bore
6	Valve body } non-return valve	BE	Fuel inlet
7	Valve block } non-return valve	HD	HP fuel to fuel rail
8	Regulating sleeve	KM	Driver (of pump plunger)
9	Toothed rack	LB	Leakage fuel outlet
10	Upper spring carrier	OB	Lubricating oil bore
11	Compression spring	OE	Lubricating oil inlet
12	Guide piston	PR	Plunger chamber
13	Lower spring carrier (with umbrella)	SP	Accumulation chamber
14	Roller	SR	Suction chamber
15	Roller pin	ST	Control groove
16	Cam	ZB	Inlet bore

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Cutting Out and Cutting In of the Fuel Pump

1. General

If a fuel pump is unserviceable (e.g. the pump plunger is seized) or there is a break in the rising pipe (between the fuel pump and the fuel rail) the fault must be rectified immediately.

If the fault cannot be rectified, because the engine must be put back into service, it is possible to cut out the unserviceable fuel pump.

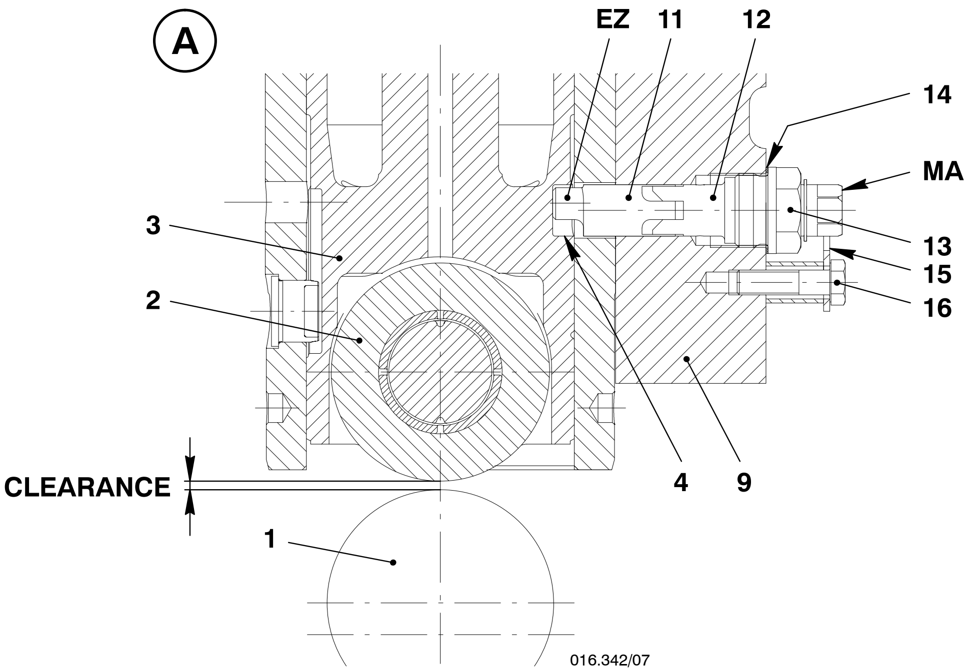
STOP Cutting out and cutting in of unserviceable fuel pumps must only be done at engine standstill.

Remark: With one fuel pump cut out, operate the engine only at the reduced loads that follow:

- 5 to 7 cylinder engines approx. 40% output
- 8 cylinder engine approx. 70% output

2. Cutting Out and Cutting In of Fuel Pump

2.1 Roller lifting tool for cutting out and cutting in



Key to Illustrations: 'A' to 'D'

1	Cam	11	Pressure pin (Roller lifting tool 94430)
2	Roller	12	Spring guide (Roller lifting tool 94430)
3	Guide piston	13	Guide screw (Roller lifting tool 94430)
4	Square hole	14	Gasket (Roller lifting tool 94430)
5	Screw plug	15	Claw (Roller lifting tool 94430)
6	Inspection cover	16	Screw (Roller lifting tool 94430)
7	Blank flange (tool 94569)	17	Fuel rising pipe
8	Blank flange (tool 94569a)		
9	Supply unit	EZ	Eccentric pin
10	Fuel rail 3.05	MA	Mark

2.2 Cutting out procedure (see Fig. ’A’ to Fig. ’C’)

- Make sure that the engine is at standstill.

⇒ Remove the applicable inspection cover 6 from the supply unit 9 and find the position of the related cam. Use the turning gear to turn the engine until the roller 2 is at the highest position on the cam peak.

⇒ Remove the applicable screw plug 5 and gasket.

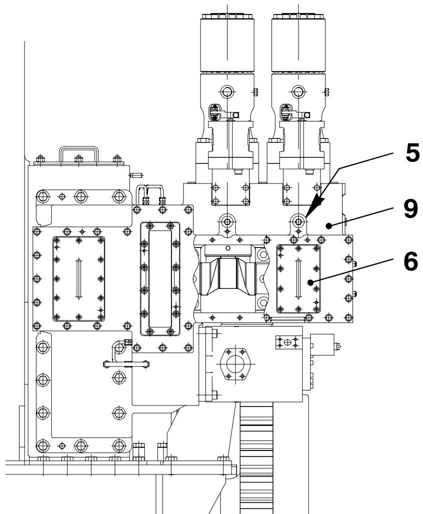
⇒ Put the roller lifting tool 94430 in position in the supply unit 9. Tighten the guide screw 13. Turn the spring guide 12 and pressure pin 11 at the same time. Make sure that the mark ’MA’ points down and the eccentric pin ’EZ’ engages in the square hole 4.

⇒ Use an open ended ring spanner AF22 to turn the spring guide 12 and the pressure pin 11 through 180° until the mark ’MA’ points up. Make sure that the eccentric pin ’EZ’ (with its spot-faced surface) lifts the guide piston 3.

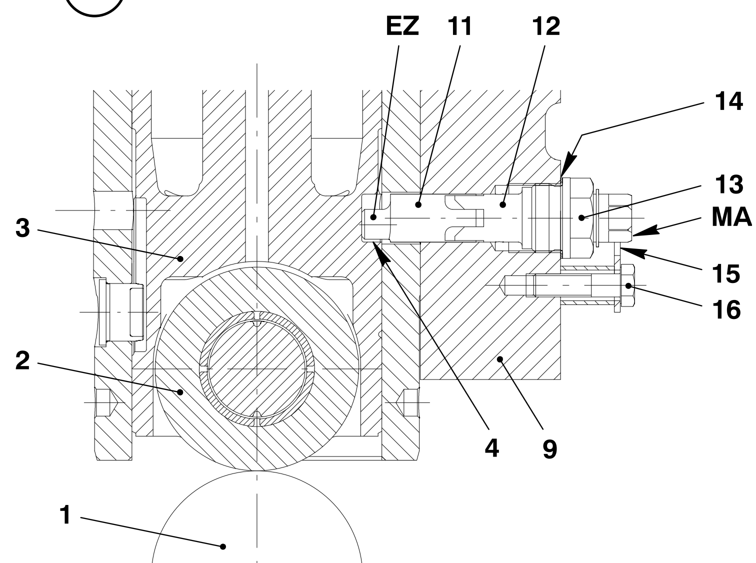
⇒ Use the claw 15 and screw 16 to lock the spring guide 12 in position.

⇒ Install the inspection cover 6 to the supply unit 9.

B



C



2.3 Blanking off fuel pump and fuel rail

Remark: If non-return valves leak, unwanted pressure can accumulate in the plunger space of the fuel pumps, which can increase the load on the roller lifting tool 94430. Do the steps that follow to prevent this unwanted pressure:

⇒ Remove the applicable fuel rising pipe 17 from the cut-out fuel pump (see Fig. ’D’ and 8752−1 ’Removal’ in the Maintenance Manual).

⇒ Fit the blank flange 7 (tool 94569) to the fuel pump.

⇒ Fit the blank flange 8 (tool 94569a) to the fuel rail 10.

- For tightening values and lubricant of the applicable screws, see 0352−1 in the Maintenance Manual.

2.4 Cutting in procedure (see Fig. 'A' to Fig. 'D')

- Make sure that the engine is at standstill.

⇒ Remove the applicable inspection cover 6 from the supply unit 9 and find the position of the related cam. Use the turning gear to turn the engine until the roller 2 is at the highest position on the cam peak.

⇒ Remove the screw 16 and the claw 15.

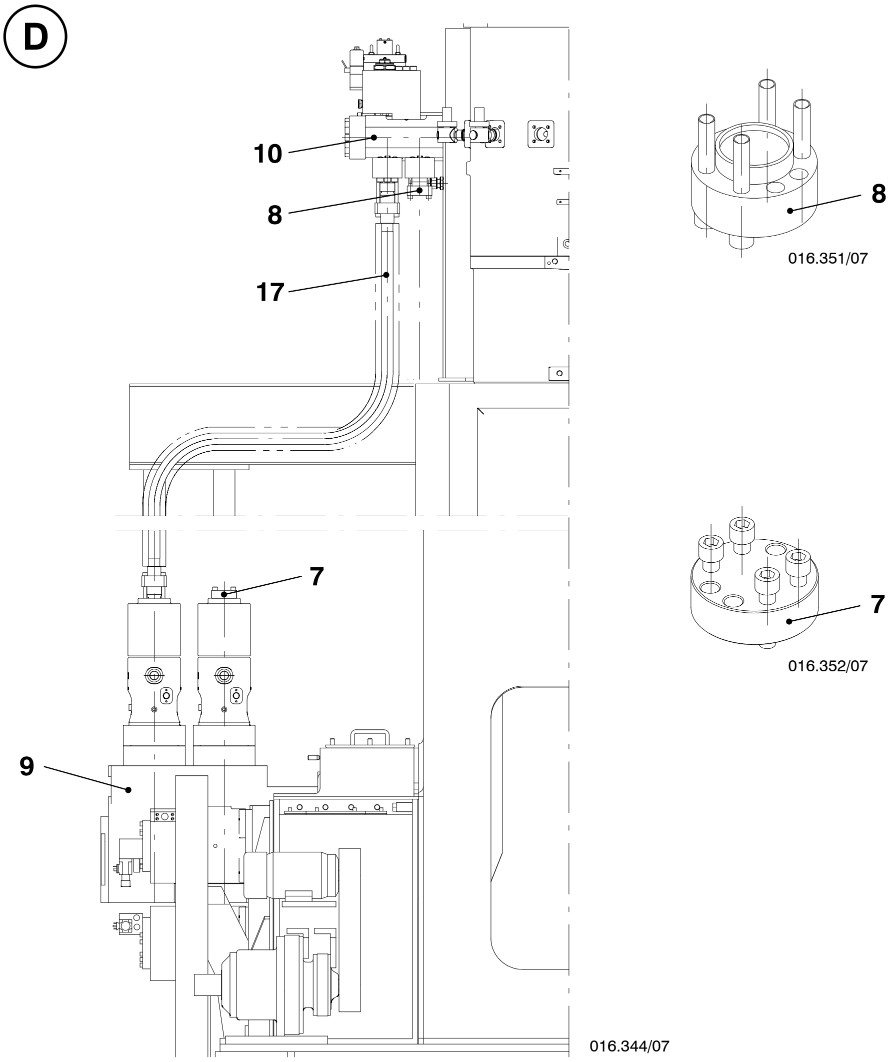
⇒ Use an open ended ring spanner AF22 to turn the spring guide 12 and pressure pin 11 through 180° until the mark 'MA' points down.

⇒ Loosen the guide screw 13, then remove the tool 94430 and gasket 14.

⇒ Install the gasket and the screw plug 5.

⇒ Install the the inspection cover 6 to the supply unit 9.

⇒ Remove the blank flanges 7 and 8. Install the fuel rising pipe 17 (see also 8752−1 'Fitting' in the Maintenance Manual).



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1. General

1.1 Normal operation

***Attention!* For normal operation the knurled screw 8 must be turned fully down (turned fully clockwise).**

WECS−9520 regulates the fuel pressure, which remains below the opening pressure of the fuel pressure control valve 1. The fuel pressure control valve 1 is normally closed (see also 4002−1 'Fuel pressure control').

The fuel pressure control valve 1 acts as a pressure relief valve and opens if the fuel pressure exceeds approximately 1050 bar. The adjusting disc 7 and the knurled screw 8 set the correct opening pressure.

1.2 Emergency stop

The safety system activates the fuel shut-down pilot valve 6, which reduces the fuel pressure to less than 200 bar (in most cases to 0 (zero) bar). Thus, an injection is no longer possible.

Remark: The fuel shut-down pilot valve 6, is one of three actuating devices that shut down the engine. The other two devices are:

- immediate injection stop (WECS−9520)
- fuel pump delivery to 0 (zero).

1.3 Emergency operation

***Attention!* For emergency operation the knurled screw 8 must be turned fully out (turned fully counterclockwise).**

If there is a failure in the fuel pressure regulating system, the fuel pressure control valve will control the fuel pressure regulating function when:

- there are missing or incorrect control signals
- the fuel pump actuator(s) is/are out of service
- a toothed rack is blocked.

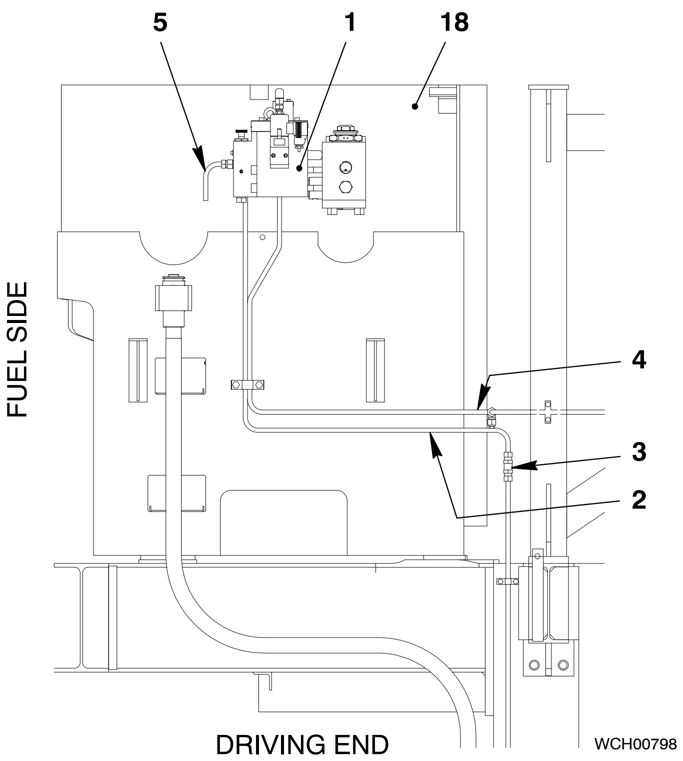
The toothed rack(s) of the fuel pump(s) are locked in the middle position. This can be applied to one fuel pump, or all fuel pumps and is dependent on the failure (see 0515−1 'Defective actuator').

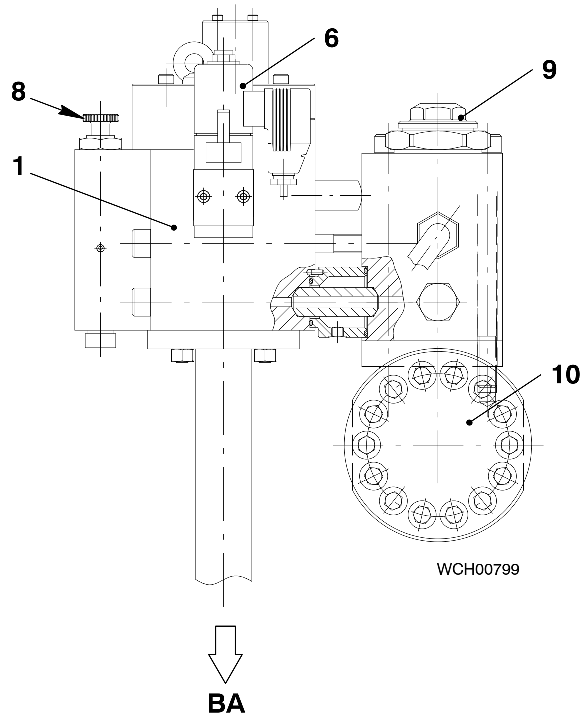
If the fuel pressure exceeds the opening pressure, the fuel pressure control valve opens, which gradually drains enough fuel to maintain the adjusted maximum pressure. In this case a longer operating time must be avoided.

The knurled screw must be turned fully out (counterclockwise) against the stop, which reduces the opening pressure to approximately 600 bar. This makes sure of safe operation over the whole load range.

Remark: When the fuel pressure control valve opens, a loud whistling noise indicates fuel drainage.

A





2. Function

2.1 Regulating function

Oil pressure above the piston 11 pushes the valve tip 12 down on to the valve seat 13. The fuel pressure also works against the oil pressure regulating valve 17. When the fuel pressure increases, the oil pressure decreases. If the oil pressure decreases below a specific threshold value, the valve tip 12 moves up from the valve seat 13 and fuel is drained.

The compression springs 14, 15 and knurled screw 8 define the regulating characteristic of the oil pressure regulating valve 17.

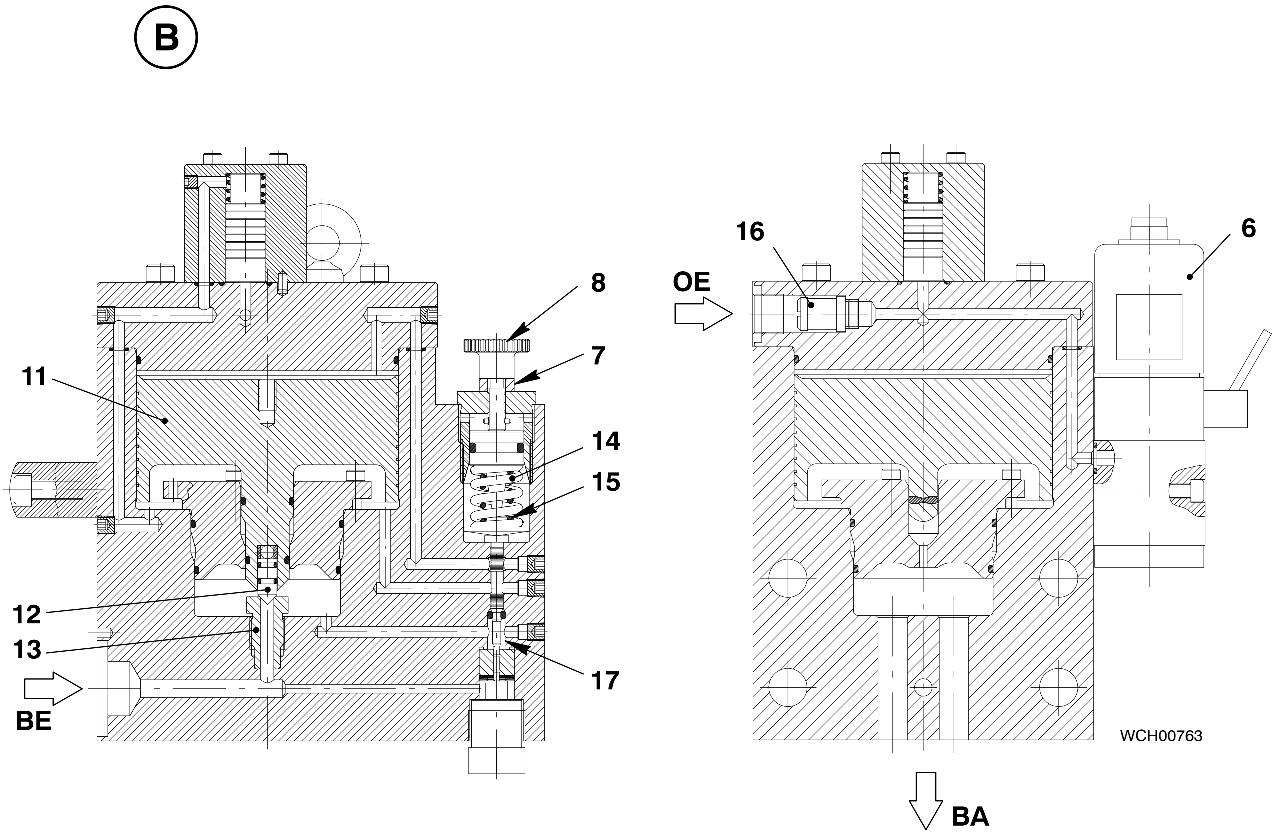
2.2 Function check

To confirm the function during normal operation, carefully turn the knurled screw 8 counterclockwise until the oil pressure regulating valve 17 starts to open. This releases the fuel pressure.

2.3 Emergency stop function

If the fuel shut-down pilot valve 6 is energized, the oil pressure above the piston 11 is released. The valve valve tip 12 moves away from the valve seat 13 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
2 Bearing oil supply pipe
3 Non-return valve 3.67
4 Bearing oil drain
5 Leakage control pipe
6 Fuel shut-down pilot valve 3.08
7 Adjusting disc
8 Knurled screw
9 Fuel overpressure safety valve 3.52
10 Fuel rail 3.05
11 Piston
12 Valve tip
13 Valve seat
14 Compression spring
15 Compression spring
16 Oil filter
17 Oil pressure regulating valve
18 Rail unit

BA Fuel outlet (drain)
BE Fuel inlet
OE Oil inlet

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1. General

Each fuel pump 1 has an electrically-operated actuator 2. The regulating linkage connects the actuator 2 to the fuel pump 1. The lever 3 moves the connecting element 4, which moves the toothed rack 5 to the necessary position to regulate the fuel flow through the fuel pump 1.

2. Function

The WECS−9520 system controls each actuator to regulate the fuel quantity and keep the necessary operating pressure in the fuel rail.

During normal operation, the actuators move at the same time i.e. the regulating positions and the fuel quantity that flows through the fuel pumps are identical.

If a pump plunger seizes, which blocks the toothed rack, electrical power to the related actuator is not disconnected (overload protection).

5 to7 cylinder engines:

If an actuator fails, its actuator lever 3 remains in position or turns slowly to the zero delivery position. The other actuator takes over the control of the fuel quantity regulation (see also 0515−1 'Defective actuator').

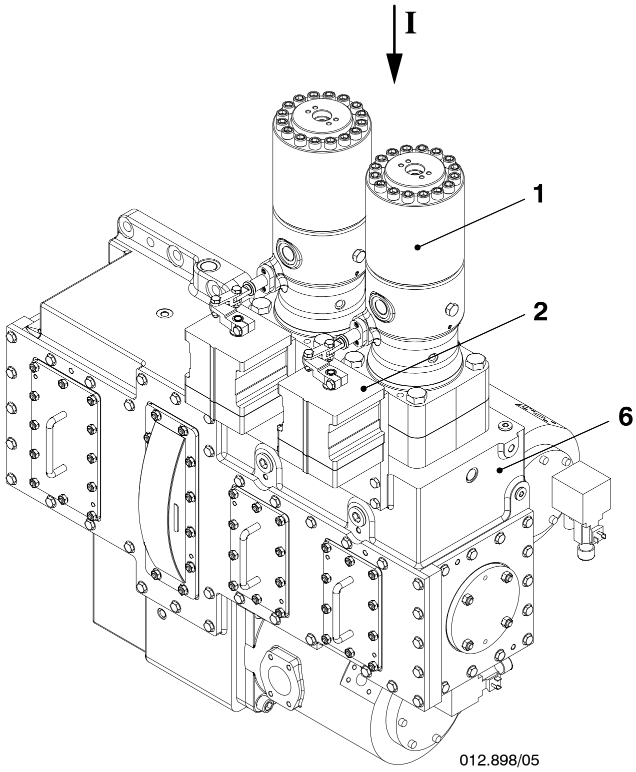
8 cylinder engine:

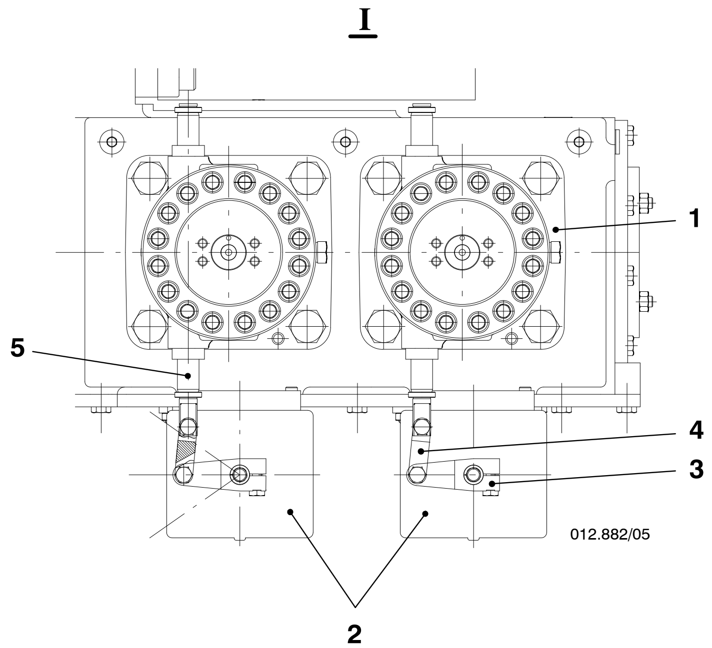
If an actuator fails, its actuator lever 3 remains in position or turns slowly to the zero delivery position. The other actuators take over the control of the fuel quantity regulation (see also 0515−1 'Defective actuator').

Remark: In the lower load range (at reduced fuel consumption) the fuel pressure control valve 3.06 controls the fuel pressure regulating function. This is because the actuator(s) cannot further reduce the fuel quantity supply (see also 5562−1'Fuel pressure control valve 3.06').

Regulating Linkage

Heinzmann Actuator:

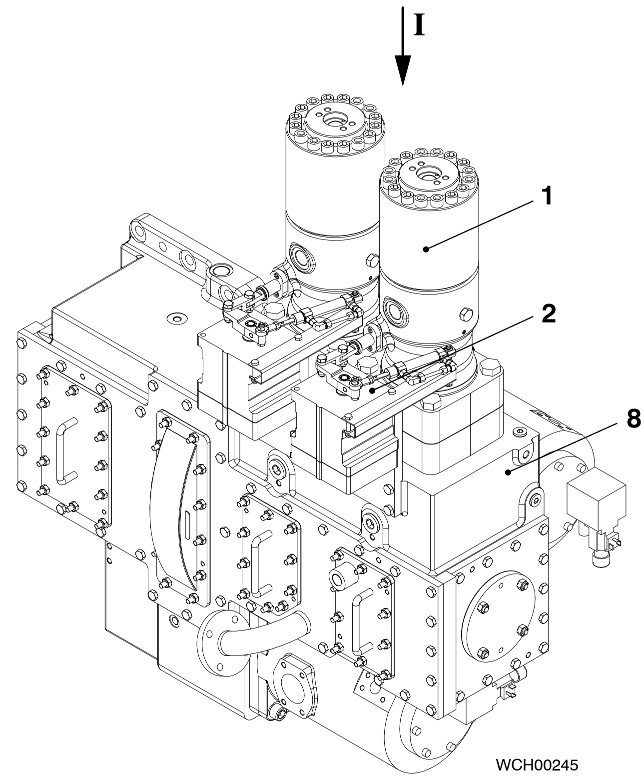


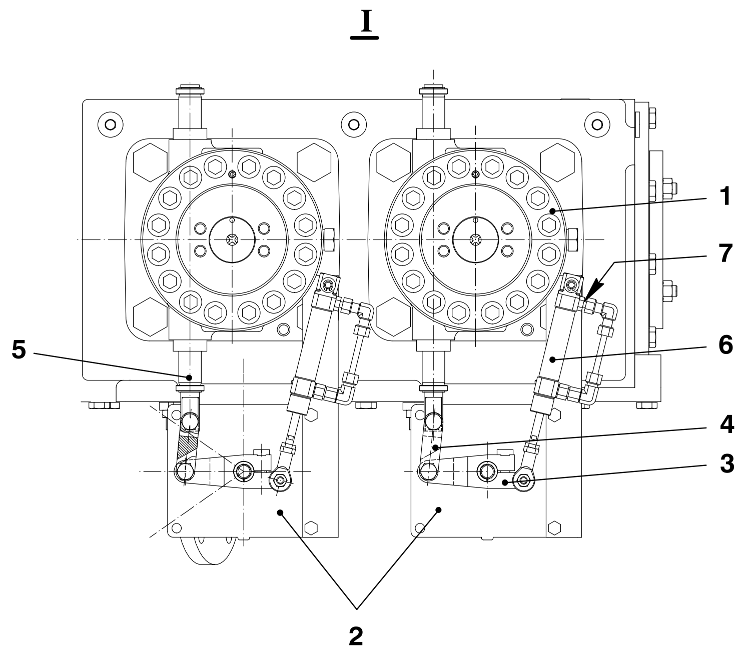


Key to Illustrations:

1 Fuel pump 3.14
2 Actuator 3.21
3 Actuator lever
4 Connecting element
5 Toothed rack
6 Supply unit

Woodward Actuator:





Key to Illustrations:

1 Fuel pump 3.14
2 Actuator 3.21
3 Actuator lever
4 Connecting element
5 Toothed rack
6 Damper
7 Orifice
8 Supply unit

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Scavenge Air System Group 6

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1. General

The scavenge air receiver 1 is fitted to the cylinder block on the exhaust side. The scavenge air receiver 1 is designed as a complete welded structure comprising: the receiver, turbocharger support, air duct and scavenge air cooler casing (see Fig. 'A'). The longitudinal wall 12 separates the two spaces 'VR' and 'RC'. Air flaps 2 are installed on the longitudinal wall 12 (see Fig. 'B').

2. Function

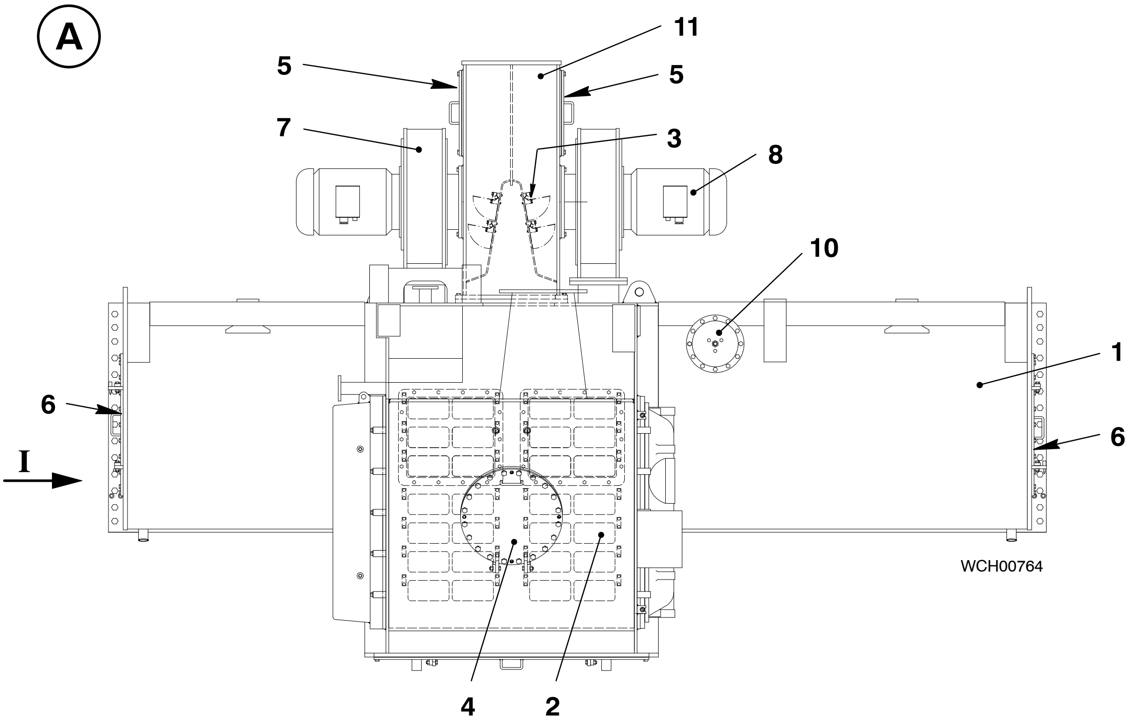
During operation, the turbocharger blows scavenge air into the air duct and scavenge air cooler, then through the water separator into pre-space 'VR'. The scavenge air flows through the air flaps 2 into the receiver space 'RC'. The scavenge air then flows through openings in the cylinder block 9 to the piston underside 'KU' and through the scavenge ports into the cylinder (when the related piston is near BDC). The air flaps 2 prevent back-flow of scavenge air into the pre-space 'VR'.

Two auxiliary blowers 7 are mounted on the top face of the scavenge air receiver 1. During engine start or at low engine load, the auxiliary blowers are switched on. The auxiliary blowers 7 suck scavenge air from the pre-space 'VR' through the suction box 11. This scavenge air then flows into the receiver space 'RC'. The air flaps 3 in the suction box 11 prevent the back-flow of air when the auxiliary blowers 7 are switched off.

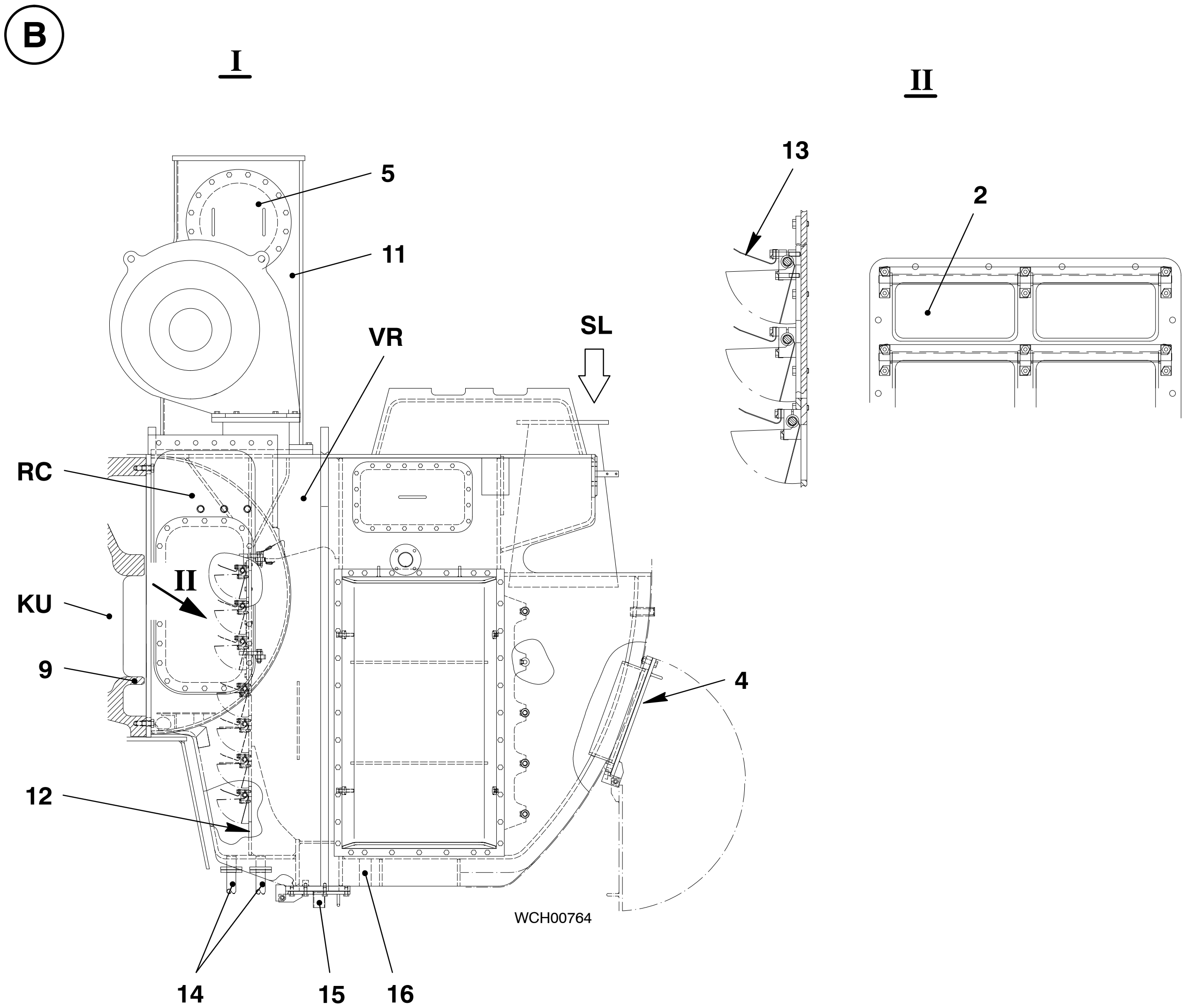
A relief valve 10 is mounted in the side of the scavenge air receiver 1. The relief valve 10, opens when the air pressure is more than the permitted value in the receiver space 'RC'.

The hinged covers 6 give access to the scavenge air receiver 1. The covers 5 can be removed to examine the air flaps 3.

Remark: If the exhaust gas turbocharger is defective, the covers 5 and the hinged cover 4 fitted in the air duct, must be opened for emergency operation. If in addition an auxiliary blower fails, do not open the cover 5 on the defective blower side (see Turbocharger out of Service 0590–1).



Scavenge Air Receiver



Key:

1	Scavenge air receiver	12	Longitudinal wall
2	Air flaps	13	Stop plate
3	Air flaps (auxiliary blower)	14	Oily-water drain
4	Hinged cover	15	Condensate drain from water separator
5	Cover	16	Condensate and wash-water drain from scavenge air cooler
6	Hinged cover		
7	Auxiliary blower		
8	Electric motor		
9	Cylinder block	KU	Piston underside
10	Relief valve	RC	Receiver space
11	Suction box (support for exhaust gas manifold)	SL	Scavenge air (from the turbocharger)
		VR	Pre-space

1. General

The turbocharger is accurately tuned to the engine and related to the number of cylinders, service output, mode of operation etc. The number of turbochargers is related to the number of cylinders on the engine.

Data about operation, maintenance and servicing are given in the related documentation of the manufacturer (which is part of the Operating Instruction).

CAUTION! **Damage Hazard: If you operate the engine with a turbocharger cut out, you must obey the operation limits given in the Service Bulletin RT-162 to prevent damage to the engine.**

For data about the operation limits of operation with a turbocharger cut out, see Service Bulletin RT-162.

2. Function

Exhaust gas 'AG' from the cylinders accumulates in the exhaust gas manifold 10. The exhaust gas 'AG' flows into the turbocharger, turns the turbine 12 then flows through the exhaust gas outlet 'AP' (and the exhaust system of the ship) to atmosphere. When the turbine 12 turns, the compressor 11 (which is mounted on the same shaft) also turns and draws fresh air 'FL' through a silencer from the engine room. The compressor 11 compresses the air (scavenge air 'SL') and the air temperature increases.

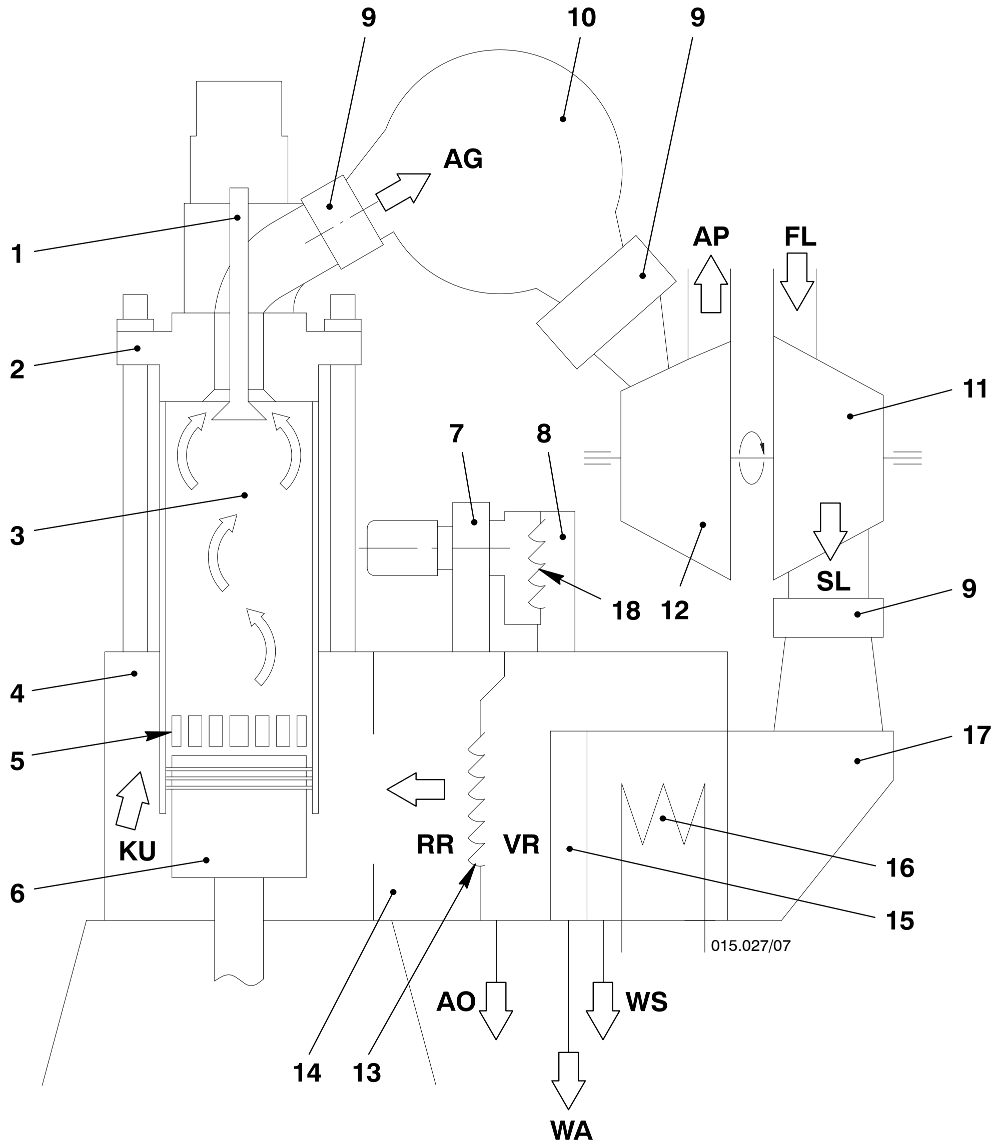
The scavenge air 'SL' flows through the air duct 17, into the scavenge air cooler 16, which cools the air to a lower temperature range and produces condensate water. The water separator 15 removes the condensate water, which drains off through several water drains 'WA'. Also, the quantity of condensate water is dependent on the humidity in the air.

The scavenge air 'SL' flows from the receiver pre-space 'VR', through the air flaps 13 to the receiver space 'RR' and then into the piston underside 'KU'. When the piston 6 is near BDC, scavenge air flows through the inlet ports 5 into the cylinder 3.

After the compression, combustion and expansion process the exhaust valve 1 opens and exhaust gas 'AG' flows into the exhaust gas manifold 10, which completes the cycle.

When starting the engine or during low engine load, the auxiliary blower 7 supplies air to the receiver space 'RR'. The air flaps 13 and 18 prevent a back-flow of air (see also Scavenge Air Receiver 6420−1).

Turbocharging



Key:

1	Exhaust valve	16	Scavenge air cooler
2	Cylinder cover	17	Air duct
3	Cylinder liner	18	Air flaps (before auxiliary blower)
4	Cylinder block		
5	Inlet ports		
6	Piston	AG	Exhaust gas (from cylinder)
7	Auxiliary blower	AO	Oily water drain
8	Air inlet casing	AP	Exhaust gas outlet
9	Expansion piece	FL	Fresh air
10	Exhaust gas manifold	KU	Piston underside space
11	Compressor	RR	Receiver space
12	Turbine	SL	Scavenge air (from compressor)
13	Air flaps	VR	Receiver pre-space
14	Receiver	WA	Water drain
15	Water separator	WS	Condensate after scavenge air cooler

Overview

1. General

The turbochargers have a system to wash the turbine and the compressor. It is possible to wash-clean the compressor and the turbine while the turbocharger runs. Periodic cleaning prevents or reduces contamination. This allows much longer intervals between overhauls. If the dirt accumulation becomes excessive (scavenge air pressure decreases and exhaust gas temperature increases), the turbocharger must be dismantled for cleaning in accordance with the instructions given in the turbocharger manual (see Operating Data Sheet 0250−1 for the permitted pressure decrease).

Regular visual checks and cleaning are necessary to keep the silencer in a serviceable condition. Clean the silencer and filter only when the engine is at shutdown and in accordance with the instructions given in the turbocharger manual.

Remark: An additional filter mat installed on top of the silencer will keep the fouling on the air side to a minimum, but will cause a loss of pressure.

Based on an increase in pressure difference Δp (of 50% compared to the shop test value at the same engine load) or the filter mat is discolored, clean the filter mat in accordance with the instructions given in the turbocharger manual.

The methods that follow are for periodic cleaning of the compressor and turbine:

- 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')

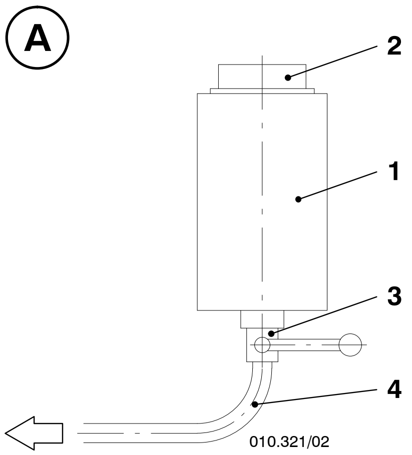
Cleaning intervals:

Every 24 operating hours.

Operating condition:

Wash-clean the compressor when the engine is at normal operating temperature and the load is as high as possible (full service load), i.e. at high turbocharger speed.

2.1 Cleaning procedure



⇒ Open the filler cap 2 (see Fig. 'A'). Fill the water container 1 with clean, fresh water (do not add cleaning agents).

- The water quantity and the number of cleaning cycles is specified in the table below.

⇒ Close the filler cap 2, then open the shut-off valve 3 for approximately three minutes.

⇒ Close the shut-off valve 3. Make sure that the water container is empty.

- An increase in scavenge air pressure, or a decrease in exhaust gas temperature shows that the cleaning procedure is successful.

Key to Illustration: 'A'

1 Water container
2 Filler cap
3 Shut-off valve
4 Water hose (to compressor inlet)

- When the compressor is clean, operate the engine under load for a minimum of five minutes.

Remark: In dirty operating conditions, do the cleaning procedure again in accordance with the table below.

If the cleaning procedure remains unsuccessful, we recommend that an authorized ABB service company does a check and an overhaul of the turbocharger.

Turbocharger Type	Water quantity [l]	Number of cleaning cycles Maximum
TPL 73	2	3
TPL 77	2	3

3. Wash-cleaning of turbine (see Fig. 'B' to 'E')

Cleaning intervals:

Every 50 to 500 operating hours

Guidance values:

- The cleaning interval is dependent on environmental influences on the intake air and the extent of turbocharger contamination.
- Regular wash-cleaning in service is recommended on a routine basis, at first every 100 running hours (e.g. weekly). Adapt the cleaning intervals to the quantity of contamination found during turbocharger overhaul.

Operating condition:

Reduce the engine power output to make sure that the exhaust gas temperature before the turbine, and the scavenge air pressure is in the values given below.

Limiting values:

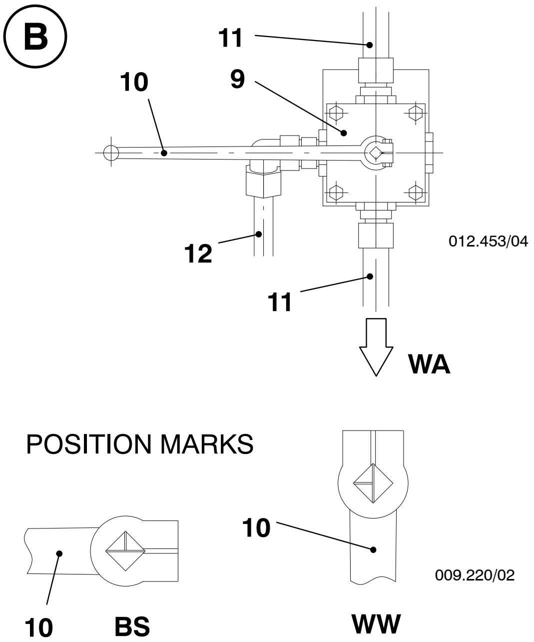
- The temperature before the turbine must be below 430°C.
- The scavenge air pressure must be between 0.3 – 0.6 bar before the turbine is wash-cleaned.
- The water pressure must be 1.0 bar after the ball cock 5 during water injection.

We recommend that the turbine is washed at a scavenge air pressure of 0.4 bar (with the auxiliary blower in operation).

- Only use clean fresh water for wet cleaning. Do not use detergents or solvents.
- The water supply pressure must be a minimum of 2.0 bar.
- If a Selective Catalytic Reduction (SCR) installation is installed, stop the ammonia or urea injection before the turbine is wash-cleaned.
- After wash-cleaning, only restart the injection when the exhaust temperature is more than 430°C.

3.1 Cleaning procedure

B



⇒ Turn the handle 10 of the ball cock 9 in the drain pipe 11 for the gas outlet casing to the position 'WW'. The tube for scavenge air 12 closes at the same time. See the position marks in Fig. 'B' for the related positions. Exhaust gas will flow from the drain pipe 11 when the outlet is free.

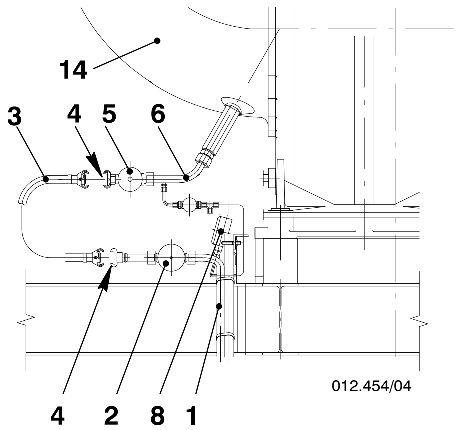
⇒ Before you start the wash-cleaning process, make sure that the outlet is free to let exhaust gas flow from the drain pipe 11.

⇒ Reduce the engine power to get the required scavenge air pressure of 0.4 bar.

⇒ Before you start the wash-cleaning procedure, operate the engine at constant load for a minimum of five minutes.

⇒ Make sure that a fresh water supply is available at the ball cock 2 (see Fig. 'C').

C



⇒ Connect the hose 3 to the claw couplings 4, then open the ball cock 2.

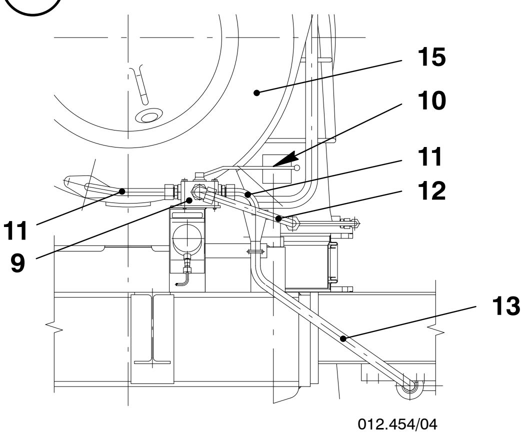
⇒ Open slowly the ball cock 5 until the pressure gauge 8 indicates 1.0 bar. Inject water for 10 minutes.

Remark: Water will discharge after approximately two to three minutes. It is possible that no water will discharge.

CHECK Make sure that the turbocharger speed is slower and the exhaust gas temperature after the turbocharger has decreased. This shows that there is sufficient water injection.

Attention! In an emergency (e.g. ship's safety), the engine load can be increased immediately during the wash-clean procedure. However, close the ball cock 5 immediately to shut off the water supply.

D



⇒ Close the ball cocks in the sequence that follows:

– Ball cock 5

– Ball cock 2 of fresh water distribution pipe 1.

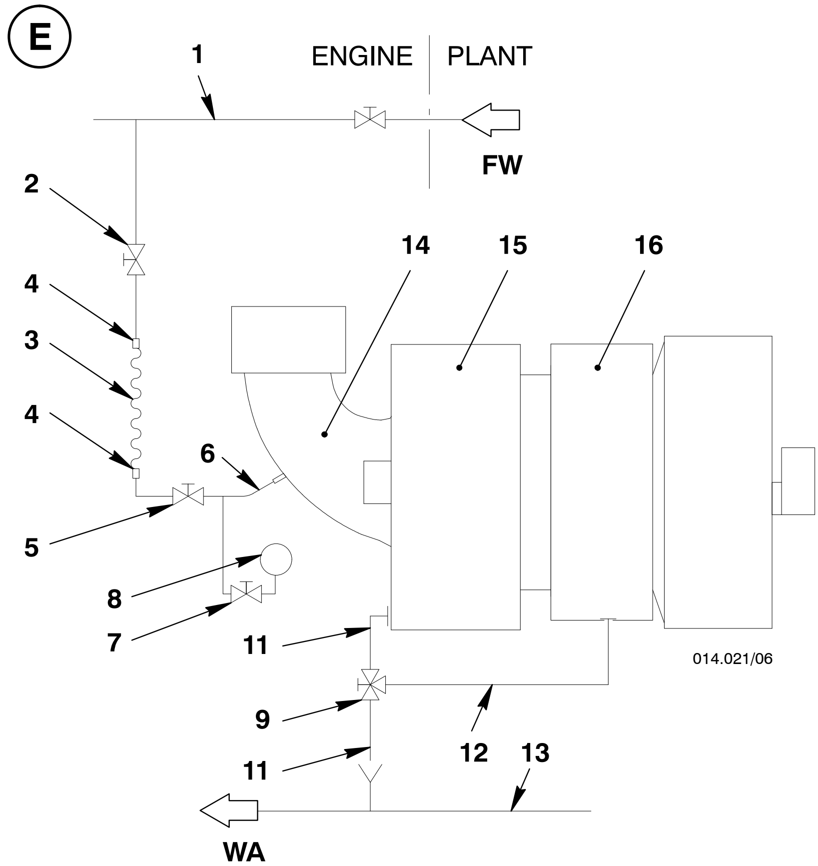
⇒ Disconnect the hose 3 from the claw couplings 4.

⇒ When no water flows from the drain pipe 11, turn the handle 10 back to the operating position 'BS'. See the position marks in Fig. 'B' for the related positions.

Remark: Operate the engine for a minimum of 10 minutes above 25% load to make sure that the exhaust gas installation is completely dry.

If the exhaust gas temperature after turbine is still too high at the higher loads, do the wash-clean procedure again.

If the exhaust gas temperature after turbine is still not correct after three wash-clean procedures, dismantle the turbocharger for cleaning. See the instructions in the turbocharger manual.



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 distribution pipe	11	Drain pipe
2	Ball cock	12	Tube (for scavenge air)
3	Hose	13	Drain pipe (with funnel)
4	Claw coupling	14	Gas inlet casing
5	Ball cock	15	Gas outlet casing
6	Tube (for water connection)	16	Air outlet casing
7	Shut-off valve		
8	Pressure gauge	BS	Operating position
9	Ball cock	WA	Wash-water drain
10	Handle (for ball cock 9)	WW	Wash position

4. Dry cleaning

Dry solid particles (granules) are used for the dry cleaning procedure. The quantity of granules used is dependent on the turbocharger size. During the dry cleaning procedure, compressed air blows the granules into the exhaust pipe before the turbocharger.

The granules have a mechanical effect that removes dirt deposits on the nozzle ring and turbine blades. However, it is not possible to remove thick dirt deposits with the relatively small quantity of granules required for each dry cleaning procedure. Therefore, frequent use of this dry cleaning method is necessary.

This dry cleaning method is effective at exhaust gas temperatures of more than 500°C before turbocharger.

4.1 Dry cleaning of turbine (see Fig. 'F' to 'G')

Cleaning intervals:

- Every 24 to 48 operating hours

Guidance values:

- The cleaning interval is dependent on environmental influences on the intake air and the extent of contamination in the turbocharger.

Operating conditions:

- Do the dry cleaning procedure 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 more than 0.5 bar.
- The required quantity of granules is shown in the table that follows:

Turbocharger Type	Quantity [l]
TPL 73	1.0
TPL 77	1.5

4.2 Granulate specification

Materials: Hard, granulated materials e.g. natural core granulates, softblast media or active charcoal particles.

Mean grain size: 1.2 mm to 2.0 mm

Density: max. 2.0 kg/dm^3

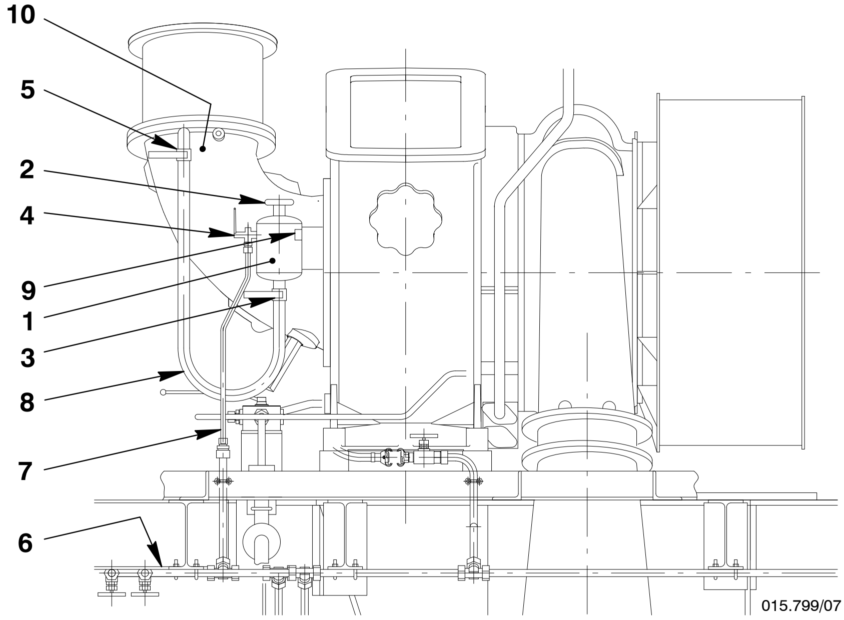
Storage: Clean and dry area

Suppliers: See the documents of the turbocharger manufacturer

Remark: Before the dry cleaning procedure, use compressed air to blow through the dry cleaning plant to remove deposits or condensates that can collect in the pipes.

4.3 Cleaning procedure

F



Key to Illustrations: **'F' Arrangement of dry cleaning plant**
'G' Schematic diagram

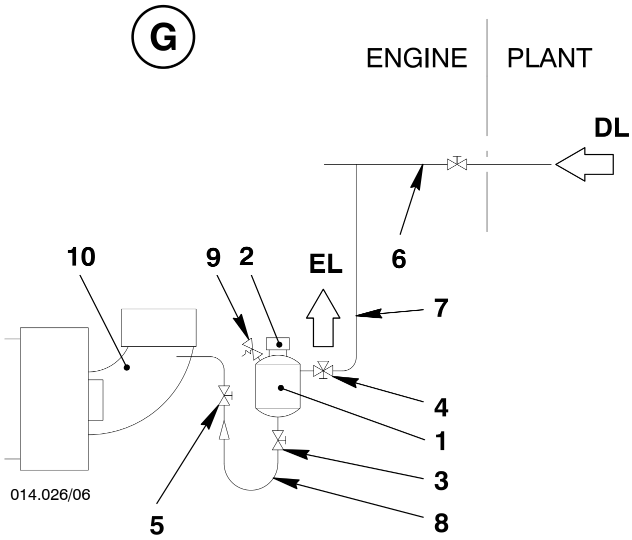
1 Pressure vessel
2 Cover
3 Shut-off valve
4 3-way valve (compressed air and vent)
5 Shut-off valve
6 Compressed air distribution
7 Compressed air supply pipe
8 Hose line
9 Relief valve
10 Gas inlet casing

DL Compressed air
EL Vent

Expelled residue:

The hot exhaust temperature burns the granules. The burnt granules are then expelled together with the dirt deposits removed from the turbocharger.

Attention! It is possible that incompletely burnt soot particles can escape through the chimney.



Initial position, *engine in normal operation (no cleaning procedure):*

- The 3-way valve 4 is in the VESSEL VENTING position.
- The shut-off valves 3 and 5 are closed.
- The pressure vessel 1 is empty and the cover 2 is fitted.
- Compressed air is available at the 3-way valve 4.

Cleaning procedure:

CHECK Make sure that the shut-off valve 3 is closed and pressure vessel 1 is vented through the 3-way valve 4.

⇒ Carefully loosen the cover 2 to release possible pressure from the pressure vessel 1.

⇒ Remove the cover 2 from the pressure vessel 1.

⇒ Fill pressure vessel 1 with the required quantity of granules.

⇒ Fit the cover 2 to the pressure vessel 1.

⇒ Open the 3-way valve 4 (the vent 'EL' closes and compressed air flows to the pressure vessel 1).

⇒ Open the shut-off valves 5 and 3.

- Compressed air blows the granules into the gas inlet casing 10.

⇒ After approximately three to four minutes, close the shut-off valves 3 and 5 (the cleaning procedure is complete).

⇒ Close the 3-way valve 4 (the vent 'EL' opens and the flow of compressed air to the pressure vessel 1 stops).

Remark: If the mean exhaust gas temperature after turbine is still too high at higher loads, do the cleaning procedure again.

If the cleaning procedure is not successful after three attempts and the exhaust gas temperature after turbine is still unsatisfactory, the turbocharger must be dismantled for cleaning. See the instructions in the turbocharger manual.

Remark: If the engine performance changes suddenly (e.g. severe surging occurs), do the cleaning procedure again with approximately half of the recommended quantity of granulate given in the table above.

Overview

1. General

The turbochargers have a system to wash the compressor and turbine. It is possible to clean the compressor and the turbine while the turbocharger runs. Periodic cleaning prevents or reduces contamination. This allows much longer intervals between overhauls. If the dirt accumulation becomes excessive (scavenge air pressure decreases and exhaust gas temperatures increase) the turbocharger must be dismantled for cleaning, in accordance with the instructions in the turbocharger manual (see Operating Data Sheet 0250−1 for permitted pressure decrease).

Regular visual checks and cleaning are necessary to keep the silencer in a serviceable condition. Clean the silencer and filter only when the engine is at shutdown and in accordance with the instructions given in the turbocharger manual.

Remark: An additional filter mat installed on top of the silencer will keep the fouling on the air side to a minimum, but will cause a loss of pressure.

Based on the increase of the pressure difference (Δp to maximum 10 mbar), or the filter mat is discolored, clean the filter mat in accordance with the instructions given in the turbocharger manual.

The methods that follow are for periodic cleaning of the compressor and turbine:

− 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:

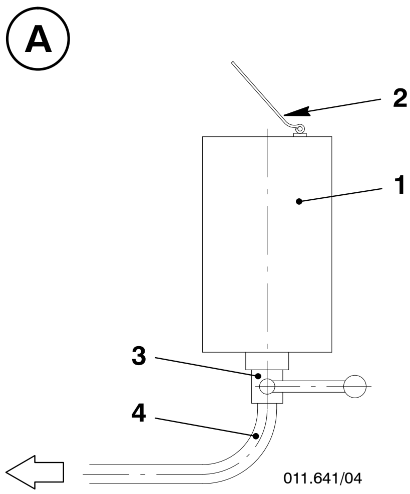
The cleaning interval depends upon environmental influences on the intake air and the extent of contamination of the turbocharger.

Operating condition:

Do the cleaning procedure at reduced engine power (< 50% load), i.e. at lower turbocharger speed as shown in the table that follows:

Turbocharger		Water quantity	Injection time
Type	Speed [rpm]	[l]	[Sec.]
MET 53MA	approx. 7000−9500	2.0	approx. 40−80
MET 60MA	approx. 6300−8500	2.25	approx. 45−90

2.1 Cleaning procedure



⇒ Reduce engine power to get the applicable turbocharger speed (see the table above).

- Before wash-cleaning, operate the engine at constant load for a minimum of five minutes.

CHECK Make sure that the strainer in the water container is not clogged.

⇒ Open the hinged cover 2. Fill the water container 1 with clean fresh water (do not add cleaning agents).

- The water quantity is specified in the table above.

⇒ Close the hinged cover 2. Open the shut-off valve 3 for approximately 50 seconds to 100 seconds.

⇒ Close the shut-off valve 3. Make sure that the water container 1 is empty.

- An increase in scavenge air pressure, or a decrease in exhaust gas temperature shows that the cleaning procedure is successful.

Key to Illustration: 'A'

1 Water container
2 Hinged cover
3 Shut-off valve
4 Water hose to compressor inlet

⇒ When the compressor is clean, operate the engine under load for a minimum of five minutes.

3. Dry cleaning

Dry solid particles (granules) are used for the dry cleaning procedure. The quantity of granules used is dependent on the turbocharger size. During the dry cleaning procedure, compressed air blows the granules into the exhaust pipe before the turbocharger.

The granules have a mechanical effect that removes dirt deposits on the nozzle ring and turbine blades. However, it is not possible to remove thick dirt deposits with the relatively small quantity of granules required for each dry cleaning procedure. Therefore, frequent use of this dry cleaning method is necessary.

This dry cleaning method is effective at exhaust gas temperatures of more than 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 is dependent on environmental influences on the intake air and the extent of contamination in the turbocharger.
- Regular dry cleaning in service is is recommended on a routine basis, at first every 100 running hours (e.g. once a week). Adapt the cleaning intervals to the quantity of contamination found during turbocharger overhaul.

Operating conditions:

- Do the dry cleaning procedure 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 more than 0.5 bar.
- The maximum turbocharger speed and required quantity of granules for the related turbocharger type is shown in the table that follows:

Turbocharger		Quantity
Type	Speed [rpm]	[l]
MET 53MA	max. 14 800	1.6
MET 60MA	max. 13 300	2.1

3.2 Granulate specification

Materials: Hard, granulated materials, such as milled walnut shell or grain (rice, wheat etc.)

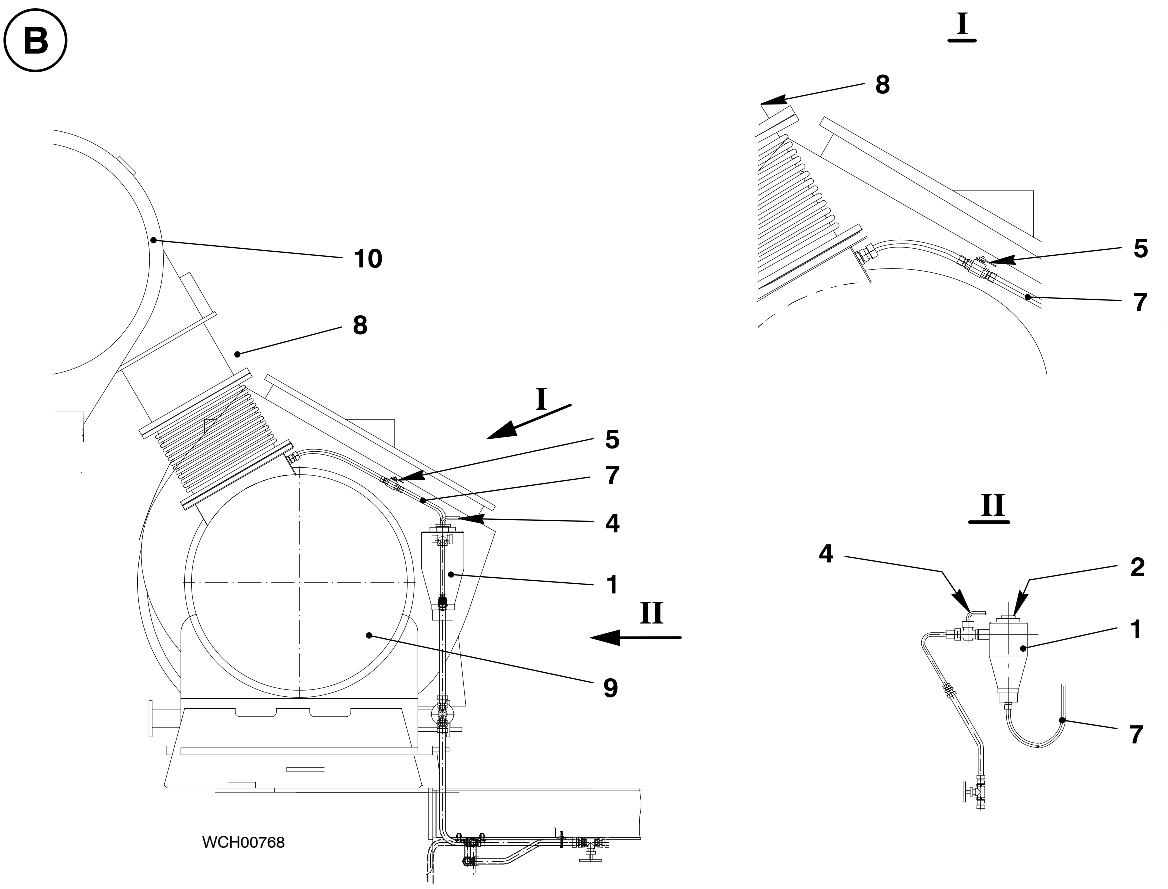
Mean corn size: 2.0 to 2.8 mm (grain diameter within 3 mm)

Storage: Clean and dry area

Suppliers: See documents of the turbocharger manufacturer

Remark: Before the dry cleaning procedure, use compressed air to blow through the dry cleaning plant to cool the plant and remove deposits or condensates that can collect in the pipes.

3.3 Cleaning procedure



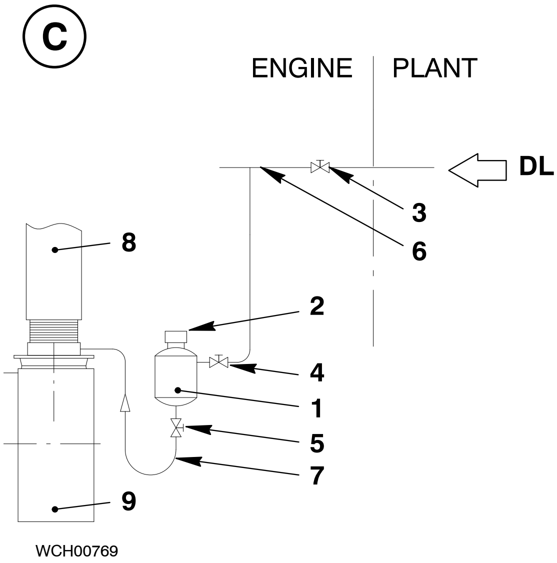
Key to Illustrations: **’B’ Arrangement of dry cleaning device**
’C’ Schematic presentation

1	Pressure vessel	7	Cleaning pipe
2	Filler cap	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

Expelled residue:

The hot exhaust temperature burns the granules. The burnt granules are then expelled together with the dirt deposits removed from the turbocharger.

Attention! It is possible that incompletely burnt soot particles can escape through the chimney.



Initial position, *engine in normal operation (no cleaning procedure):*

- Shut-off valves 4 and are 5 closed.
- The pressure vessel 1 is empty and the filler cap 2 is fitted.
- The shut-off valve 3 is open and compressed air is available at the shut-off valve 4.

Preparation - blow-through:

⇒ Open the shut-off valves 4 and 5.

⇒ After approximately two minutes, close the shut-off valves 5 and 4 (blow-through is completed).

Cleaning procedure:

⇒ Carefully loosen the filler cap 2 to release possible pressure from the pressure vessel 1.

⇒ Remove the filler cap 2 from the pressure vessel 1.

⇒ Fill the pressure vessel 1 with the required quantity of granules.

⇒ Fit the filler cap 2 to the pressure vessel 1.

⇒ Open shut-off valves 4 and 5.

- Compressed air blows the granules into the exhaust pipe 8.

⇒ After approximately two minutes, close the shut-off valves 5 and 4 (the cleaning procedure is completed).

Remark: If the mean exhaust gas temperature after turbine is still too high at higher loads, do the cleaning procedure again.

If the cleaning procedure is not successful after three attempts and the exhaust gas temperature after turbine is still unsatisfactory, the turbocharger must be dismantled for cleaning. See the instructions in the turbocharger manual.

Remark: If the engine performance changes suddenly (e.g. severe surging occurs), do the cleaning procedure again with approximately half of the recommended quantity of granules given in the table above.

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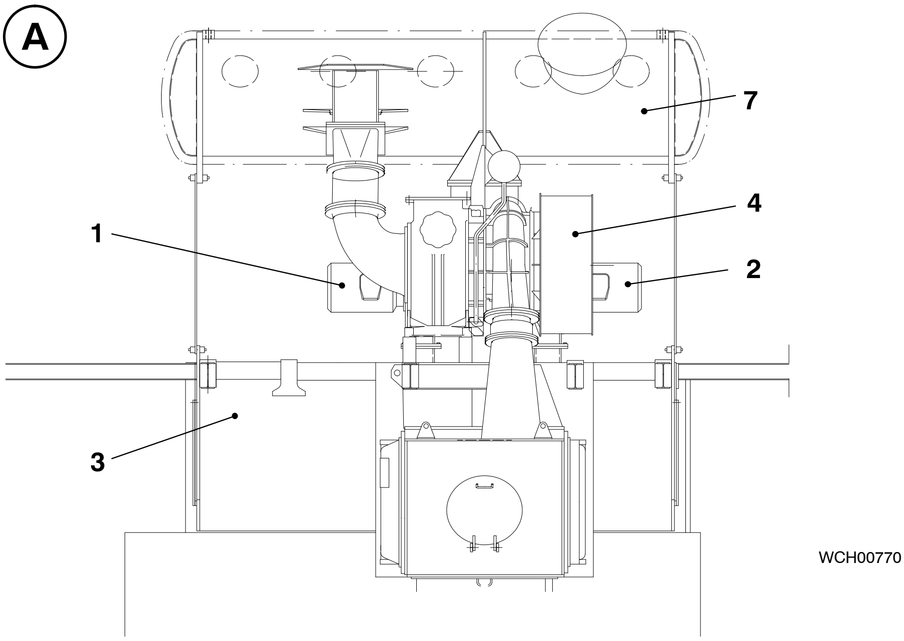
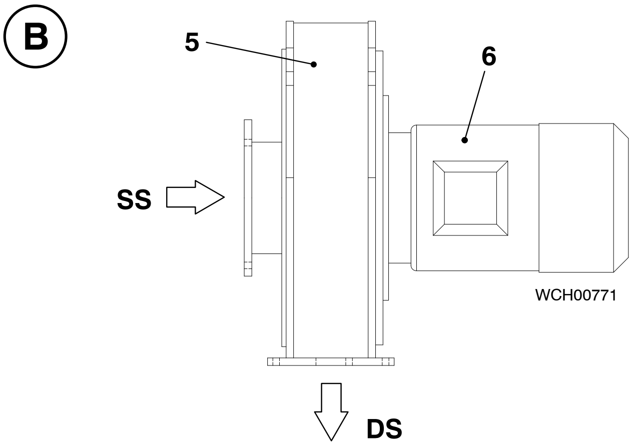
1. Auxiliary blower

The auxiliary blowers 5 are mounted on the top face of the receiver 3. The electric motors 6 drive the auxiliary blowers 5. The auxiliary blowers supply air from the receiver pre-space through the suction casing into the receiver space during engine start and operation at low load. Air flaps prevent the back-flow of air from the auxiliary blowers to the receiver (see Scavenge Air Receiver 6420−1).





Key to Illustrations: **'A' Arrangement of auxiliary blower**
'B' Auxiliary blower

1 Auxiliary blower (left hand design)
2 Auxiliary blower (right hand design)
3 Receiver
4 Exhaust gas turbocharger
5 Blower
6 Electric motor
7 Exhaust manifold

DS Pressure side
SS Suction side

2. Switch box

The engine builder supplies the switch box 1 for the two auxiliary blowers. The switch box has one section for each auxiliary blower (see Fig.’C’).

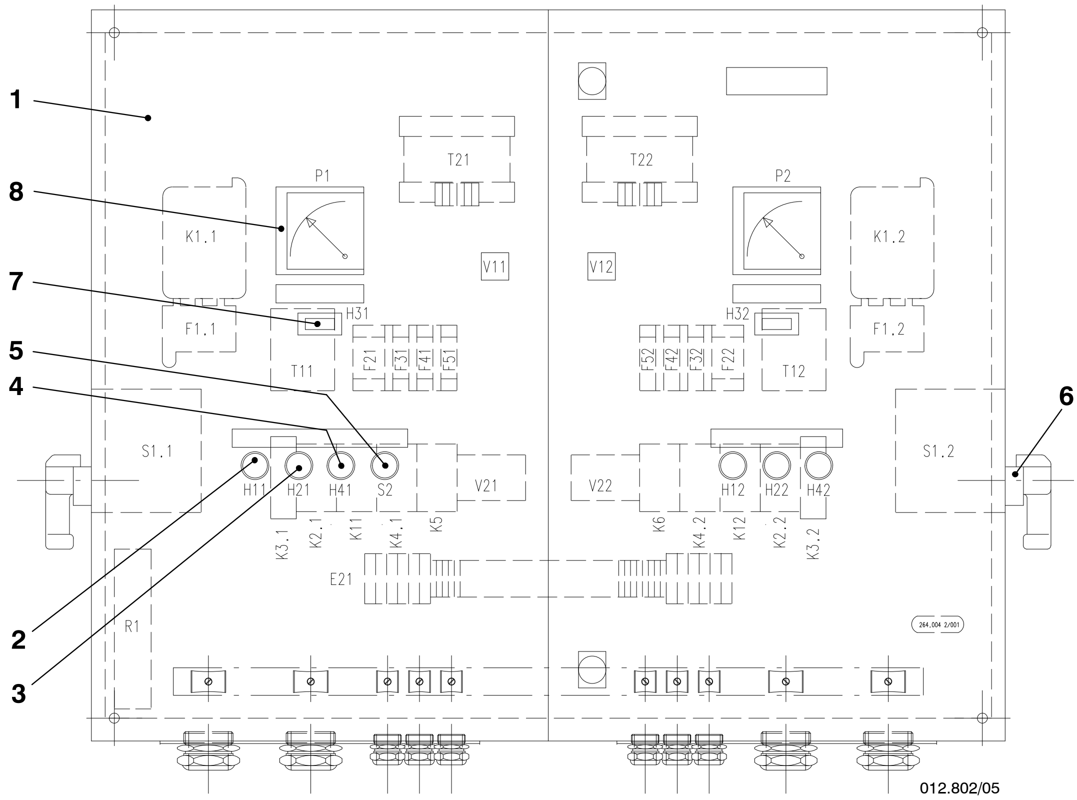
Operating function:

The two main switches 6 (S1.1 and S1.2) are set to on and the voltage indicators (H11 and H12) come on. When a selection is made in the local control panel (e.g. the START AHEAD button is pressed), auxiliary blower No.1 starts immediately. After a delay of approximately two to three seconds, auxiliary blower No.2 starts.

When the exhaust gas turbocharger produces sufficient high pressure in the receiver, the auxiliary blowers shut down.

If the scavenge air pressure decreases below the minimum pressure, the auxiliary blowers operate as given above. For more data, see 4003−1 ’Auxiliary Blowers’.

C



Key to Illustration: ’C’ Switch box (example)

1 Switch box
2 Voltage indicator
3 Service indicator
4 Overload indicator
5 Lamp test
6 Main switch
7 Hour counter
8 Amperage indicating instrument

Scavenge Air Cooler

Operating Instructions and Cleaning

1. General

The scavenge air cooler (SAC) is a single-stage, multi-pass unit installed below the turbocharger. The function of the SAC is to cool the compressed air (scavenge air) that flows from the compressor in the turbocharger. The scavenge air flows through the water separator and the scavenge air receiver to the cylinders.

The cooling water enters the SAC through 'KE', flows through the core tubes in the SAC then flows out through 'KA'. The temperature difference between the water and scavenge air is distributed equally through the SAC.

2. Operating instructions

Air that accumulates in the cooling water system of the SAC can affect engine operation and cause damage to the SAC. Correct venting of the SAC must be maintained.
Regular checks of the SAC temperature must be done in accordance with data in Operating Data Sheet 0250−1.

If the level switch 19 of float / solenoid switch unit 17 activates an alarm, the cause, (condensate water or scavenge air cooling water) must be investigated. If the cause is scavenge air cooling water, the SAC must be dismantled and repaired (see Maintenance Manual 6606−2).

To prevent damage to the SAC, the correct cooling water flow must be maintained during operation. Do not reduce the flow of cooling water at partial load or during manoeuvring.

Remark: The butterfly valves at the cooling water inlet and outlet pipes must not be used to control the flow rate. Scavenge air temperatures that are too high at higher loads can cause damage to the plastic water separators.

If the SAC is defective during operation, see the recommendations given in 0550−1.

As a guide to the correct function of the SAC, the temperature difference between scavenge air outlet and cooling water inlet 'KE' can be used as a basis. The two temperature values must have regular checks. If the temperature difference increases while engine load and cooling water flow remain unchanged, it is an indication of increased 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 (Δp) 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 (note the limiting values). More detailed indications to monitor of the SAC in operation are given in Operating Data Sheet 0250−1.

Higher scavenge air temperature and reduced air flow increases thermal loading of the engine and increased exhaust gas temperatures.

Air side cleaning of the SAC can be done when engine is running. The water side of the SAC can only be cleaned at engine standstill. The procedure to clean the water side of the SAC at engine standstill is given in 6606−1 of the Maintenance Manual.

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

When the engine is new, we recommend that the SAC is cleaned weekly. If there is no change in the pressure difference (∆p) through the SAC, the cleaning interval can be increased (e.g. monthly).

The pressure difference must not exceed the maximum limit (∆p increase of 50% compared to shop test value at same engine load) (see also Maintenance Manual 0380–1).

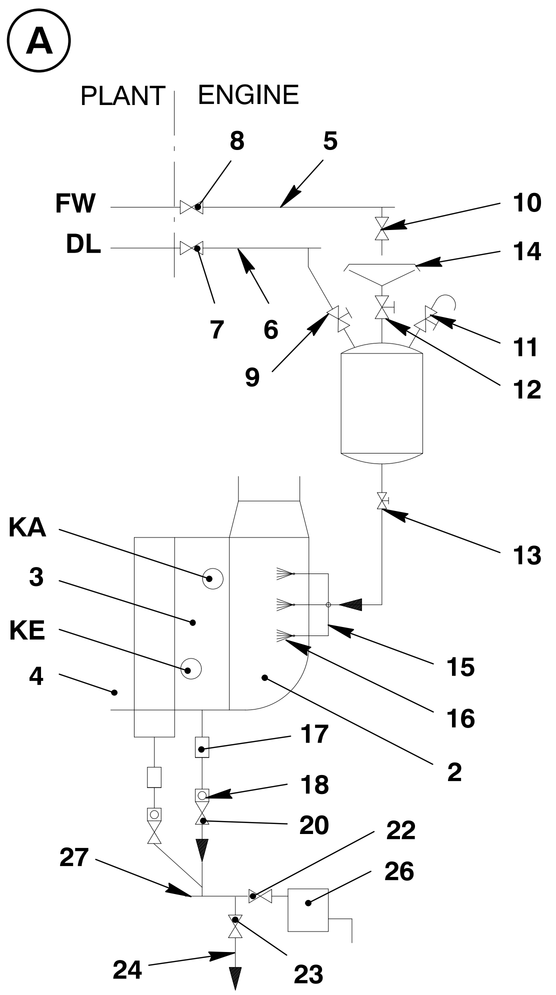
The quantity of SAC contamination is dependent on the condition of the air intake and maintenance of the air filter on the turbocharger.

Remark: If possible, do not clean the SAC in tropical conditions (increased condensate).

3.2 Cleaning procedure

Do the cleaning procedure with the engine operating at partial load, i.e. below 50% load. The air temperature after compressor (turbocharger) must not be more than 100°C because the cleaning agent will vaporize.

- Reduce the engine power to the values given above.
- Compressed air / fresh water must be available at the shut-off cocks 9 and 10.



⇒ Open the shut-off valve 11 and ball cock 12.

⇒ For the specified quantity of cleaning agent, see paragraph 'Cleaning agent'.

⇒ Carefully open the shut-off valve 10 to let fresh water FW flow through the funnel 14 to the container 1. Add the specified quantity of cleaning agent into the funnel 14.

- Open the shut-off valve 10 slowly to prevent fresh water overflow from the funnel 14.

⇒ Close the ball cock 12 and shut-off valve 11 (vent).

⇒ Open the shut-off valve 9 and ball cock 13. The water / cleaning agent mixture will flow through the spray nozzles 16 in approximately one minute. Open the two butterfly valves 20. Close the ball valve 22, then open the ball valve 23 (see also 8345–1 'Condensate drain').

⇒ Close the shut-off valve 9 and ball cock 13.

⇒ Open the shut-off valve 11 until the container 1 fully vents.

⇒ Close the two butterfly valves 20. Open the ball valve 22 and close ball valve 23 (see also 8345–1 'Condensate drain').

⇒ After approximately 10 minutes do the procedure again, but use only clean water. This completes the cleaning process.

Remark: You can also use a 20 liter container with the applicable quantity of cleaning fluid diluted with fresh water to fill the container 1. If this method is used, make sure that the shut-off valve 10 stays closed.

Remark: Dirt that is loosened from the cooling fins can accumulate in the water separator elements or in the scavenge air receiver 4. Do a periodic check of the water separator elements and the receiver 4. If it is necessary to clean the water separator elements and the receiver 4, see the related data in the Maintenance Manual.

3.3 Cleaning agent

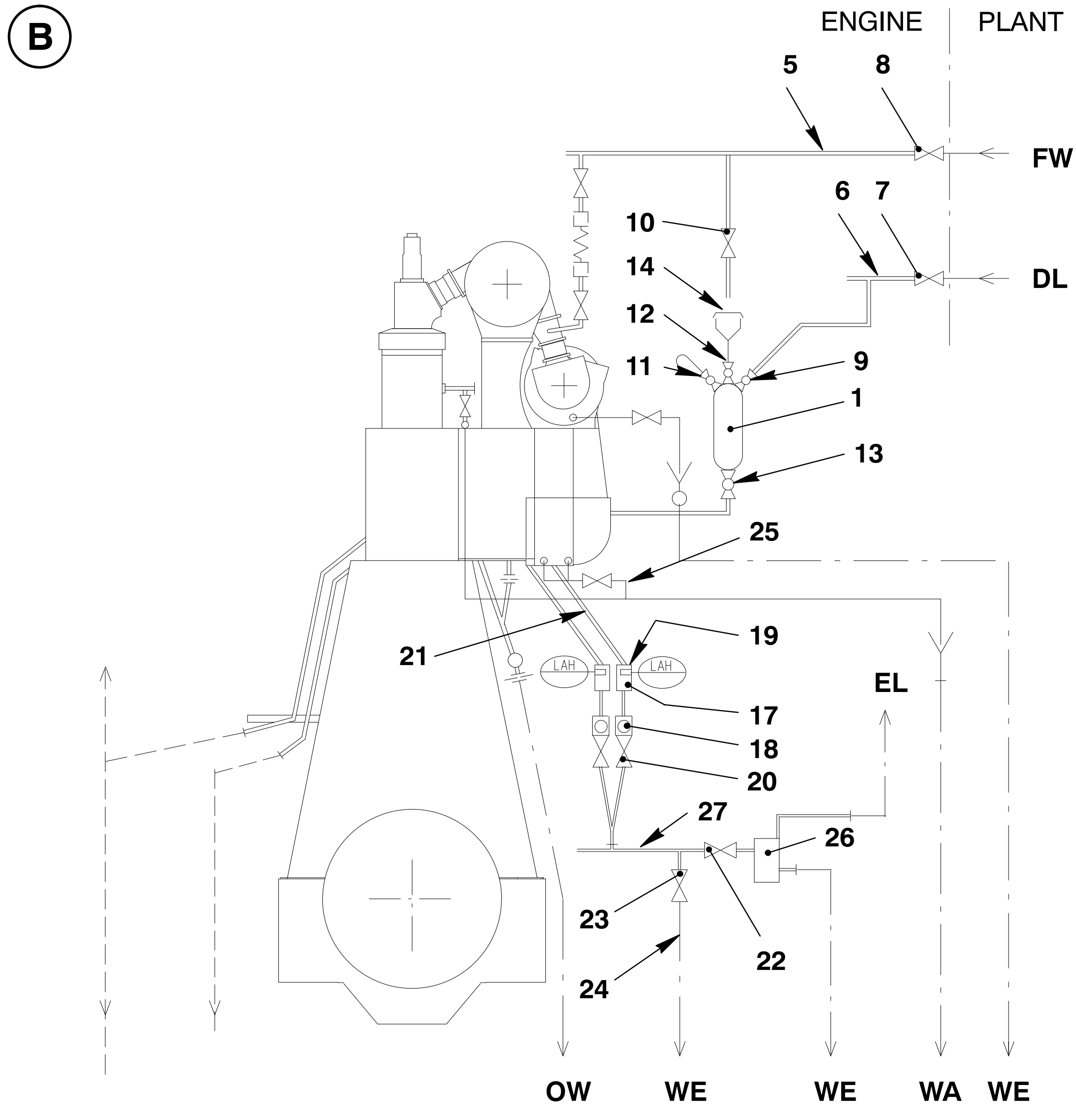
In principle, only use products from reputable manufacturers. Follow closely the manufacturers instructions for the correct ratio of cleaning agent to water.

For in-service cleaning, use only the cleaning agents that have a sufficiently high flash point. The cleaning agent must be diluted with fresh water in accordance with the manufacturers instructions.

Remark: Detailed instructions on operation, maintenance and repair of scavenge air coolers are given in the Instruction Leaflet issued separately by the SAC manufacturer.
It is practical to obtain these Instruction Leaflets directly from the manufacturers. It is also possible to order such Instruction Leaflets from the engine manufacturer or supplier. The information that follows must be given on request:

- Engine type and No.
- Engine supplier
- SAC 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 the engine

1	Container (20 liter)	19	Level switch
2	Air duct	20	Butterfly valve (with bore)
3	Scavenge air cooler	21	Condensate and wash-water drain pipe
4	Receiver	22	Ball valve
5	Fresh water distribution pipe	23	Ball valve
6	Compressed air distribution pipe	24	Cleaning fluid and wash-water drain
7	Ball valve	25	SAC drain
8	Ball valve	26	Venting unit
9	Shut-off valve	27	Condensate and dirty water collecting pipe
10	Shut-off valve		
11	Shut-off valve (vent)	DL	Compressed air from plant, 7 bar to 8 bar
12	Ball cock	EL	Vent
13	Ball cock	FW	Fresh water at 2.5 bar
14	Funnel	KA	Cooling water outlet
15	Distribution tube	KE	Cooling water inlet
16	Spray nozzle	OW	Drain to sludge water tank (oleiferous)
17	Float / solenoid switch unit	WA	Drain to water drain tank
18	Sight glass	WE	Drain to bilge water tank

Cylinder Lubrication Group 7

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Overview

1. General

The lubrication of the cylinder liners and pistons 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).

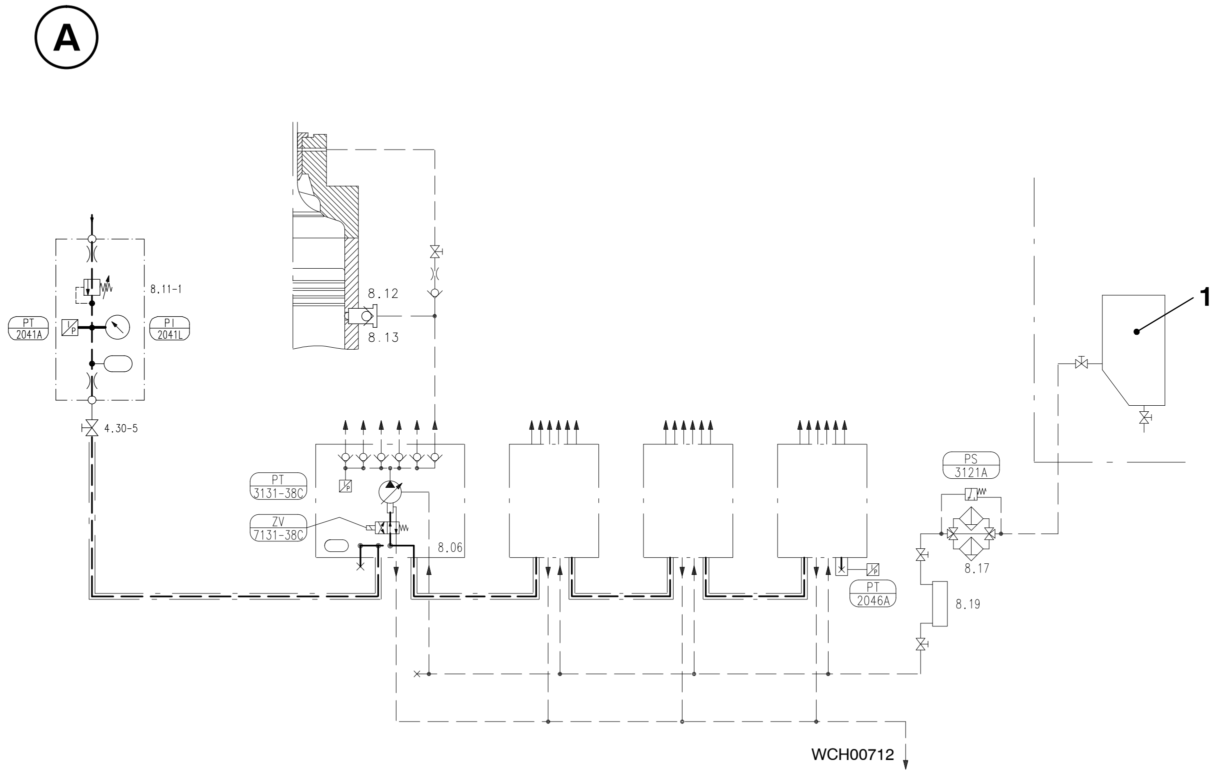
1.2 Cylinder lubricating oil for running-in

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 8.12 with injection nozzle . . . . (six per cylinder)
  - Non-return valve 8.13
- Controlling of the system via the engine control system WECS−9520 (see 4002−1 'Cylinder lubricating system control')



2.1 Daily service tank (plant side)

The daily service tank 1 for the cylinder lubricating oil is 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.

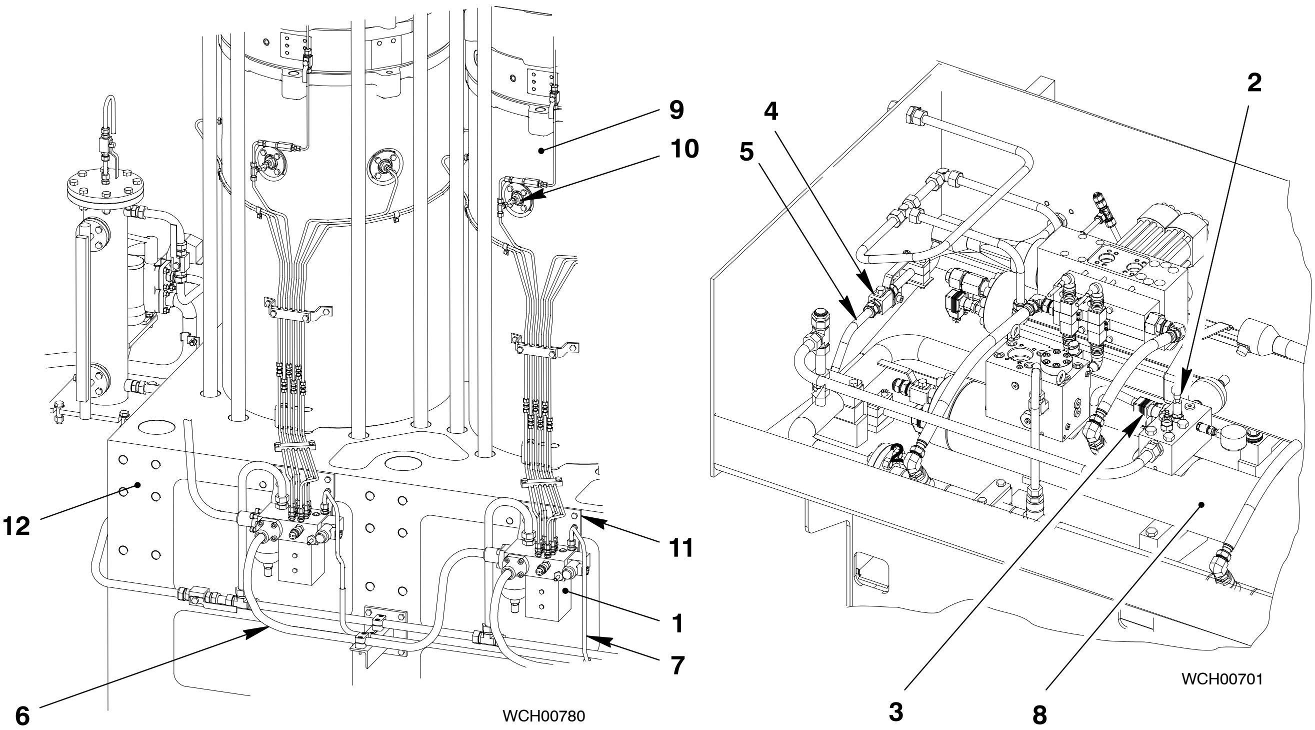
2.2 Arrangement of lubricating pumps (Fig. 'B')

For each cylinder there is a lubricating pump 1 designed as a compact self-supporting unit and fastened to cylinder block 12 on fuel side with the support 11.

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 6 (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 5 and 6 to the lubricating pumps are double-walled.
Leakages (e.g. breakage of the inner HP piping) are monitored by pressure transmitter 12 and then an alarm is triggered in the alarm and monitoring system. Such problems can also be recognized visually by opening screw plug 8 (max. two turns) on the last lubricating pump(s) (see Fig. 'E').

B



Key to Illustration: B Arrangement of lubricating pumps

1	Lubricating pump 8.06	7	Servo oil return pipe
2	Pressure reducing valve 8.11−1	8	Servo oil rail 4.11
3	Pressure transmitter PT2041A	9	Supporting ring
4	Stop valve 4.30−5	10	Lubricating quill
5	Servo oil pipe	11	Support
6	Servo oil connecting pipe	12	Cylinder block

3. Lubricating oil filter and measurement tube (Fig. ’C’)

The lubricating oil filter (filter) 1 and measurement tube 4 are installed before the lubricating oil distribution to the lubricating pumps. Ball valve 8 after measurement tube 4 must always be open during operation. The fouling factor is monitored by differential-pressure sensor 6, built on to 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

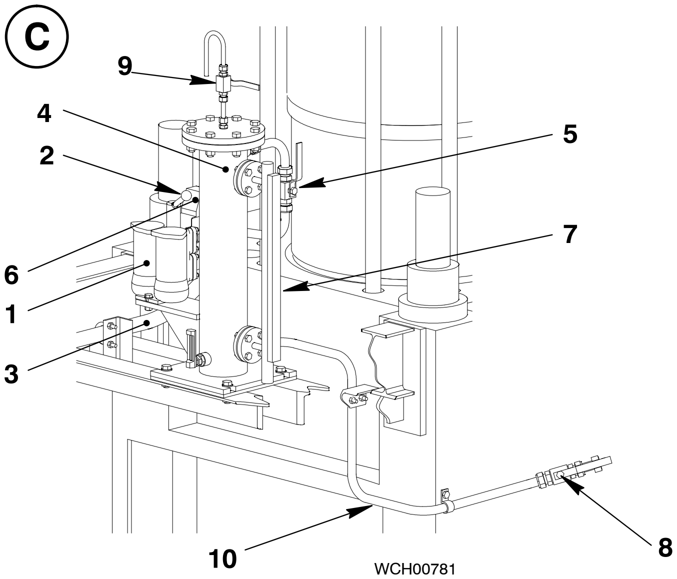
The filter is to be vented:

- by the first commissioning
- after changing filter elements

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.

⇒ Move the lever 2 on the (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 Scale
8 Ball valve
9 Venting cock
10 Distributing pipe

3.3 Measurement of consumption at measurement tube

The integrated magnetic level indicator and the scale 7 is used 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 correct 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 must never drop below the mark (1) on scale because air can get into the system and cause malfunctions.

Procedure:

⇒ Close the ball valve 5.

⇒ Open the venting cock 9.

⇒ When the oil appears on the scale 7, mark the position and then start the time measurement.

⇒ After a determined measuring time (15 to 20 minutes), stop the time measurement and mark the oil level again.

⇒ Open the ball valve 5.

⇒ Keep the venting cock 9 open until bubble-free oil flows, then close it.

⇒ Read the distance between the two marks on the scale 7, then apply the relevant conversion factor (1 cm = 0.14 l) to determine the consumed oil quantity in liters.

Remark: The conversion factor depends on the size of the measurement tube. Note the marking (lettering) on the scale.

The actual feed rate can be subsequently determined (see Instructions Concerning Measurement of Cylinder Lubricating Oil Consumption 7218–2).

4. Lubricating pump

4.1 General

The modular design of the lubricating pump means that the main components can be quickly replaced.
The lubricating pump consists of: Pump body 1, baseplate 2, 4/2-way solenoid valve 3 and accumulator 4.

ALM–20 module (control unit) is located near 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:

The 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 looped through the baseplate to the downstream lubricating pump.

In order to replace 4/2-way solenoid valve 3, shut-off valve 6 (servo oil inlet) is 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:

The 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 to determine the metering rate, which is equal for all metering pistons. Venting screws 9 and 10 are for venting the lubricating pump (see paragraph 4.3).

4/2-way solenoid valve:

Corresponding signals control the 4/2-way solenoid valve 3, which then releases relevant oil bores to actuate the central piston in the pump body.

Accumulator:

The function of accumulator 4 is to cushion pressure peaks in the servo oil piping, keeping a largely constant servo oil pressure.

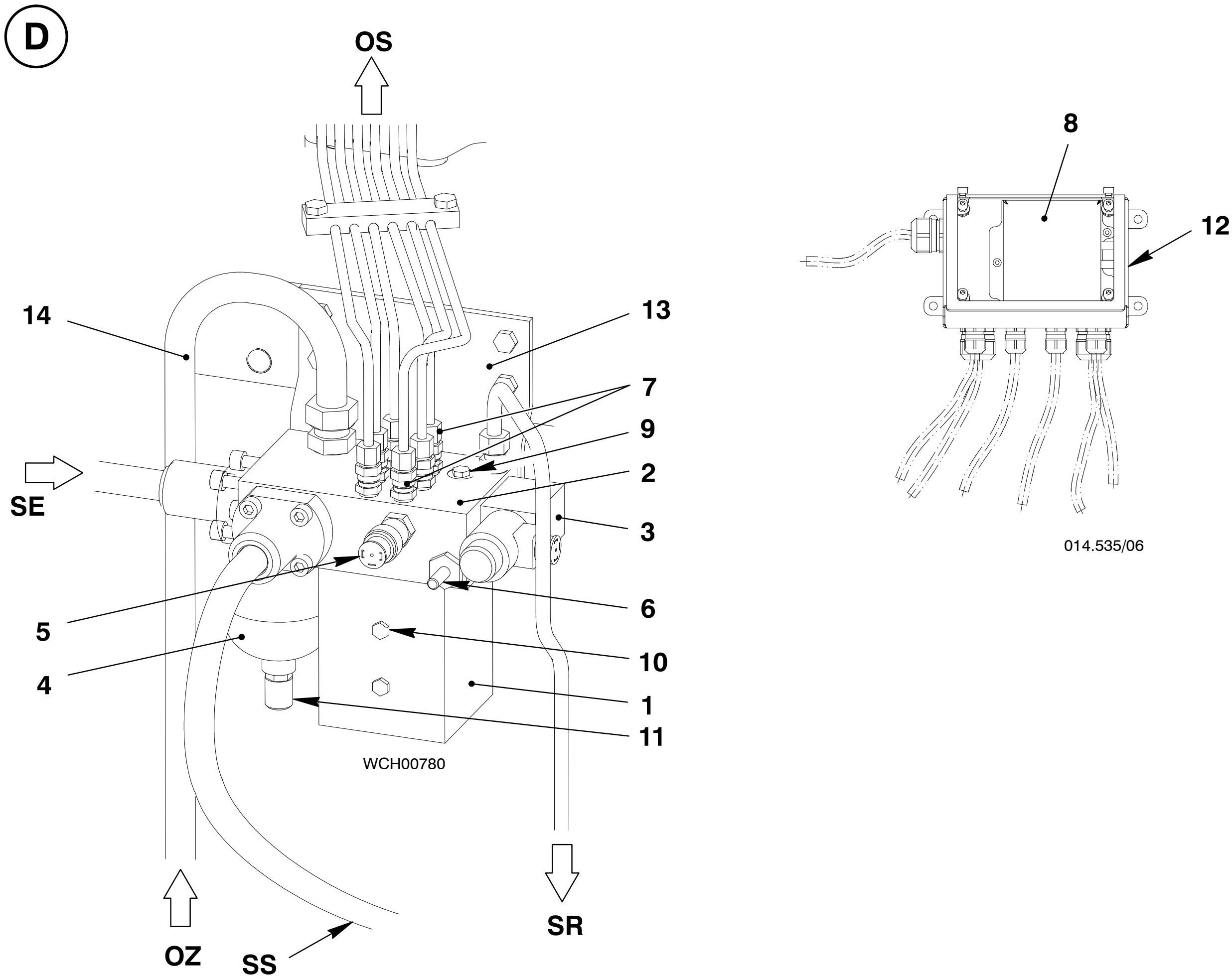
The pre-start check and recurrent tests of the gas cushion (gas pre-charge pressure) must be done in accordance with the documentation of the lubricating pump supplier (see Maintenance Manual 7218–1).

ALM–20 module (control unit):

To make sure that the lubricating pump functions correctly, an ALM–20 module 8 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).



Key to Illustration: ’D’ Lubricating pump

1	Pump body	11	Testing port and filling connection
2	Baseplate	12	Control box E41.01−08
3	4/2-way solenoid valve ZV7131−38C	13	Support
4	Accumulator	14	Distributing pipe
5	Pressure transmitter PT3131−38C		
6	Shut-off valve (servo oil)		
7	Lubricating oil outlet port with non-return valve	OS	Oil to lubricating quill
		OZ	Oil supply
8	ALM−20 module (control unit)	SE	Servo oil inlet
9	Venting screw (servo oil)	SR	Servo oil return
10	Venting screw (lubricating oil)	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 the engine control system WECS−9520 triggers a lube pulse, the ALM−20 module actuates the 4/2-way solenoid valve. Servo oil flows to the drive side of the central piston. The servo oil on the underside of the central piston flows back into the servo oil return pipe through the reversed 4/2-way solenoid valve. The central piston is pressed into its lower limit position. At the same time lubricating oil flows at high pressure through the non-return valves in the lubricating oil outlet ports. The lubricating oil is then injected into the cylinder liner through the lubricating quills.

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 through the 4/2-way solenoid valve to the underside of the central piston and presses the central piston 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, ready for another lube pulse.

4.3 Venting the lubricating pump

Venting screw 9 (servo oil) and vent screw 10 (lubricating oil) are used to vent 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
- in case of operating troubles (operating pressure, feed rate)

Lubricating oil:

⇒ Place an oil tray beneath the lubricating pump.

⇒ Open venting screw 10 a maximum of three turns.

⇒ Keep venting screw 10 open until bubble-free oil flows, then close and retighten it.

Servo oil:

Attention! The servo oil system is under high pressure. Always wear safety goggles because oil may spurt when loosening the venting screw 9.

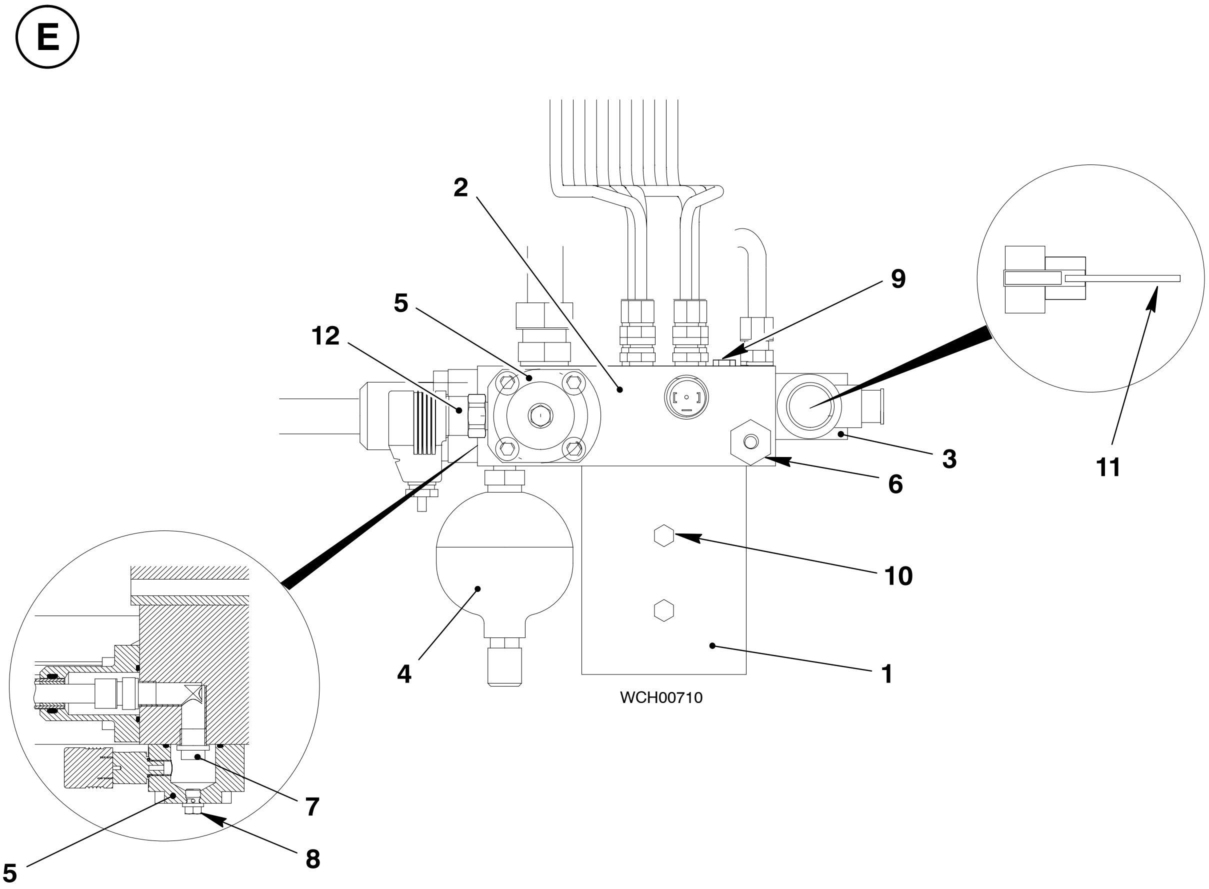
⇒ Place an oil tray beneath the lubricating pump.

⇒ 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').

⇒ Carefully open the venting screw 9 a maximum of three turns.

⇒ Keep venting screw 9 open until bubble-free oil flows, then close and tighten it.

⇒ Remove the oil tray.



Key to Illustration: 'E' Last Lubricating pump

1	Pump body	7	Screw plug
2	Baseplate	8	Screw plug
3	4/2-way solenoid valve ZV7131–38C	9	Venting screw (servo oil)
4	Accumulator	10	Venting screw (lubricating oil)
5	Blind flange	11	Assembly pin (max. ∅ 3.5 mm)
6	Shut-off valve (servo oil)	12	Pressure transmitter PT2046A

4.4 Venting the lubricating oil system

After venting the filter, the measurement tube and lubricating pumps, the pipes to the lubricating quills must be vented.

⇒ Loosen all cap nuts of the pipes by approximately 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 bubble-free oil flows, tighten the 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 the assembly pin 11 is pushed inwards, the central piston in the lubrication pump moves a full stroke to release a single lube pulse.
Note that manual lubrication is not the same as pre-lubrication. Pre-lubrication is part of the PLS control system and is executed automatically.

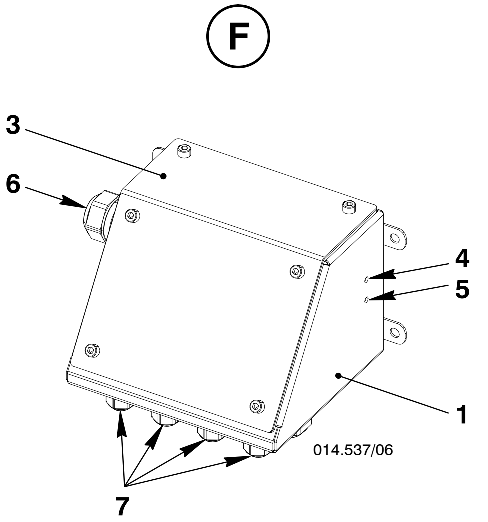
4.5 Maintenance on lubricating pump components

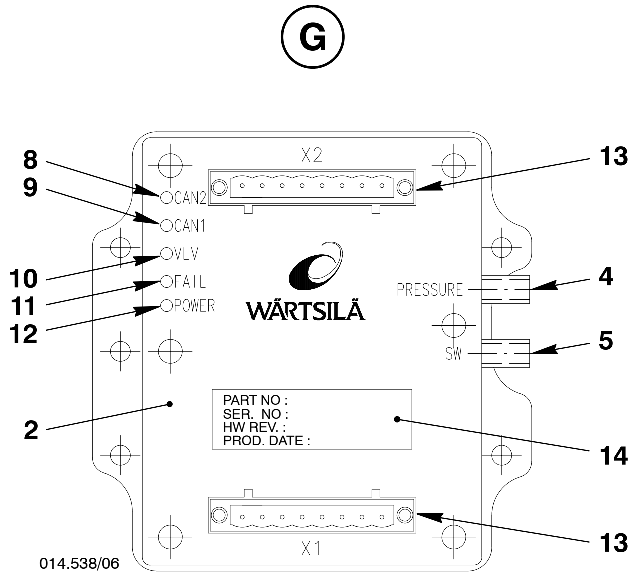
If it is necessary to overhaul or replace lubricating pump components, see the pump manufacturer's documentation for the maintenance procedures and torque-tightening values.

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)

The ALM−20 module actuates the 4/2-way solenoid valve, which releases a lube pulse. By means of metering pressure, it checks also lubricating quill failures, air cavities, or any lubricating oil deficiency and driving problems (evaluation of pressure curves during oil flow).





Key to Illustration: 'F' Control box
'G' ALM−20 module

1	Control box E41.01−08	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 connections (to control)	14	Name plate

5.1 LED indications

LEDs 4 and 5, which are visible from outside, indicate the function status of the lubricating pump and the control (see Fig. ’F’ and Fig. ’G’).

LED	Indication	Function status
LED 4 (pressure) (SW)	flashes YELLOW	Indicates a successful lube pulse
	shows RED	Indicates an electrical short-circuit of pressure transmitter (PT3131–38C)
LED 5	flashes GREEN	Module ready for software download
	shows GREEN	Ready for operation

Remark: A lube pulse is not released at every piston stroke. At part load, the lube pulses start only after several piston strokes.

When the cover 3 is removed from the ALM–20 module, more LEDs that give detailed information are visible (see Fig. ’G’).

LED	Indication	Function status
LEDs 8 / 9 (CAN2 / CAN1)	flashes YELLOW	Active CAN Bus
	shows RED	Failed CAN Bus (failure)
LED 10 (VLV)	flashes YELLOW	Indicates instantaneous lube pulse released
	shows RED	and LED 11 (FAIL) shows RED: Indicates an electrical short-circuit of 4/2-way solenoid valve
	shows RED	and LED 11 (FAIL) flashes RED once: Indicates a cable failure on 4/2-way solenoid valve
LED 11 (FAIL)	None	Injection circuit ok
	shows RED	and LED 10 (VLV) remains off: Indicates an electrical short-circuit of pressure transmitter (PT3131–38C)
	flashes RED, twice	Indicates a cable failure of pressure transmitter (PT3131–38C)
	flashes RED, three times	Indicates an identification failure of ALM–20 module
LED 12 (POWER)	shows GREEN	Power supply on
	None	Power supply off

5.2 Resistor in plug X1

Each ALM−20 module has a built-in resistor in the plug X1 (at terminals 16 and 17). The value of each resistor relates to the cylinder number.

Remark: Before inserting a new resistor, make sure that the value is correct for the related cylinder number. See the table below:

Cylinder No.	Control box No.	Resistor Ohm [Ω]
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

6. Lubricating quill

Lubricating oil flows to the row of lubricating grooves through the lubricating quills located on the circumference of the supporting ring.

The function of the lubricating quill is described in 2138−1.

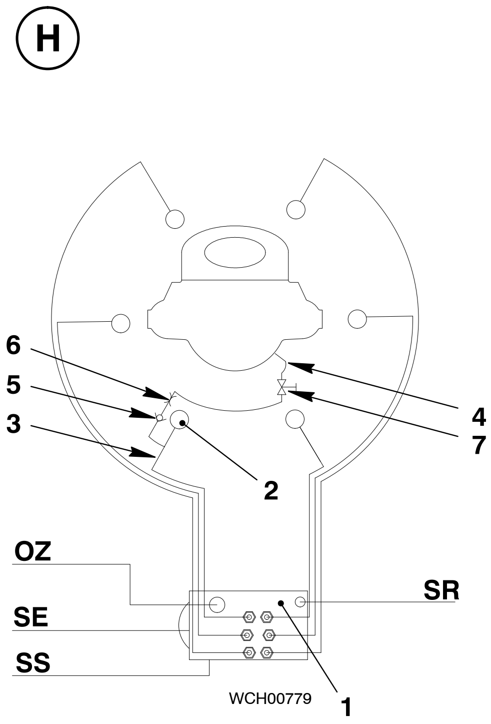
7. Additional lubrication of exhaust valve spindle

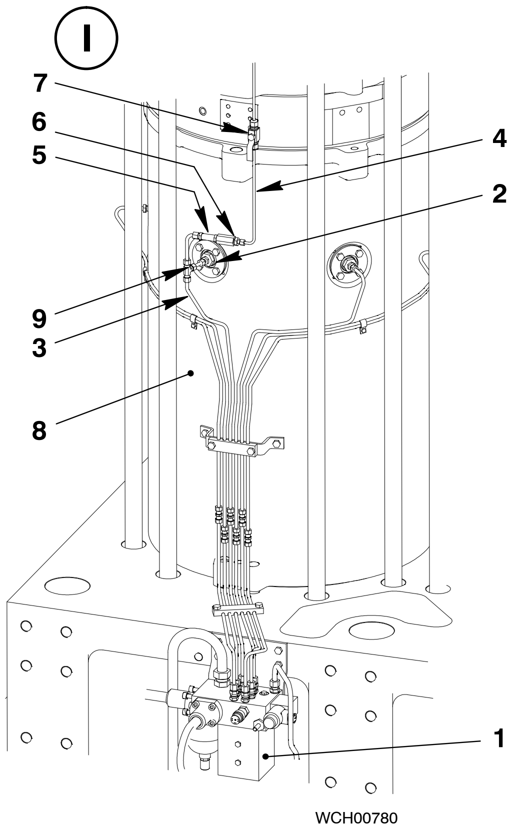
Lubricating oil flows through the the lubricating oil pipe 4 to give additional lubrication of the exhaust valve spindle. This additional lubrication is normally cut out (the stop valve 7 is closed). However, during the first operating hours or after an exhaust valve overhaul the stop valve 7 is open. (see also Exhaust Valve 2751–1).

The lubricating oil pipe 4 is branched off from the tee union 9 at one of the lubricating quills 2. When the lubricating pump 1 releases a lube pulse, some lubricating oil flows through the non-return valve 5, orifice 6 and stop valve 7 to the exhaust valve spindle.

Remark: In accordance with service experience, we recommend that the stop valve 7 is closed after:

- approximately 100 operating hours after conclusion of the sea trial.
- approximately 24 operating hours after an exhaust valve overhaul.





Key to Illustrations:

'H' Schematic presentation

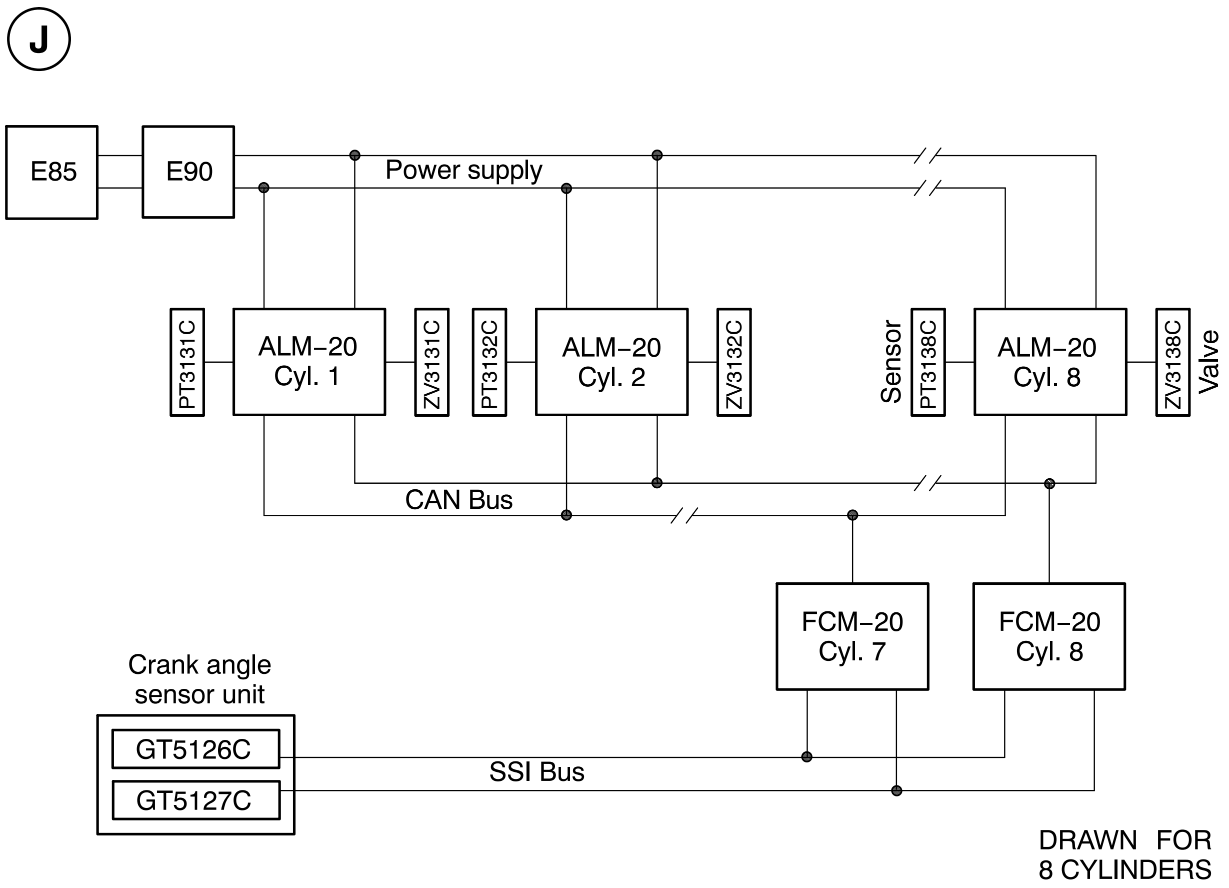
'I' Arrangement on cylinder No. 1

1 Lubricating pump 8.06
2 Lubricating quill 8.12
3 Lubricating oil pipe (lubr. quill)
4 Lubricating oil pipe (exh. valve)
5 Non-return valve
6 Orifice
7 Stop valve
8 Supporting ring
9 Tee union

OZ Oil supply
SE Servo oil inlet
SR Servo oil return
SS Servo oil to next lubr. pump

8. Control of cylinder lubricating system

8.1 Control system



The control system consists of a row of ALM–20 modules (one module for each cylinder). The communication is ensured via CAN Bus, however, for safety reasons a 2nd CAN Bus provides the redundancy. The power supply box E85 supplies electrical power to the control box E90 and then to the ALM–20 modules.

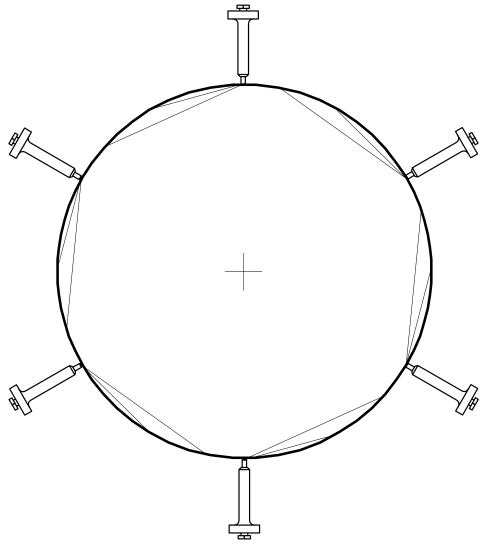
Each ALM–20 module has a pressure transmitter and a 4/2-way solenoid valve. The pressure transmitter monitors the metering pressure. The 4/2-way solenoid valve actuates the lubricating pump.

The arrangement above 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).

8.2 Radial oil distribution

Spray holes in the nozzle tip of the injection unit in the lubricating quill determine the radial oil distribution. Based on the relevant engine type, the number of spray holes and oil jet angle make sure of complete distribution on the whole circumference of the cylinder liner wall.

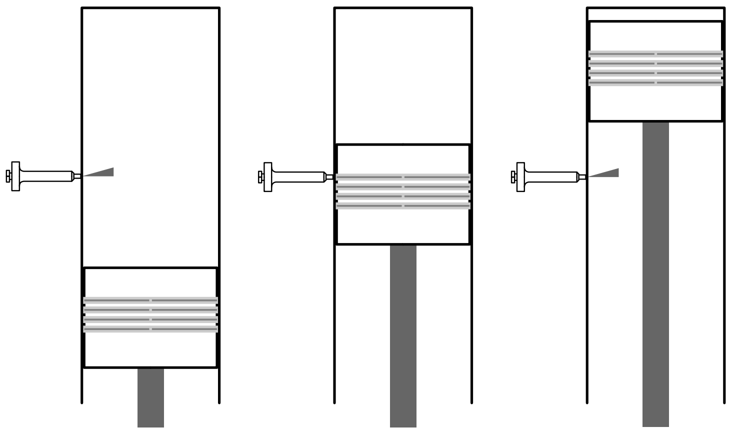
K



8.3 Vertical oil distribution

The injection 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.

L



8.4 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, in steps of 0.1 g/kWh. This adjustment can be done by means of the user parameters, Lubrication and Feed Rate, individually for each cylinder or globally for all cylinders.

The guide feed rates for running-in of new cylinder liners and piston rings, and after the running-in 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

The cylinder lubricating oil consumption can be measured at all engine power outputs.

The engine has a load-dependent cylinder lubricating system. Therefore make sure that during the measurement, the engine speed and power are kept as constant as possible.

The cylinder lubricating system has a measurement tube, which has a scale that gives accurate measurement of the lubricating oil consumption in a short time (see 7218–1 'Measurement of consumption at measurement tube').

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.

To find the consumed oil quantity, read the distance between the two marks and convert into liters (liters x density = weight of oil in kg).

To calculate the specific cylinder lubricating oil consumption, the power output during the test must be known. This output can be established:

a) 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.

b) 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):

Spec. cylinder lubricating oil consumption = $\frac{1000 \cdot G}{P}$ *g/kWh [g/BHPh]*

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 (ρ) (typical value 0.92 kg/l)
– Number of injection pulses (Z) during measurement period of time (t) in sec.

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:

$$R = \frac{3600 \cdot (h \cdot k) . \rho}{f \cdot t \cdot P}$$

R = Specific cylinder lubricating oil consumption (g/kWh)

h = Measuring height (cm)

k = Conversion factor (l/cm)

ρ = 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 · k])

Engine power output %	Correction factor f
100	1.00
75	1.02
50	1.06
20	1.25
10	1.56

Example 6 RT-flex48T–B:

$$R = \frac{3600 \cdot (14.0 \cdot 0.14) \cdot 920}{1.02 \cdot 1200 \cdot 6650} = 0.8 \text{ g/kWh}$$

– Meas. period of time	20 min. = 1200 sec.
– Measuring height	14.0 cm
– Conversion factor	0.14 l/cm
– Oil density	920 g/l
– Correction factor	1.02
– Output at 75%	6650 kW

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 the cylinder lubricating oil quantity that is most economical for a given engine.

When information is given to us about the consumption of cylinder lubricant, it must always be related to liter 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

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▽ **Lubricating Oil System**

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Overview

1. General

The oil necessary for 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 and exhaust valve spindle 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 pipe 7 and main bearings 6 through bores in the bearing girders via oil distributing pipe 4 on fuel side.
Bearing oil is also used to cool the piston and to lubricate crosshead pins 11 and bottom end bearings 10 via toggle lever 12.

For actuating the exhaust valves, oil ('hydraulic rod') is led to the exhaust valve control units via the servo oil system (see section 3 and Control Diagram 4003–2).

The integrated axial damper 5, and if there is a vibration damper 25, intermediate wheel 17 and the drive supply unit 16 are supplied or cooled with bearing oil.

Via distributing pipes 15 and internal bores in supply unit 16 oil supply is ensured for the bearings, spray nozzles and fuel pumps (see Supply Unit 5552–1 and Fuel Pump 5556–1).

Bearing oil is supplied to turbocharger 27 through oil inlet pipe 26 via oil distributing pipe 4 on fuel side. The oil is returned via vent tank 28 (air separator integrated in the scavenge air receiver) to the column.

A device (ball valves 36 & 37) for taking oil samples is arranged in the outlet (drain) for dirty oil 35 from piston underside (see also 0750–1 'Cylinder lubricating oil').

Remark: Ball valves 36 remain open and ball valves 37 closed during operation.

2.1 Taking dirty oil samples

2.1.1 Preparation

1.) Write the applicable data on the oil analysis form (e.g. operation conditions, fuel parameters, cylinder lubricating oil feed rate etc).

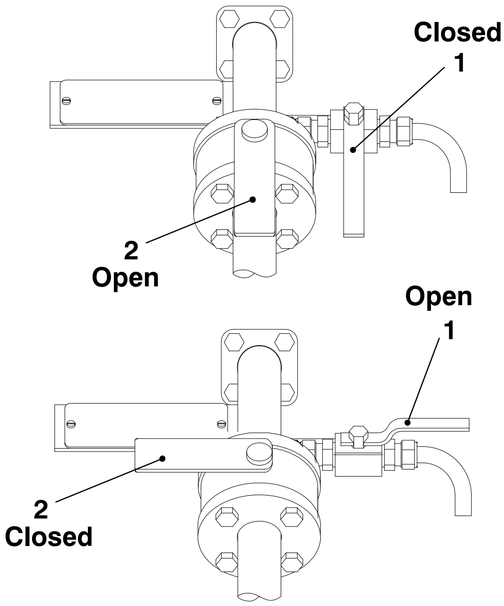
2.) Make sure that the labels on the sample bottles refer to the related cylinders.

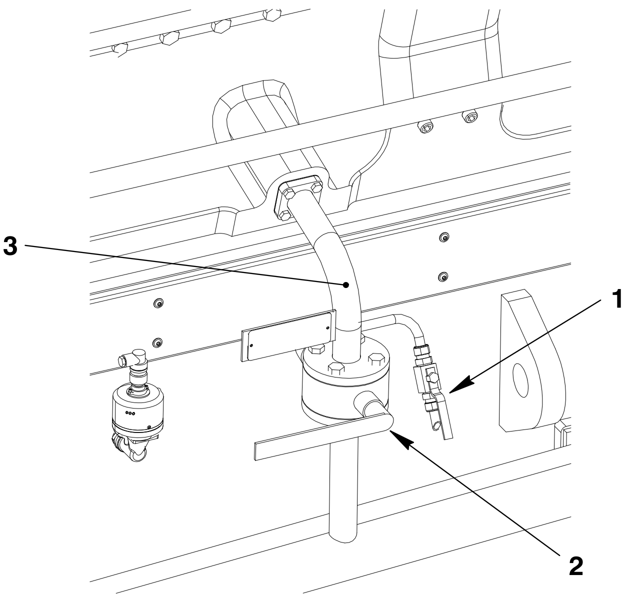
2.1.2 Procedure

1.) Close the ball valve (2) for approximately 30 minutes to 60 minutes.

Remark: Some parts can look different.

Ball Valve Positions





2.) Put an applicable container under the ball valve (1).

3.) Slowly open the ball valve (1) to flush out oil and possible dirt.

4.) Close the ball valve (1).

5.) Open the ball valve (2) to drain the remaining oil from the dirty oil pipe (3).

6.) Close the ball valve (2).

7.) Put the sample bottle under the ball valve (1).

8.) After approximately 10 minutes to 60 minutes, slowly open the ball valve (1) to fill the sample bottle.

9.) Close the ball valve (1).

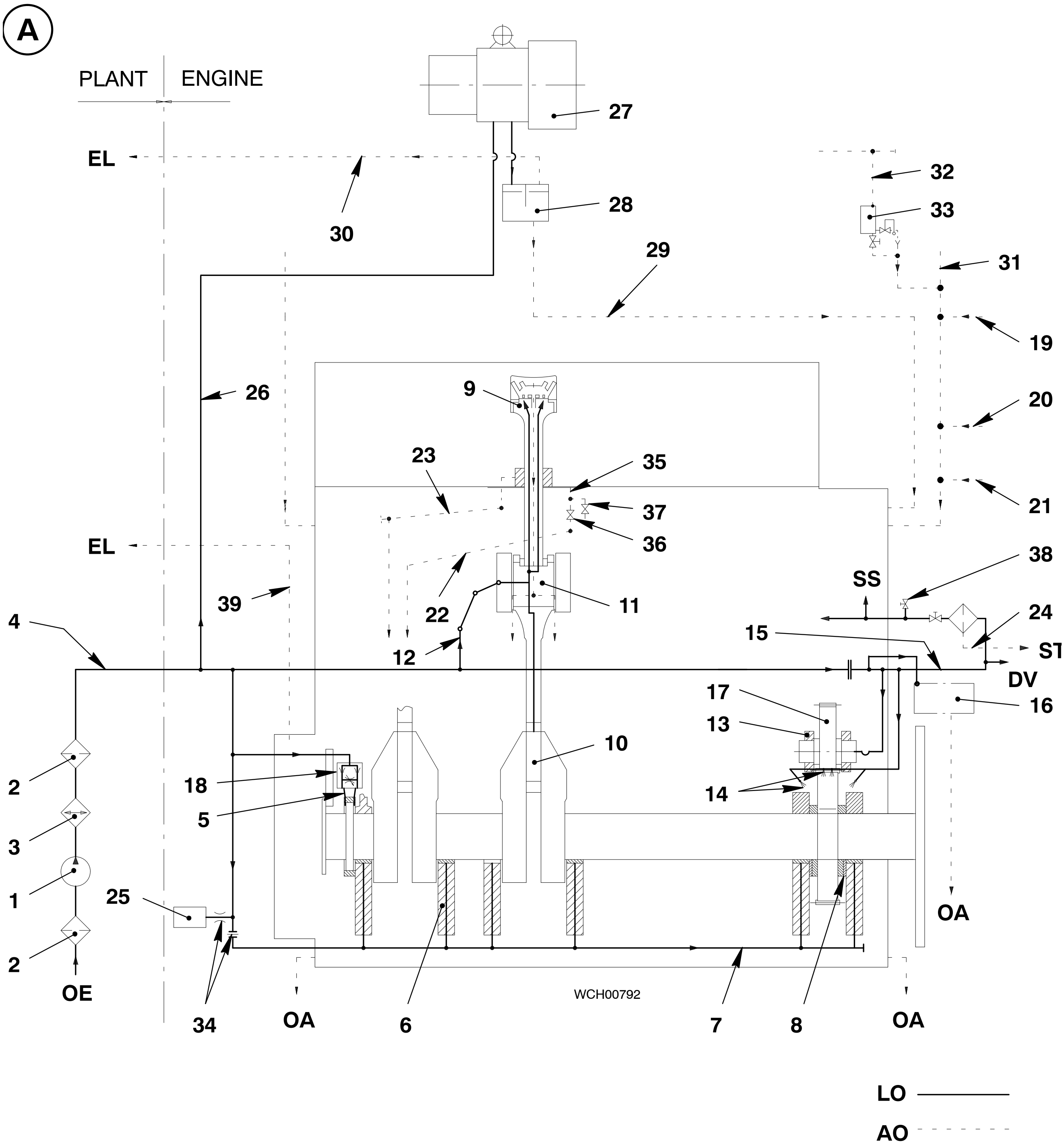
10.) Open the ball valve (2) to drain the oil that collected in the dirty oil pipe (3).

11.) Do the steps 1) to 10) again on each cylinder.

Remark: WinGD recommends that you get an oil sample of the cylinder lubricating oil downstream of the duplex filter. Send the oil sample to the laboratory to make an analysis to make sure the initial cylinder lubricating oil had the correct quality and no contamination.

12.) Make sure that the sample bottles are tightly closed and use an applicable package.

13.) Send the samples to the laboratory to make an analysis.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Key to Illustrations: ’A’ Bearing and turbocharger oil system

1 Oil pump
2 Oil filter
3 Oil cooler
4 Oil distributing pipe on fuel side
5 Axial damper
6 Main bearing
7 Oil inlet to main bearing
8 Thrust bearing
9 Piston
10 Bottom end bearing
11 Crosshead pin
12 Toggle lever for piston cooling and crosshead lubrication
13 Intermediate wheel bearing
14 Spray nozzle
15 Distributing pipe
16 Supply unit
17 Intermediate wheel
18 Axial damper monitoring
19 Oil drain from fuel pressure control valve 3.06
20 Servo oil return from cylinder lubrication pumps
21 Return from servo oil service pump 4.88
22 Dirty oil collector main from piston underside
23 Leakage oil collector main from piston rod gland
24 Flushing oil drain f. automatic filter
25 Vibration damper
26 Oil inlet pipe
27 Turbocharger
28 Venting tank
29 Outlet pipe
30 Venting pipe
31 Leakage oil collector main from exhaust valves
32 Leakage oil pipe from air spring
33 Leakage oil return
34 Throttle
35 Outlet (drain) pipe for dirty oil
36 Ball valve
37 Ball valve (for taking oil samples from piston underside)
38 Ball valve (for taking oil samples of system oil)
39 Crankcase venting pipe

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
ST to sludge tank

3. Servo oil system (Fig. 'B')

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.

3.1 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.

STOP Do **not** start the servo oil service pump if the bearing oil pump is not running.

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.

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 valve 14 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.

3.2 Servo oil system

Oil reaches the servo oil pumps 4 via automatic filter 1, supply pipe 5 and distributor pipe 13.

STOP Do **not** operate the engine with the oil supply to the servo oil pumps interrupted. Stop valve 14 must always be open during operation!

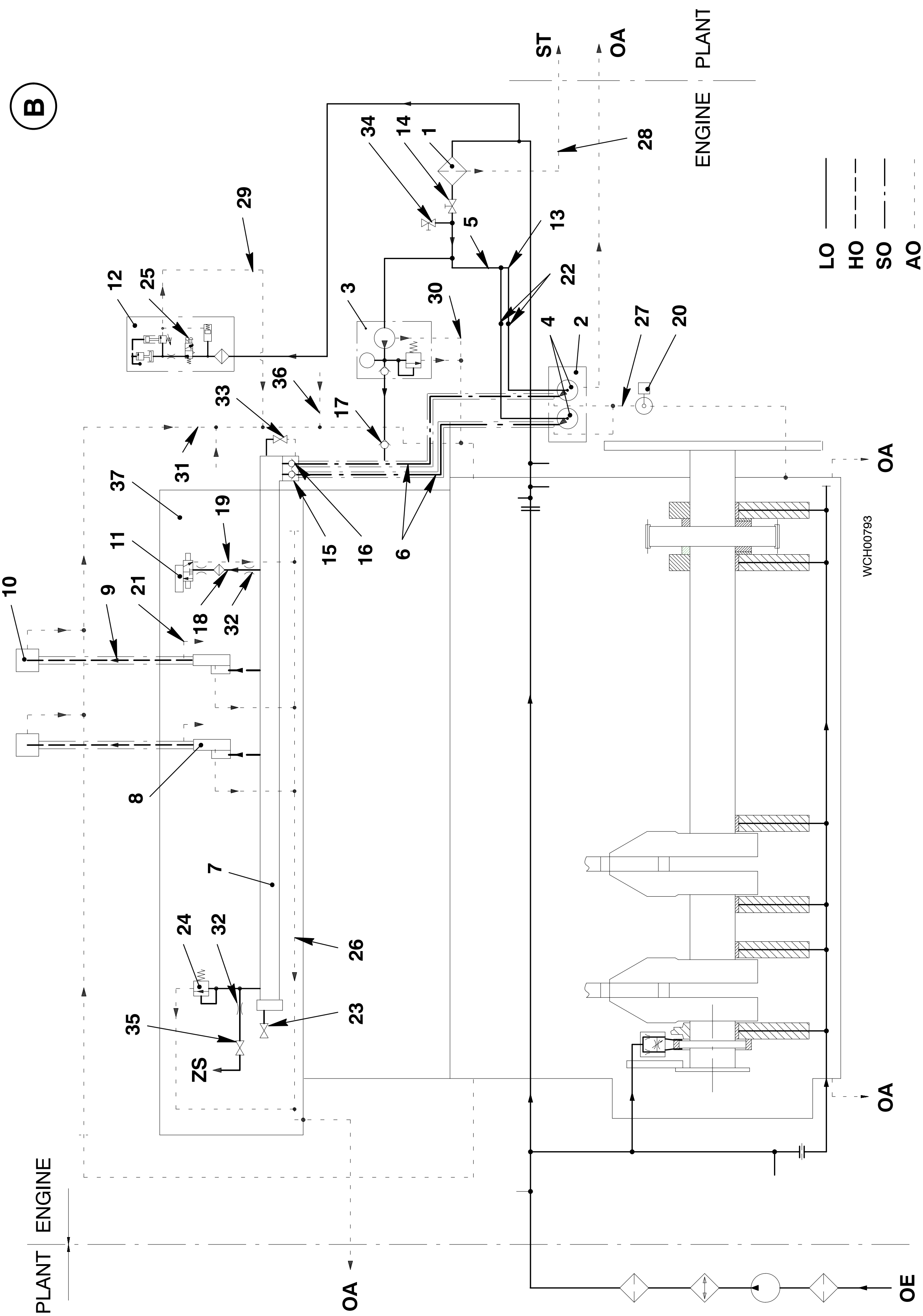
Dependent on the electrically controlled pressure regulating system (nominal pressure value depending on engine load), the servo oil pumps deliver oil to servo oil rail 7 via rising pipe 6. Leakage oil pipe 27 is arranged at the connecting block of the rising pipes (see section 4).

Remark: Flow sensors 22 (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 Oil Pump 5551–1).

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 back to the plant through return piping 26.

For actuating ('hydraulic cam') the injection control units 11 and their control valves (rail valves) oil is used which flows from the servo oil rail to the injection control units via the flexible hose 18, and then back to the plant through return piping 26.

The lubricating pumps of the of cylinder lubricating system are driven by servo oil from rail 7. The pressure of the branched off servo oil 'ZS' is reduced to 60 bar by means of pressure reducing valve (see Cylinder Lubrication 7218–1 and Control Diagram 4003–2).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Key to Illustration: 'B' Servo oil system

1 Automatic filter 4.20
2 Servo oil supply D
3 Servo oil service pump 4.88
4 Servo oil pump 4.15
5 Supply pipe 4.51
6 Servo oil rising pipe 4.55
7 Servo oil rail 4.11
8 Exhaust valve control unit 4.10
9 Actuator pipe 4.66
10 Exhaust valve 4.01
11 Injection control unit 3.02
12 Fuel pressure control valve 3.06
13 Distributing pipe
14 Stop valve 4.37
15 Non-return valve 4.24−1
16 Non-return valve 4.24−2
17 Non-return valve 4.53
18 Flexible hose (inlet)
19 Flexible hose (outlet)
20 Level switch LS2055A
21 Leakage inspection point 4.17 (check bore)
22 Flow sensor FS2061−62A
23 Stop valve 3.40
24 Safety valve 4.23
25 Fuel shut-down pilot valve 3.08
26 Servo oil return piping 4.63
27 Leakage oil pipe from rising pipes
28 Flushing oil drain from automatic filter
29 Drain from fuel pressure control valve 3.06
30 Return from servo oil service pump
31 Collecting main for leakage oil from exhaust valves
32 Orifice
33 Drain screw 4.82
34 Ball valve (for taking oil samples)
35 Stop valve 4.30−5
36 Servo oil return from cylinder lubricating pumps
37 Rail unit

AO Drain
HO Hydraulic oil
LO Bearing oil
OA to oil drain tank
OE from oil drain tank
SO Servo oil
ST to sludge tank
ZS to cylinder lubricating pumps

4. Servo oil leakage system

4.1 Leakage and oil drains

Part of the drains flows via engine and the other drains via oil drain tank in the plant back to the bearing oi system (see Fig. 'B').

Drains into the bedplate:

- Leakage oil pipe 27 from rising pipes 6.

Drains into the column:

via collecting main for leakage oil from exhaust valves 31:

- Drain 29 from fuel pressure control valve 3.06.
- Return 30 from servo oil service pump 4.88.
- Servo oil return 36 from cylinder lubricating pumps.

Drains back to the plant:

- Servo oil return piping 26 from rail unit (from exhaust valve control units 8, injection control units 11 and drain of safety valve 24).
- Flushing oil drain 28 from automatic filter to sludge tank in the plant.

All important leakages in the servo oil system are monitored by level switches (LS).

In case of excessive quantity of leakage oil the corresponding alarm is triggered:

Level switch	Monitored components
LS3444A	Leakages (fuel, servo oil) from rail unit, by leaky hydraulic piping between exhaust valve control unit (check bore in cover) and exhaust valve
LS2055A	Leakages from rising pipes

4.2 Leakage localization

Risk of injury! Always use gloves when working on hot components! And always wear safety goggles; oil may spurt out when opening ball & stop valves and loosening screwed pipe connections.

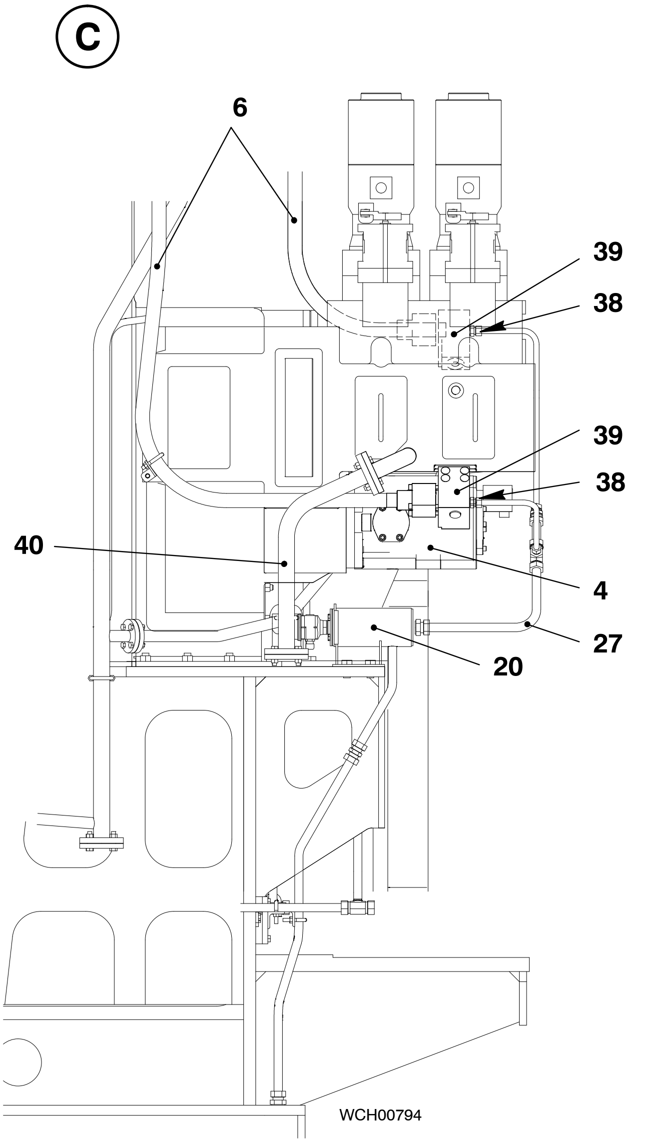
For the proper leakage localization of the rising pipes 6, the screwed pipe connection 38 of leakage oil pipe 27 can be loosened **carefully by max. two turns.**

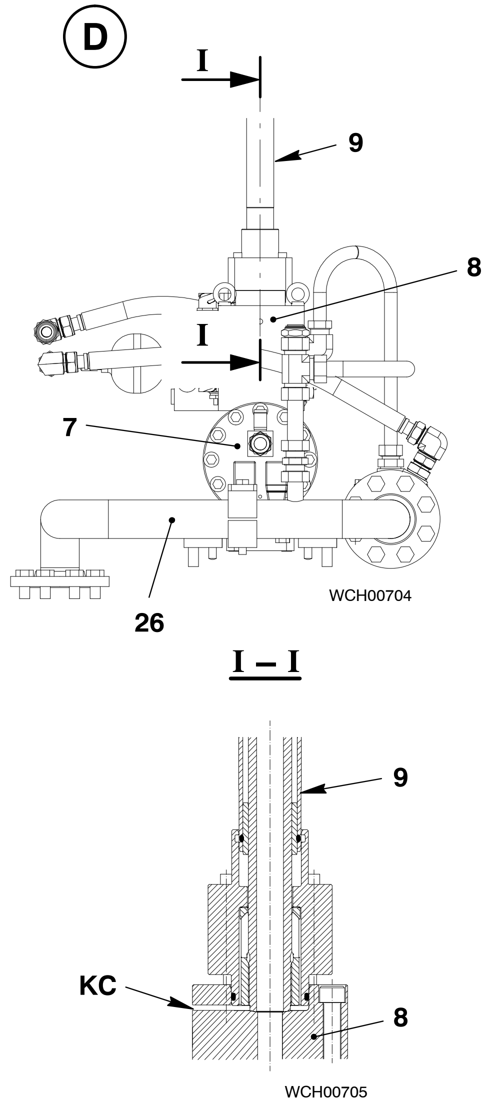
If an alarm has been triggered by level switch 20 (LS2055A), the screwed pipe connections allow the location of the leakage and corresponding measures can be taken.

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 only one rising pipe, the engine may be maintained in unrestricted operation until the defective pipe has been replaced.

Defective actuator pipes may be detected when oil flows out at check bore 'KC' in housing of the corresponding exhaust valve control unit 8 (see Fig. 'D' and Operation with Exhaust Valve Control Unit Cut Out 0520–1).





Key to Illustrations: **'C' Servo oil supply** **D**
'D' Exhaust valve control unit 4.10

4	Servo oil pump 4.15	27	Leakage oil pipe from rising pipes
6	Servo oil rising pipe 4.55	38	Screwed pipe connection
7	Servo oil rail 4.11	39	Connecting block
8	Exhaust valve control unit 4.10	40	Oil drain from supply unit
9	Actuator pipe 4.66		
20	Level switch LS2055A		
26	Servo oil return piping 4.63	KC	Check bore

5. Filling and pressure relief of servo oil rail

5.1 Filling and venting (see Fig. 'B')

⇒ Check whether stop valve 14 is open after automatic filter 1.

⇒ 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 15 and 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.

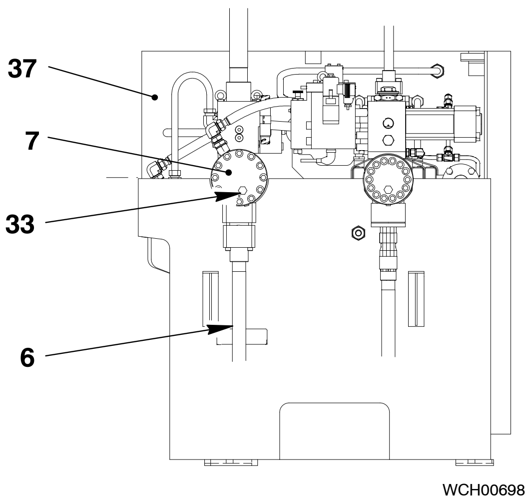
5.2 Pressure relief and draining (see Fig. 'B' and 'E')

Pressure relief and draining of the servo oil rail may be carried out by means of drain screw 33.

⇒ Open drain screw 33.

Attention! After draining the servo oil rail the drain screw 33 must be closed and tightened to a torque of 200 Nm.

E



DRIVING END

Key to Illustrations: 'E' Servo oil rail 4.11

6 Servo oil rising pipe 4.55
7 Servo oil rail 4.11
33 Drain screw 4.82
37 Rail unit

Overview

1. General

The oil necessary for 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 and exhaust valve spindle 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 pipe 7 and main bearings 6 through bores in the bearing girders via oil distributing pipe 4 on fuel side.
Bearing oil is also used to cool the piston and to lubricate crosshead pins 11 and bottom end bearings 10 via toggle lever 12.

For actuating the exhaust valves, oil ('hydraulic rod') is led to the exhaust valve control units via the servo oil system (see section 3 and Control Diagram 4003–2).

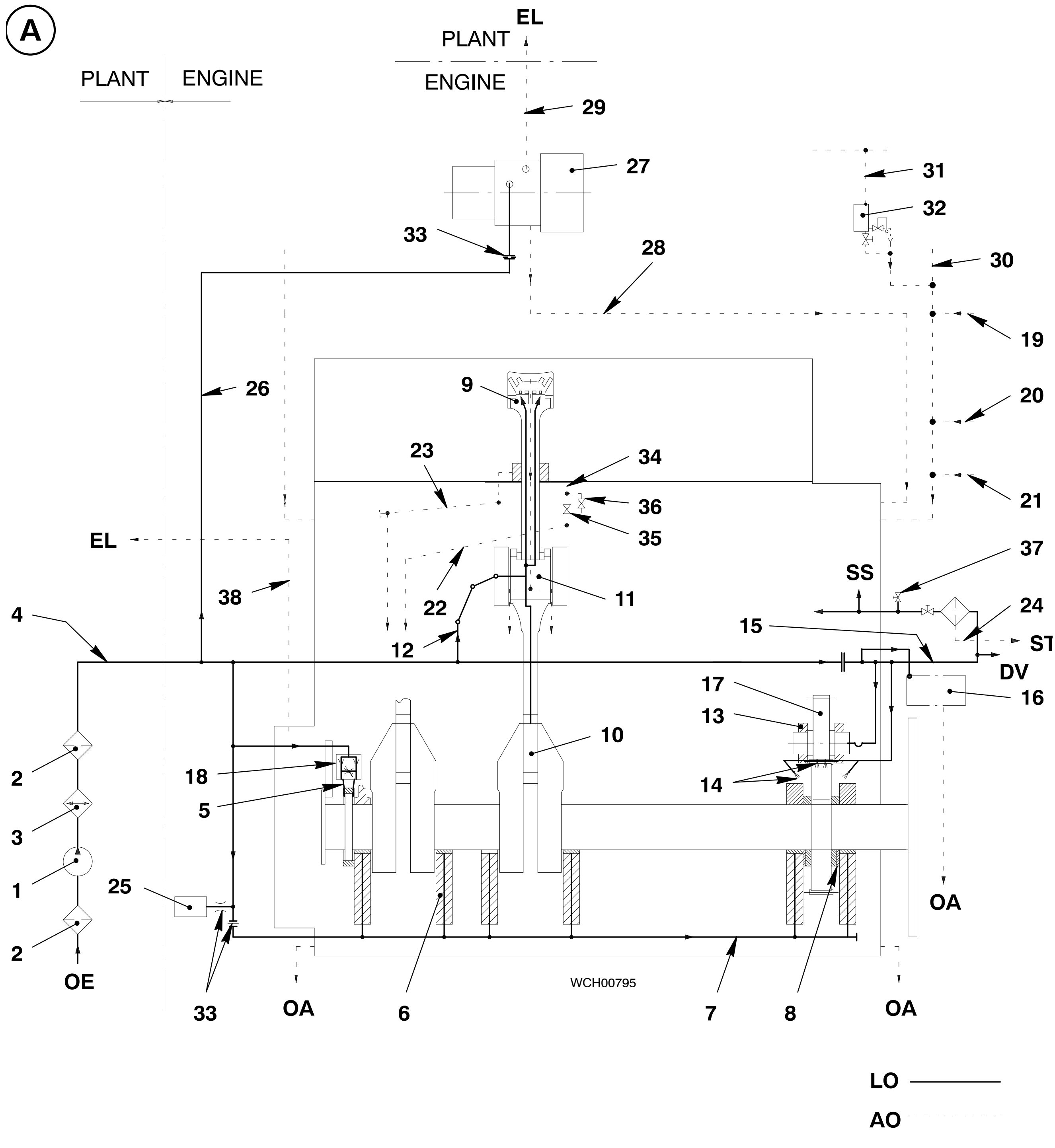
The integrated axial damper 5, and if there is a vibration damper 25, intermediate wheel 17 and the drive supply unit 16 are supplied or cooled with bearing oil.

Via distributing pipes 15 and internal bores in supply unit 16 oil supply is ensured for the bearings, spray nozzles and fuel pumps (see Supply Unit 5552–1 and Fuel Pump 5556–1).

Bearing oil is supplied to turbocharger 27 through oil inlet pipe 26 via oil distributing pipe 4 on fuel side. The oil is returned via outlet pipe 28 to the column.

A device (ball valves 35 & 36) for taking oil samples is arranged in the outlet (drain) for dirty oil 34 from piston underside (see also 0750–1 'Cylinder lubricating oil').

Remark: Ball valves 35 remain open and ball valves 36 closed during operation.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Key to Illustrations: 'A' Bearing and turbocharger oil system

1 Oil pump
2 Oil filter
3 Oil cooler
4 Oil distributing pipe on fuel side
5 Axial damper
6 Main bearing
7 Oil inlet to main bearing
8 Thrust bearing
9 Piston
10 Bottom end bearing
11 Crosshead pin
12 Toggle lever for piston cooling and crosshead lubrication
13 Intermediate wheel bearing
14 Spray nozzle
15 Distributing pipe
16 Supply unit
17 Intermediate wheel
18 Axial damper monitoring
19 Oil drain from fuel pressure control valve 3.06
20 Servo oil return from cylinder lubrication pumps
21 Return from servo oil service pump 4.88
22 Dirty oil collector main from piston underside
23 Leakage oil collector main from piston rod gland
24 Flushing oil drain f. automatic filter
25 Vibration damper
26 Oil inlet pipe
27 Turbocharger
28 Outlet pipe
29 Venting pipe
30 Leakage oil collector main from exhaust valves
31 Leakage oil pipe from air spring
32 Leakage oil return
33 Throttle
34 Outlet (drain) pipe for dirty oil
35 Ball valve
36 Ball valve (for taking oil samples from piston underside)
37 Ball valve (for taking oil samples of system oil)
38 Crankcase venting pipe

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
ST to sludge tank

3. Servo oil system (Fig. 'B')

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.

3.1 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.

STOP Do **not** start the servo oil service pump if the bearing oil pump is not running.

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.

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 valve 14 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.

3.2 Servo oil system

Oil reaches the servo oil pumps 4 via automatic filter 1, supply pipe 5 and distributor pipe 13.

STOP Do **not** operate the engine with the oil supply to the servo oil pumps interrupted. Stop valve 14 must always be open during operation!

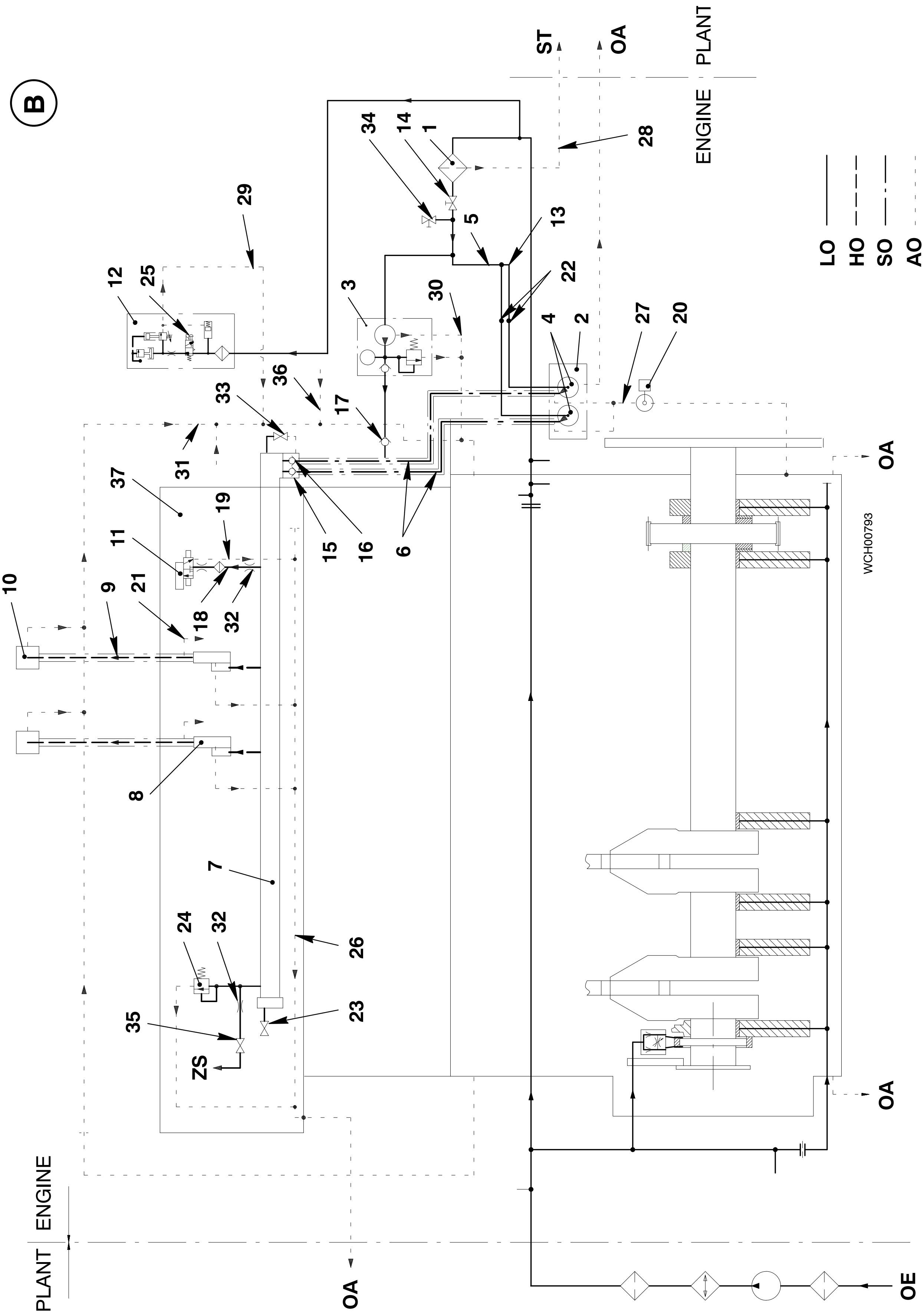
Dependent on the electrically controlled pressure regulating system (nominal pressure value depending on engine load), the servo oil pumps deliver oil to servo oil rail 7 via rising pipe 6. Leakage oil pipe 27 is arranged at the connecting block of the rising pipes (see section 4).

Remark: Flow sensors 22 (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 Oil Pump 5551–1).

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 back to the plant through return piping 26.

For actuating ('hydraulic cam') the injection control units 11 and their control valves (rail valves) oil is used which flows from the servo oil rail to the injection control units via the flexible hose 18, and then back to the plant through return piping 26.

The lubricating pumps of the of cylinder lubricating system are driven by servo oil from rail 7. The pressure of the branched off servo oil 'ZS' is reduced to 60 bar by means of pressure reducing valve (see Cylinder Lubrication 7218–1 and Control Diagram 4003–2).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Key to Illustration: ’B’ Servo oil system

1 Automatic filter 4.20
2 Servo oil supply D
3 Servo oil service pump 4.88
4 Servo oil pump 4.15
5 Supply pipe 4.51
6 Servo oil rising pipe 4.55
7 Servo oil rail 4.11
8 Exhaust valve control unit 4.10
9 Actuator pipe 4.66
10 Exhaust valve 4.01
11 Injection control unit 3.02
12 Fuel pressure control valve 3.06
13 Distributing pipe
14 Stop valve 4.37
15 Non-return valve 4.24−1
16 Non-return valve 4.24−2
17 Non-return valve 4.53
18 Flexible hose (inlet)
19 Flexible hose (outlet)
20 Level switch LS2055A
21 Leakage inspection point 4.17 (check bore)
22 Flow sensor FS2061−62A
23 Stop valve 3.40
24 Safety valve 4.23
25 Fuel shut-down pilot valve 3.08
26 Servo oil return piping 4.63
27 Leakage oil pipe from rising pipes
28 Flushing oil drain from automatic filter
29 Drain from fuel pressure control valve 3.06
30 Return from servo oil service pump
31 Collecting main for leakage oil from exhaust valves
32 Orifice
33 Drain screw 4.82
34 Ball valve (for taking oil samples)
35 Stop valve 4.30−5
36 Servo oil return from cylinder lubricating pumps
37 Rail unit

AO Drain
HO Hydraulic oil
LO Bearing oil
OA to oil drain tank
OE from oil drain tank
SO Servo oil
ST to sludge tank
ZS to cylinder lubricating pumps

4. Servo oil leakage system

4.1 Leakage and oil drains

Part of the drains flows via engine and the other drains via oil drain tank in the plant back to the bearing oi system (see Fig. 'B').

Drains into the bedplate:

– Leakage oil pipe 27 from rising pipes 6.

Drains into the column:

via collecting main for leakage oil from exhaust valves 31:

– Drain 29 from fuel pressure control valve 3.06.
– Return 30 from servo oil service pump 4.88.
– Servo oil return 36 from cylinder lubricating pumps.

Drains back to the plant:

– Servo oil return piping 26 from rail unit (from exhaust valve control units 8, injection control units 11 and drain of safety valve 24).
– Flushing oil drain 28 from automatic filter to sludge tank in the plant.

All important leakages in the servo oil system are monitored by level switches (LS).

In case of excessive quantity of leakage oil the corresponding alarm is triggered:

Level switch	Monitored components
LS3444A	Leakages (fuel, servo oil) from rail unit, by leaky hydraulic piping between exhaust valve control unit (check bore in cover) and exhaust valve
LS2055A	Leakages from rising pipes

4.2 Leakage localization

Risk of injury! Always use gloves when working on hot components! And always wear safety goggles; oil may spurt out when opening ball & stop valves and loosening screwed pipe connections.

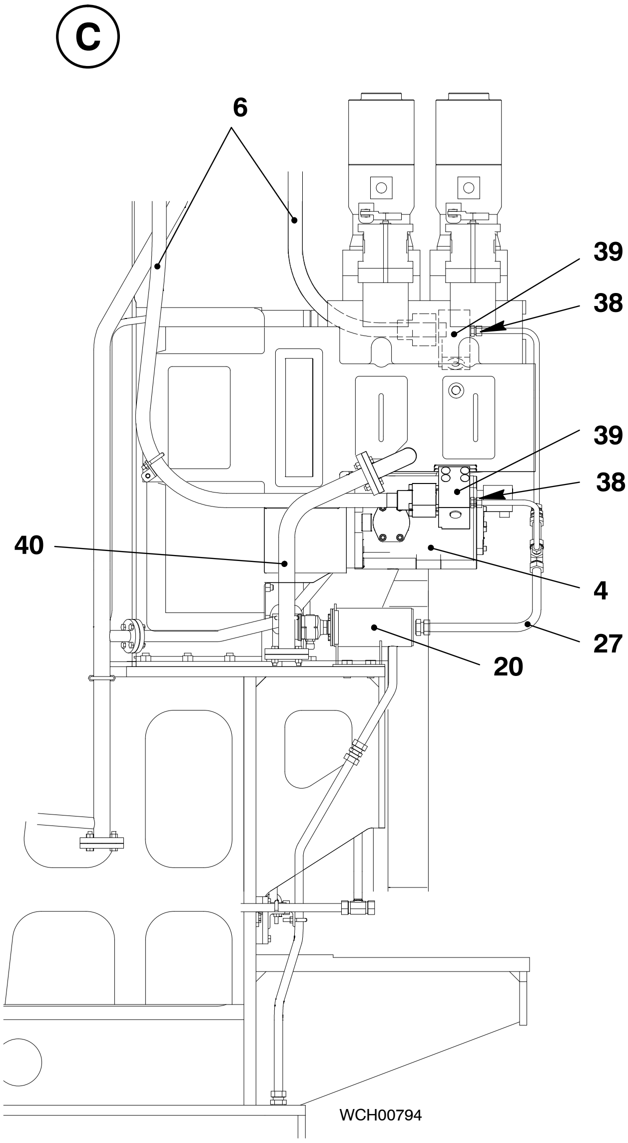
For the proper leakage localization of the rising pipes 6, the screwed pipe connection 38 of leakage oil pipe 27 can be loosened **carefully by max. two turns.**

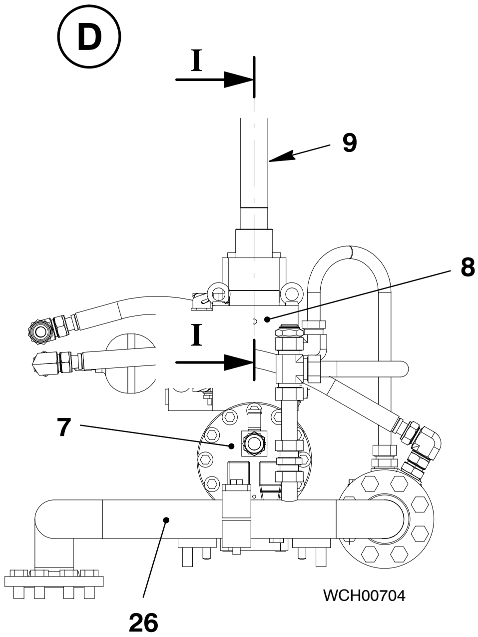
If an alarm has been triggered by level switch 20 (LS2055A), the screwed pipe connections allow the location of the leakage and corresponding measures can be taken.

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 only one rising pipe, the engine may be maintained in unrestricted operation until the defective pipe has been replaced.

Defective actuator pipes may be detected when oil flows out at check bore 'KC' in housing of the corresponding exhaust valve control unit 8 (see Fig. 'D' and Operation with Exhaust Valve Control Unit Cut Out 0520−1).





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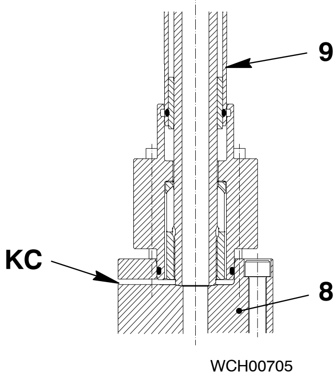


Key to Illustrations: **’C’ Servo oil supply** D
’D’ Exhaust valve control unit 4.10

4	Servo oil pump 4.15	27	Leakage oil pipe from rising pipes
6	Servo oil rising pipe 4.55	38	Screwed pipe connection
7	Servo oil rail 4.11	39	Connecting block
8	Exhaust valve control unit 4.10	40	Oil drain from supply unit
9	Actuator pipe 4.66		
20	Level switch LS2055A		
26	Servo oil return piping 4.63	KC	Check bore

5. Filling and pressure relief of servo oil rail

5.1 Filling and venting (see Fig. 'B')

⇒ Check whether stop valve 14 is open after automatic filter 1.

⇒ 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 15 and 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.

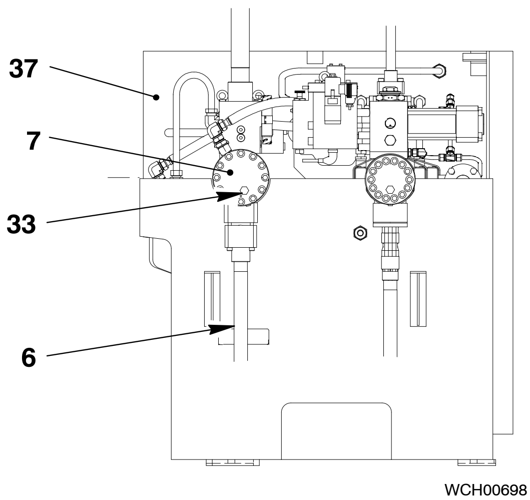
5.2 Pressure relief and draining (see Fig. 'B' and 'E')

Pressure relief and draining of the servo oil rail may be carried out by means of drain screw 33.

⇒ Open drain screw 33.

Attention! After draining the servo oil rail the drain screw 33 must be closed and tightened to a torque of 200 Nm.

E



DRIVING END

Key to Illustrations: 'E' Servo oil rail 4.11

6 Servo oil rising pipe 4.55
7 Servo oil rail 4.11
33 Drain screw 4.82
37 Rail unit

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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 (seawater) 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 and is connected to an expansion tank, which has a static pressure. Cooling water treated with an inhibitor, cools the cylinder liners, cylinder covers and exhaust valve cages.

A water heater, installed in the plant, brings the cooling water to operating temperature before the engine has started.

The cooling water must be treated with an approved inhibitor to prevent corrosive attack, sludge formation and scale deposits in the system (see Cooling Water / Cooling Water Treatment 0760−1).

Attention! If the engine is taken out of operation for a long period of time and it is possible that frost / cold conditions can occur, the cooling water system must be drained. The cooling water is chemically treated and must be decontaminated in accordance with local environmental regulations. See the water treatment instructions when the cooling system is filled with new coolant water.

Automatic cooling water temperature control:

If possible, keep the temperature of the cooling water outlet constant during all load conditions. This will prevent too much expansion and contraction of the combustion chamber components e.g. cylinder liners and cylinder covers.

The maximum permitted temperature fluctuations are:

- $\pm 2°C$ 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.

2. Function

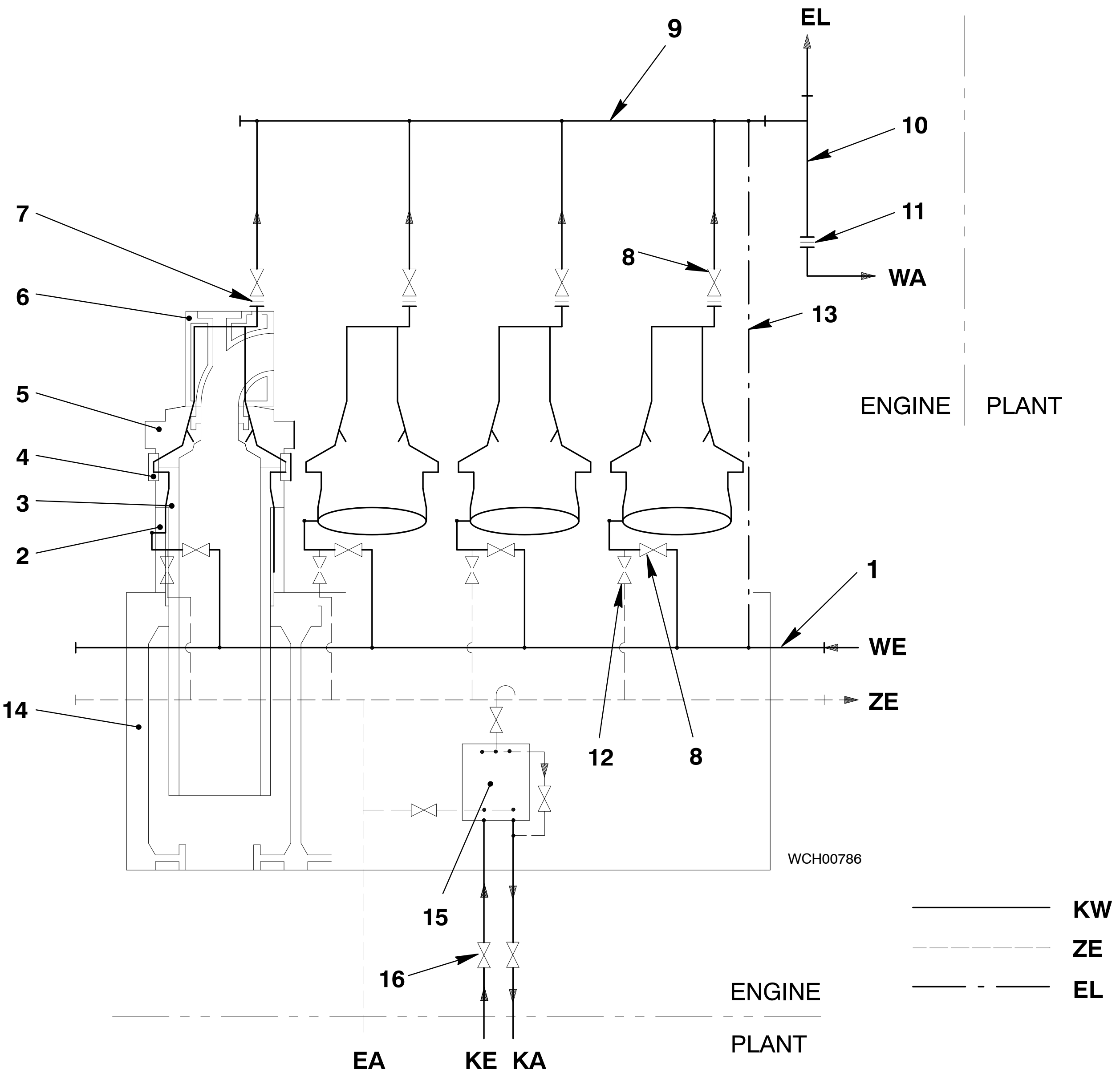
The cooling water pump supplies cooling water to the distributing pipe 1, on the exhaust side, to the cylinders. The cooling water flows from the distributing pipe through the cylinder liner 3, water guide jacket 4, cylinder cover 5 and exhaust valve cage 6. The shut-off valves 8 and 12 are can be used to isolate the related cylinder(s) from the cooling water system and drained. The outlet collecting main 9 is connected to the air separator 10. A vent pipe connects the air separator 10 to the expansion tank, which gives continuous venting of the system.

The water flows from the air separator 10 through a temperature regulating valve to the cooler and back to the pump. A balance pipe joins joins the suction side of the pump to the expansion tank. This balance pipe ensures the static pressure and compensates for possible water loss and water expansion.

A throttling disc 7 is fitted in the outlet piping of each cylinder and is adjusted to let a specified flow of cooling water through to the cylinder.

The throttling disc 11, fitted in the outlet piping after the air separator 10, is used to adjust the operating pressure in the system.

Cooling Water System



Key:

1	Distributing pipe	13	Venting pipe
2	Support ring	14	Cylinder block
3	Cylinder liner	15	Scavenge air cooler
4	Water guide jacket	16	Shut-off valve
5	Cylinder cover		
6	Exhaust valve cage	EA	Water drain
7	Throttling disc, cylinder outlet	KE	SAC cooling water inlet
8	Shut-off valve at cylinder	KA	SAC cooling water outlet
9	Outlet collecting main	EL	Vent
10	Air separator	KW	Cooling water
11	Throttling disc, water outlet	WA	Cooling water outlet
12	Shut-off valve for draining	WE	Cooling water inlet

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Starting Air Diagram

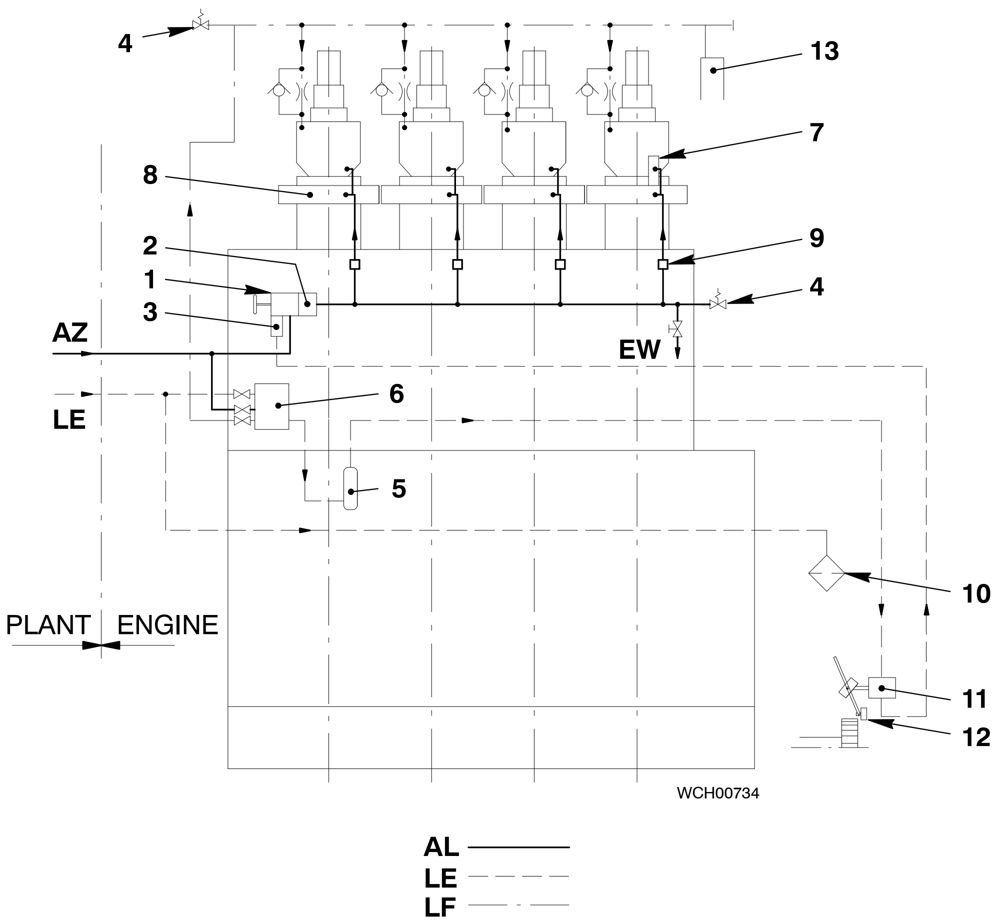
1. General

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 the 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 as clean and dry as possible.

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
2 Non-return valve
3 Control valve and valve unit for start E
4 Safety valve
5 Air bottle for control air supply unit A
6 Control air supply unit A
7 Starting valve
8 Cylinder cover
9 Flame arrester
10 Automatic fine filter
11 Turning gear
12 Blocking valve on turning gear
13 Oil leakage return from air spring

AL Starting air
AZ Starting air inlet
EW Vent and drain
LE Control air (board supply)
LF Air spring air

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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 13 are provided with heating pipes and insulated accordingly.

For safety reasons rail unit 30 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 31 is turned in a clockwise direction (+) and, when it is turned in an anti-clockwise rotation, lowered (−). Both locking nuts 32 and 33 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 screw plugs 34 (see Fig. ’A’ and ’E’).

3. High pressure circuit

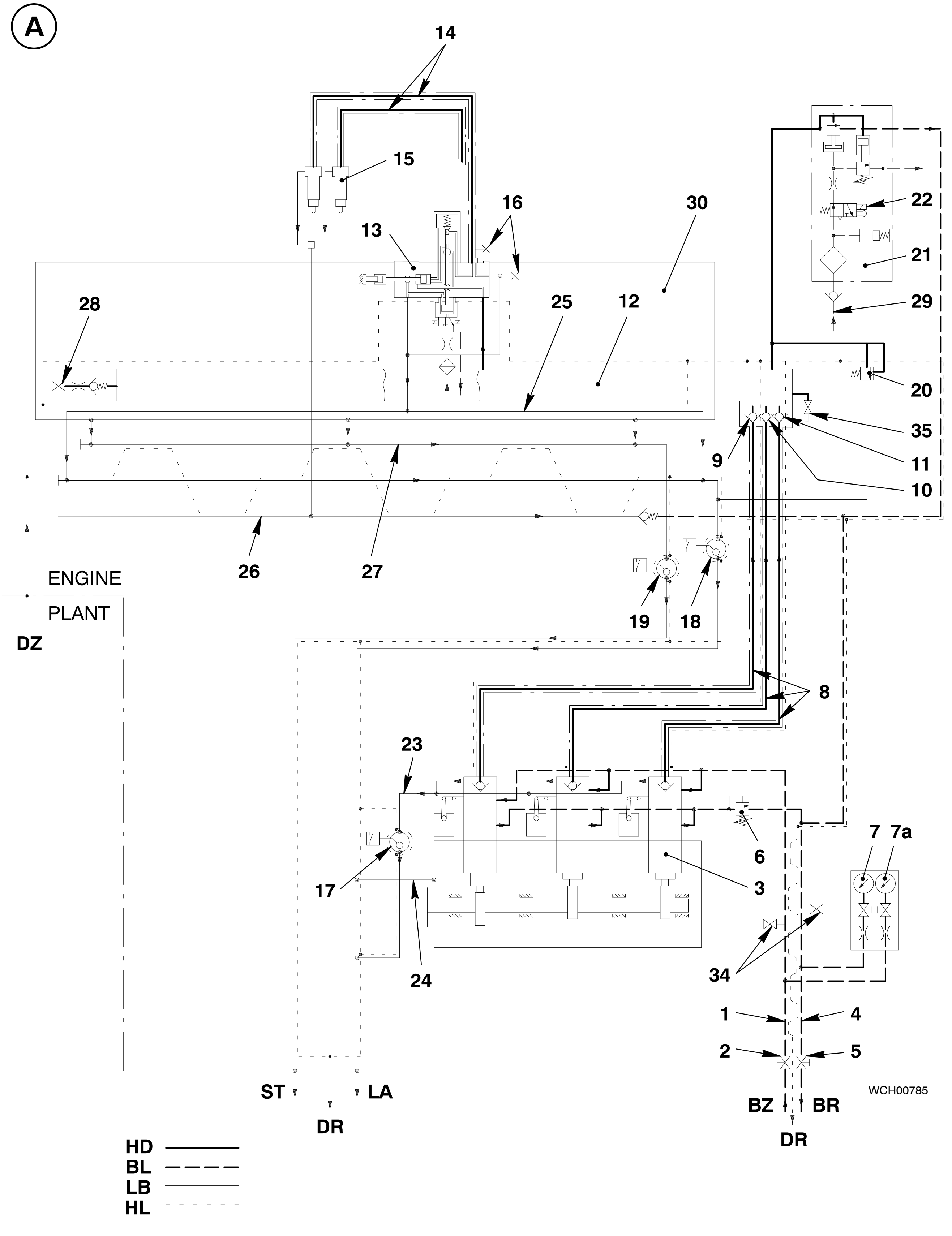
Prior to the first commissioning or after maintenance works on the high pressure circuit, fuel rail 12 can be connected to the servo oil rail (4.11) by tool 94583 (pipe). The servo oil service pump generates the required pressure via the servo oil system for a leak test and quick venting the high pressure 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 13 control the fuel injection volume to each injection valve 15.

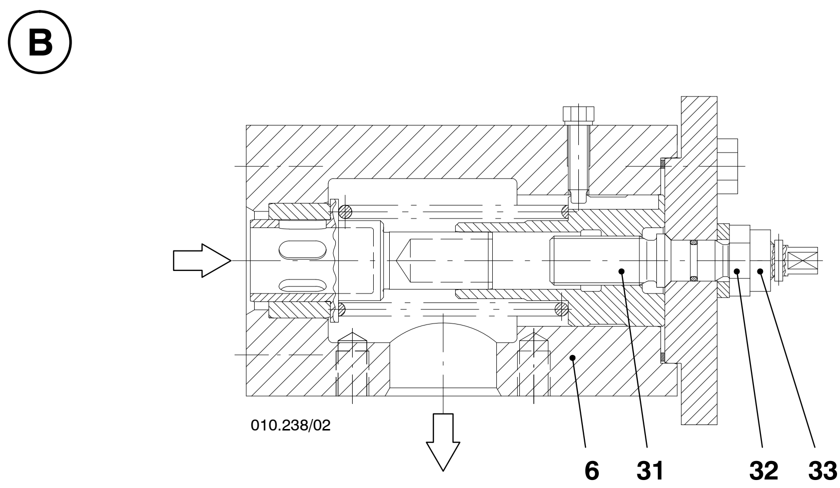
Non-return valves 9, 10 or 11 are provided to prevent a pressure drop in the fuel rail by breakage of a fuel rising pipe 8 (see section 4).

Fuel Oil System



Key to Illustrations: 'A' Fuel oil system on engine
'B' Pressure retaining valve

1	Fuel inlet pipe 3.24	24	Leakage fuel from fuel pumps
2	Shut-off valve	25	Leakage fuel (collecting) pipe 3.46
3	Fuel pump 3.14	26	Leakage fuel collecting pipe from injection valves
4	Fuel outlet pipe	27	Leakage drain from rail unit
5	Shut-off valve	28	Plug 3.39
6	Pressure retaining valve 3.53	29	Connection from bearing oil system
7, 7a	Pressure gauge	30	Rail unit (casing)
8	Fuel rising pipe 3.29 (high pressure)	31	Adjusting spindle
9	Non-return valve 3.81−1	32	Locking nut
10	Non-return valve 3.81−2	33	Locking nut
11	Non-return valve 3.81−3 (8 Cyl. only)	34	Screw plug
12	Fuel rail 3.05	35	Drain screw 3.82
13	Injection control unit 3.02		
14	Injection pipe 3.47		
15	Injection valve 3.01	BL	Fuel piping system
16	Leakage inspection point 3.17	BR	Fuel return
17	Level switch LS3426A	BZ	Fuel supply
18	Level switch LS3446A	DR	Steam outlet
19	Level switch LS3444A	DZ	Steam inlet
20	Fuel overpressure safety valves 3.52	HD	High pressure piping system
21	Fuel pressure control valve 3.06	HL	Heating (tracing) pipe
22	Fuel shut-down pilot valve 3.08	LA	to fuel overflow tank
23	Leakage fuel collecting pipe of rising pipes and fuel pumps	LB	Leakage fuel pipe
		ST	to sludge tank



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
LS3446A	Injection pipes 14, injection control units 13 (fuel quantity pistons), responding fuel overpressure safety valve 20
LS3426A	Rising pipes 8, fuel pumps 3

4.1 Leakage inspection points

Several leakage inspection points are provided for proper leakage localization.

If an alarm has been triggered by level switch 17 (LS3426A) or 18 (LS3446A), the leakage can be localized by means of loosening the corresponding drain screws 36, nut with conical plug 38 or screwed pipe coupling of leakage fuel pipe 39, 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, nuts with conical plugs when opening them or loosening screwed pipe couplings.

4.2 Leakage localization at fuel rising pipes 8 (3.29)

- Alarm by level switch 17 (LS3426A).

Procedure:

⇒ **Carefully loosen** screwed pipe coupling of leakage fuel pipe 39 **by max. two turns** and check whether fuel flows out or not (see Fig. ’E’).

⇒ Replace defective fuel rising pipe (see 0515−1 ’Exchange of defective 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 fuel pump cut out the engine can only be operated at reduced load (see Cutting Out and Cutting In of the Fuel Pump 5556−2 as well as Regulating Linkage 5801−1).

4.3 Leakage localization at injection pipes 14 (3.47)

- Alarm by level switch 18 (LS3446A).

Procedure:

⇒ Carefully loosen drain screw 36 on flange 37 of injection pipe 14 by approx. two turns and check whether fuel flows out or not (see Fig. 'C').

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.

4.4 Leakage localization at injection control units 13 (3.02)

- Alarm by level switch 18 (LS3446A).
- No leakage was ascertained during checking injection pipes 14.

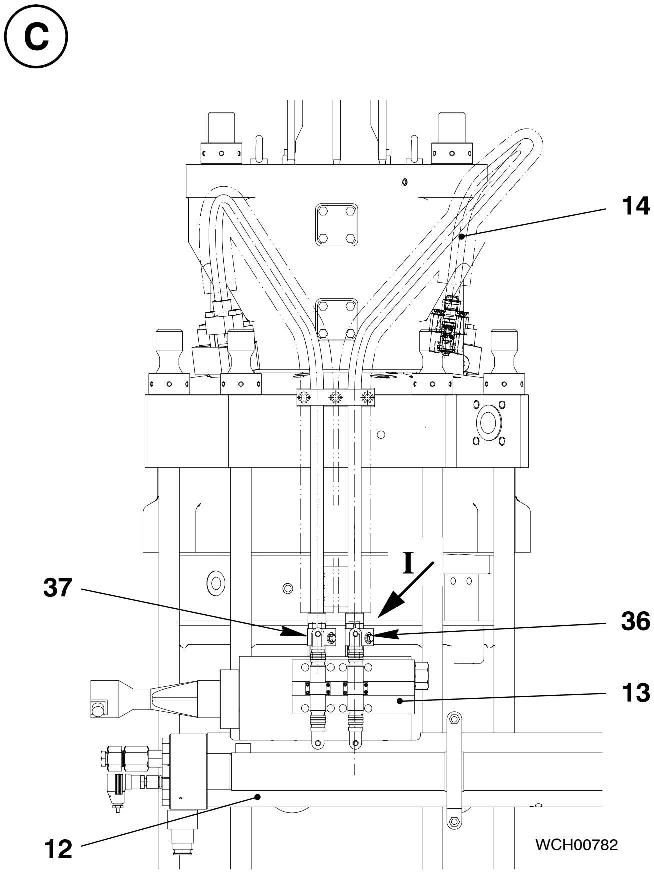
Procedure:

⇒ **Carefully loosen** nut with conical plug 38 on return pipe 40 **by max. two turns** and check whether fuel flows out or not (see Fig. 'D').

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).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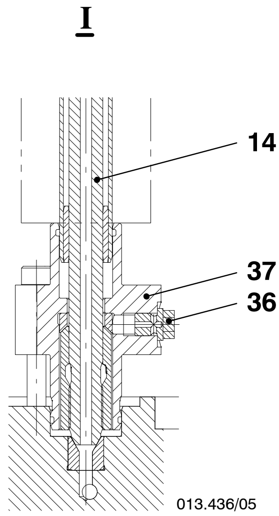
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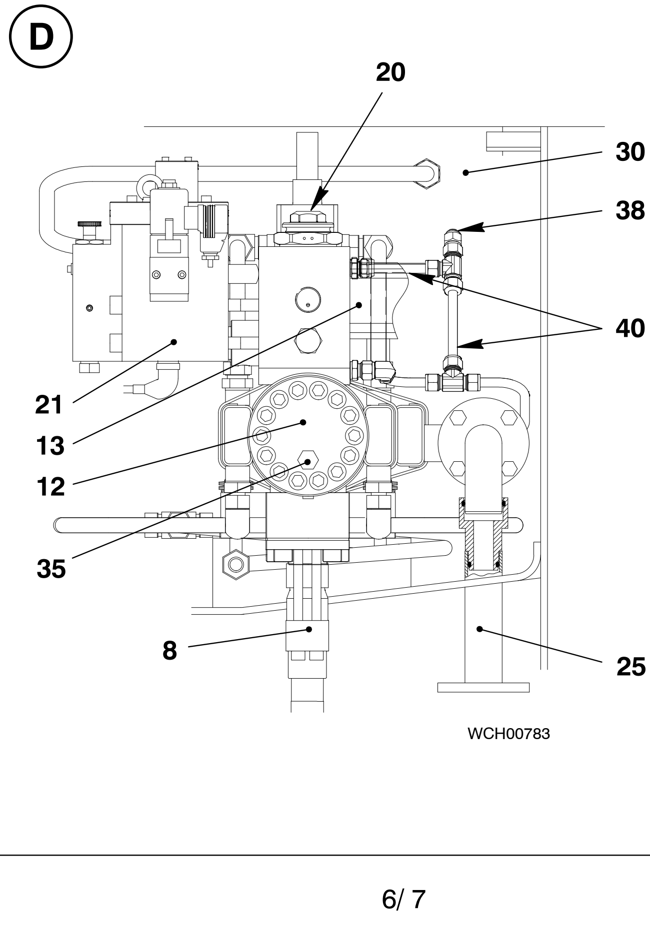
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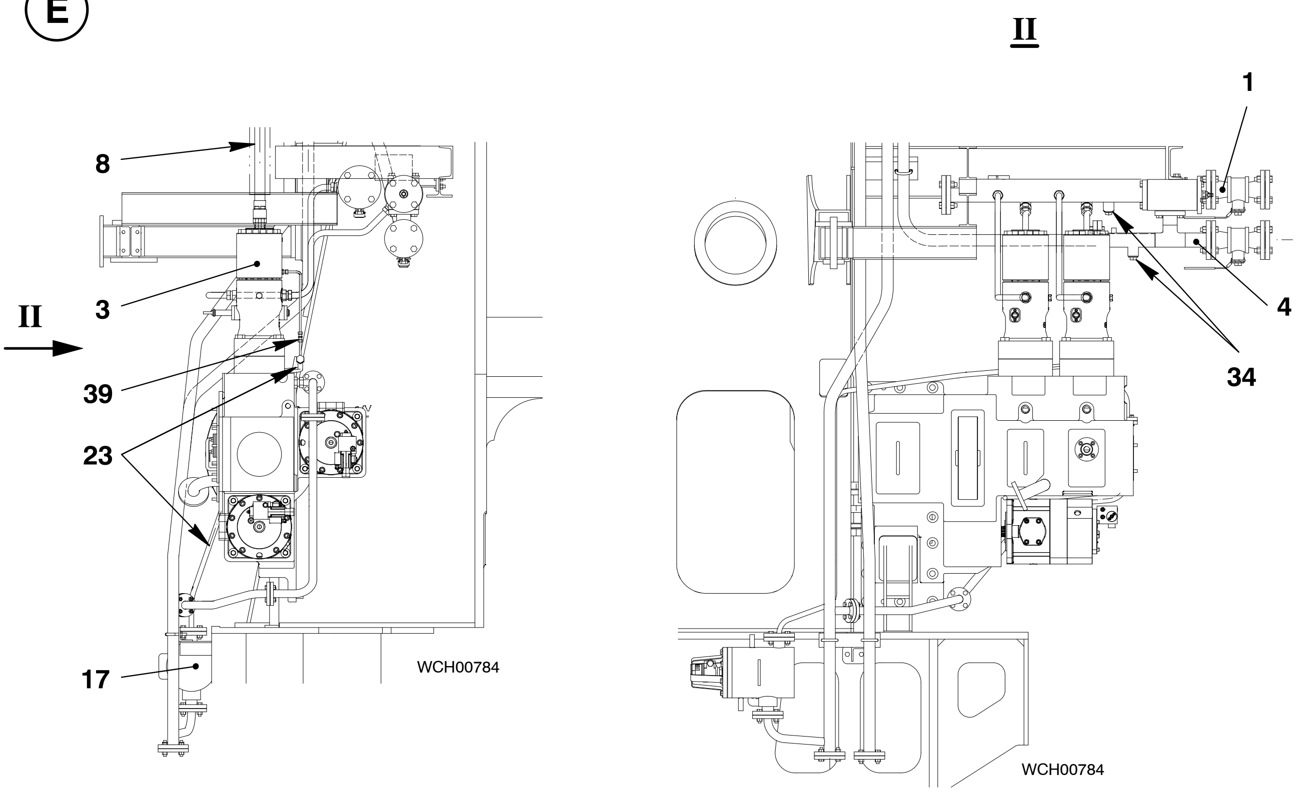

Key to Illustrations: **’C’ Leakage inspection point of injection pipes**
’D’ Leakage inspection point of injection control units
’E’ Leakage inspection point of rising pipes

1 Fuel inlet pipe 3.24
3 Fuel pump 3.14
4 Fuel outlet pipe
8 Fuel rising pipe 3.29
12 Fuel rail 3.05
13 Injection control unit 3.02
14 Injection pipe 3.47
17 Level switch LS3426A
20 Fuel overpressure safety valve 3.52
21 Fuel pressure control valve 3.06
23 Leakage fuel collecting pipe of rising pipes and fuel pumps
25 Fuel leakage pipe 3.46
30 Rail unit (casing)
34 Screw plug
35 Drain screw 3.82
36 Drain screw
37 Flange
38 Nut with conical plug
39 Leakage fuel pipe of rising pipe and fuel pump
40 Return pipe

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1. General

The drain piping, in particular that from the piston underside 10, from piston rod glands 26 and from the exhaust gas turbocharger 3, must be periodically checked for free passage.

Condensate may flow out before and after the cooler at the water drain 12, 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

The charging module is equipped with four individual condensate drains.

A perfect functioning of these drains must be ensured.

The following important points have to be taken into account:

- All perhaps existing valves must be fully open in the drain pipe.

Remark: Ball valves 22 and 23 must be usually in position NORMAL OPERATION (see Fig. 'B').
During engine operation butterfly valves 18 and 18a must always set to **CLOSED POSITION**! The condensate flows off via the orifice plate (bore), however.

- Dirt particles (rust residue) may be accumulated in the butterfly valves 18 and 18a; they must be removed periodically by shortly opening the butterfly valves.
- Check periodically the water flow at the sight glasses 20 and 20a.

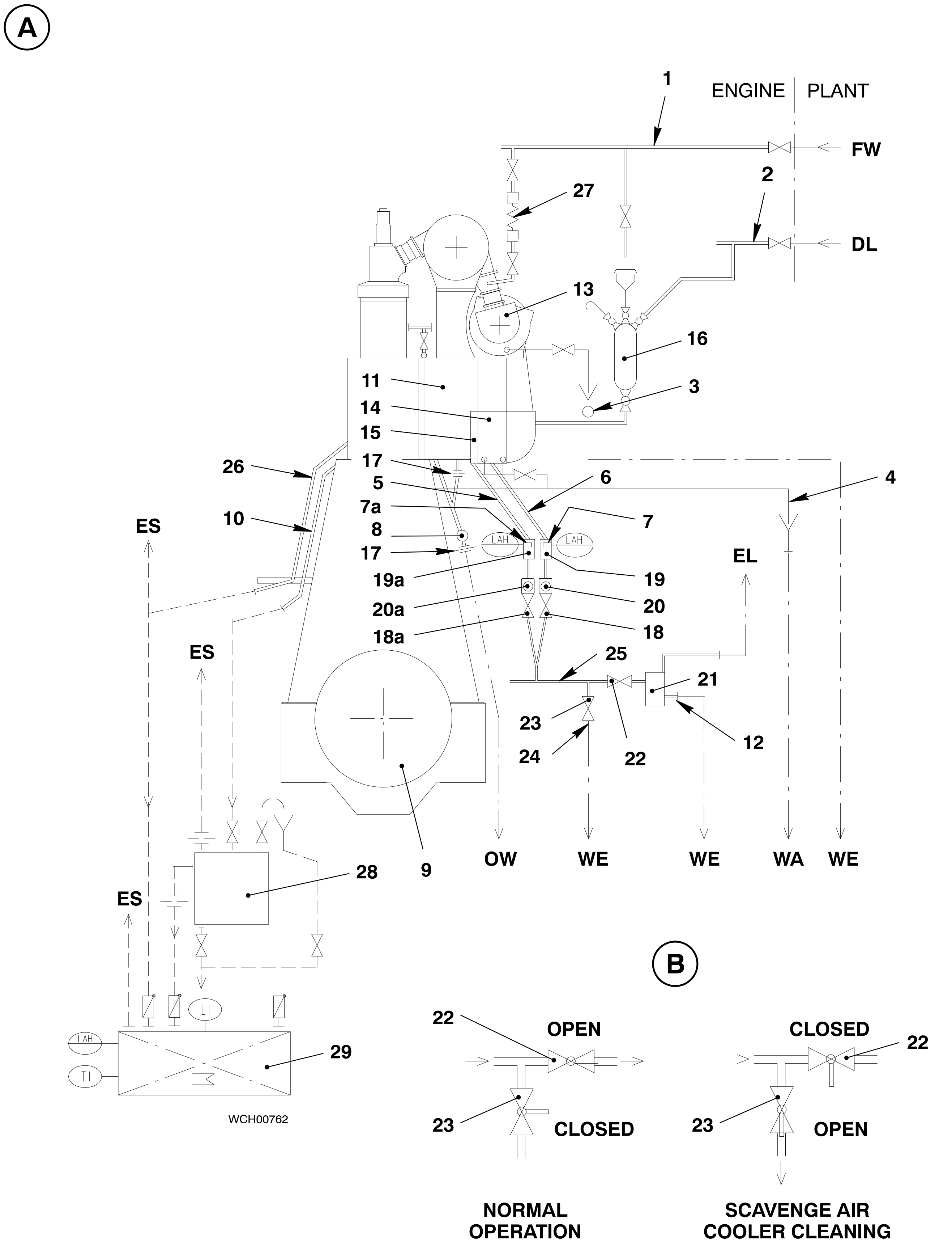
See also 0240–1 'Check and precautions'.

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**.

- Ball valves 22 and 23 in position CLOSED (see Fig. 'B').
- Defective scavenge air cooler (see 0550–1).
- Excessive dirt deposits in the butterfly valves 18 and 18a (orifice plate clogged)

Attention! Cleaning of the butterfly valves with orifice plate can only be carried out at engine standstill.
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



Key to Illustrations: ’A’ Diagram
’B’ Positions of ball valves 22 and 23

1	Wash-water distributing pipe
2	Compressed air distributing pipe
3	Wash-water drain from turbocharger (for TPL type)
4	Cylinder cooling water and scavenge air cooler drain
5	Condensate pipe from water separator
6	Condensate and wash-water pipe from scavenge air cooler
7, 7a	Level switch for condensate drain
8	Water drain from receiver (oleiferous)
9	Engine
10	Dirty oil drain from piston underside
11	Scavenge air receiver
12	Condensate drain from water separator and scavenge air cooler
13	Exhaust gas turbocharger
14	Scavenge air cooler
15	Water separator
16	Scavenge air cooler washing plant
17	Orifice plate
18, 18a	Butterfly valve with orifice plate (bore)
19, 19a	Float / solenoid switch unit
20, 20a	Sight glass
21	Venting unit
22	Ball valve
23	Ball valve
24	Cleaning agent and wash-water drain from scavenge air cooler
25	Condensate and dirty water collecting pipe
26	Leakage oil collecting pipe from piston rod gland
27	Connecting hose
28	Sludge oil trap (with heating coil)
29	Sludge oil tank

DL	Air line from board system
EL	Vent
ES	to venting collector
FW	from fresh-water hydrophore system
LAH	Level alarm high
LI	Level indicator
OW	Drain to oil / water drain tank
TI	Temperature indicator
WA	to water drain tank
WE	Drain to bilge water tank

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Engine Monitoring — Group 9

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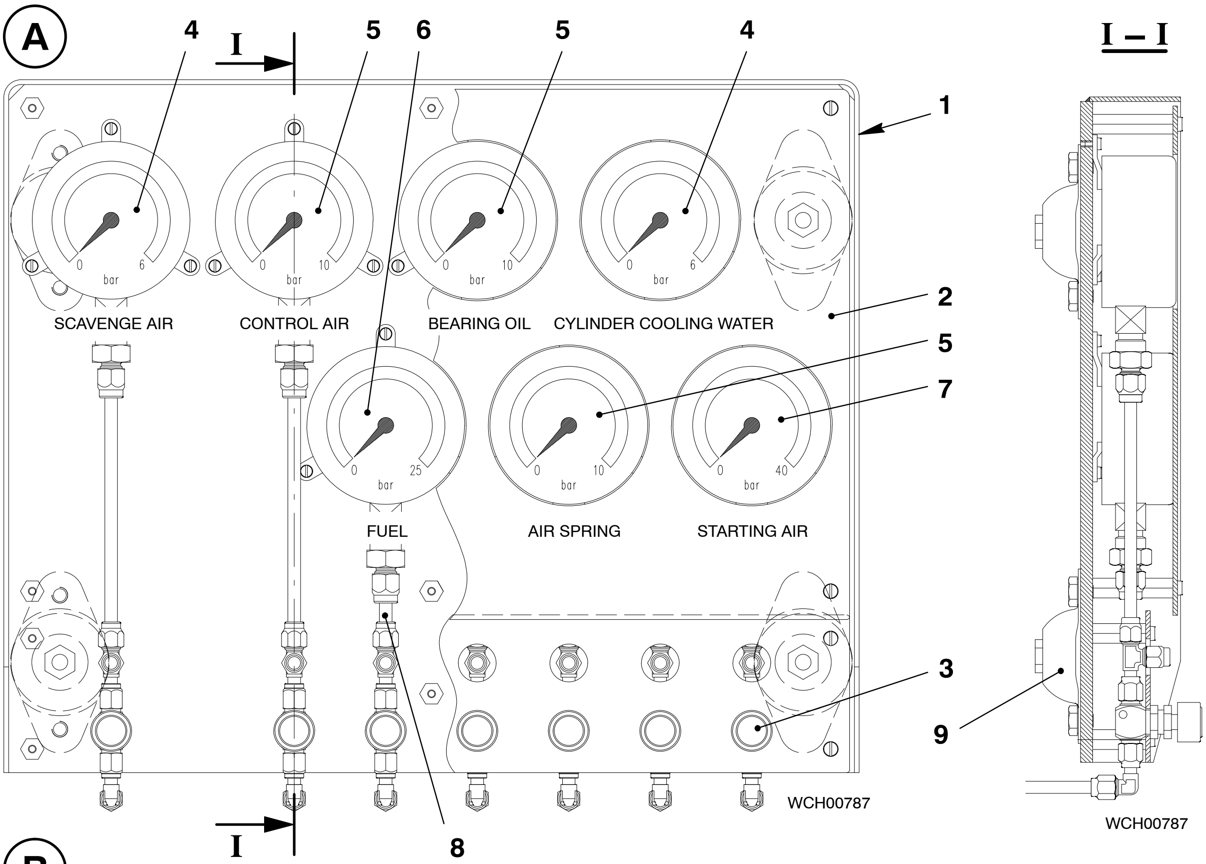
1. General

The instrument panel 1 is located next to the control box and contains the pressure gauges required for visual observation of the pressures. Pressure indications for fuel and servo oil are provided in the local control panel (see 4618–1).

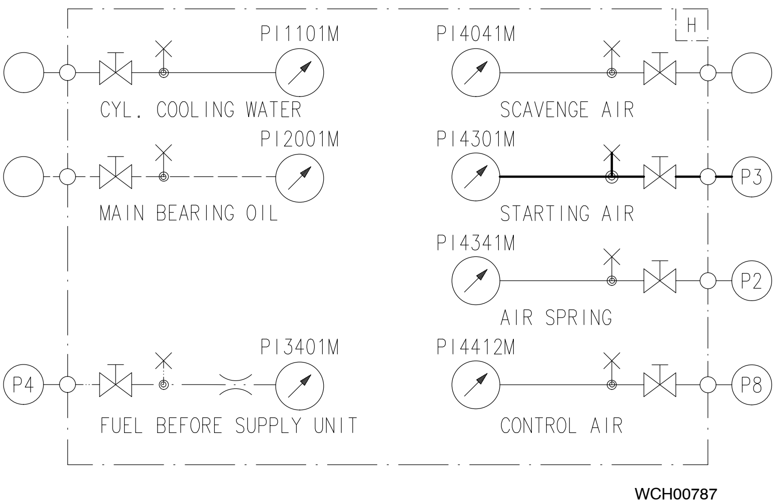
Fig. 'B' shows the schematic arrangement of the instrument panel H with the same indications also contained in the Control Diagram 4003–2.

The corresponding pressure switches and pressure transmitters are described in 9258–1.

A



B



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

Intentionally blank

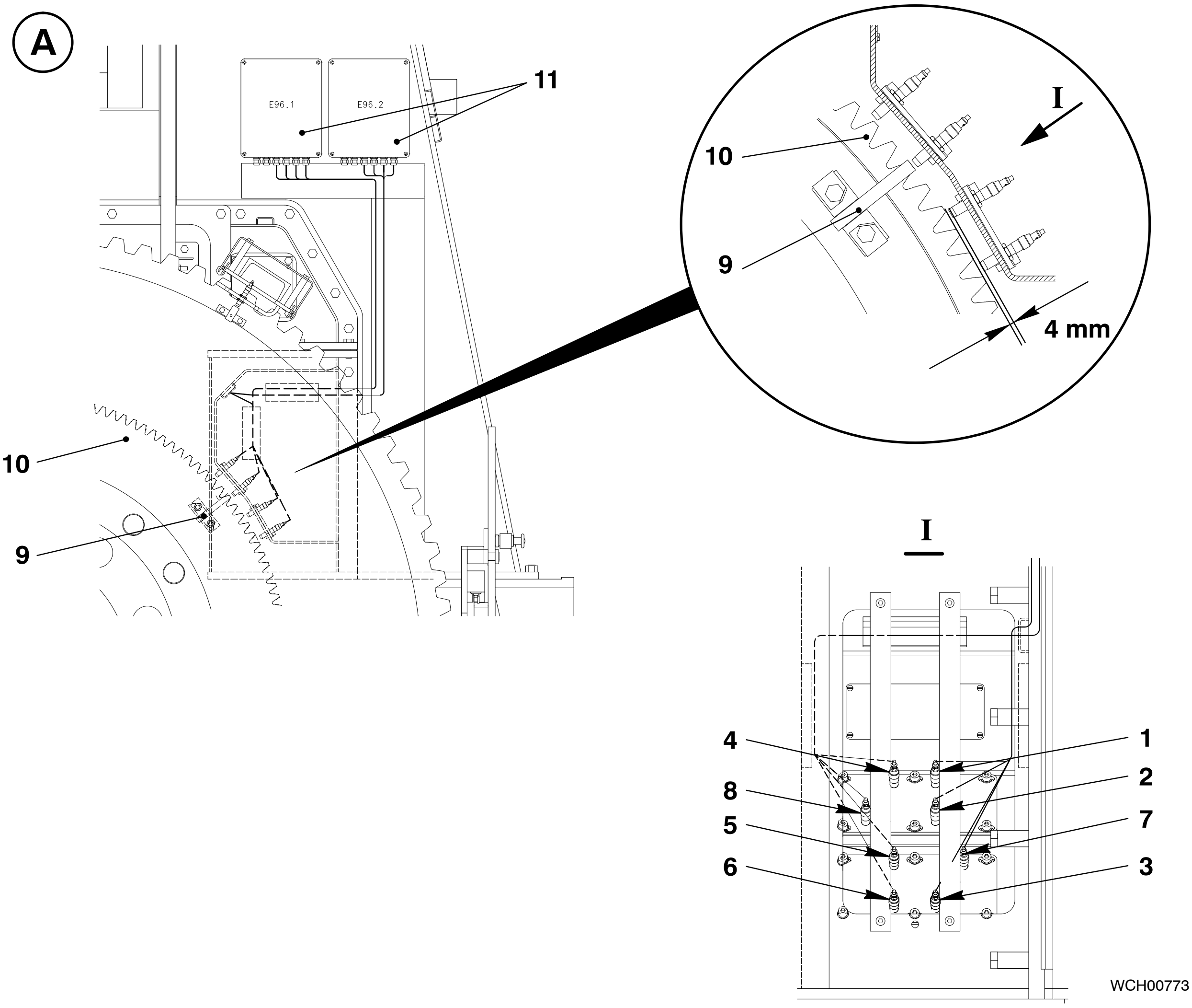
1. General

Attention! When you work in the area of the thrust bearing, or on the Crank Angle Sensor (CAS) and the cover is removed, you must shut down the WECS−9520.

1.1 Crank angle sensor

Two CAS units that operate independently are installed at the driving end. Each CAS unit has three proximity sensors for position measurement of the gear wheel on crankshaft 10. The fourth proximity sensors 7, 8 finds the related crank angle reference mark (TDC or BDC). The proximity sensors are connected to the ACM−20 modules in the terminal boxes 11.

Each of the two ACM-20 modules send the crank angle data through the SSI bus to the FCM−20 module on cylinder No.1 (see 4002−1 'Crank angle sensor').



Key to Illustration: **'A' Crank angle sensor unit**

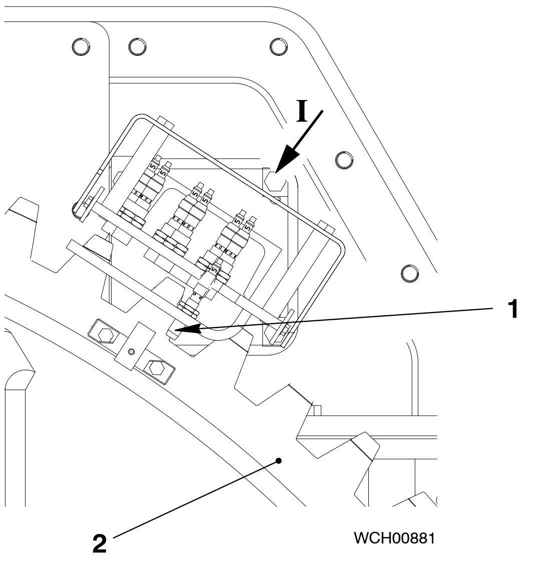
1 Proximity sensor ST5131C (A1)
2 Proximity sensor ST5132C (B1)
3 Proximity sensor ST5133C (C1)
4 Proximity sensor ST5134C (A2)
5 Proximity sensor ST5135C (B2)
6 Proximity sensor ST5136C (C2)
7 Proximity sensor ZS5124C (BDC)
8 Proximity sensor ZS5125C (TDC)
9 Crank angle mark
10 Gear wheel on crankshaft
11 Terminal boxes

1.2 Pick-up for position

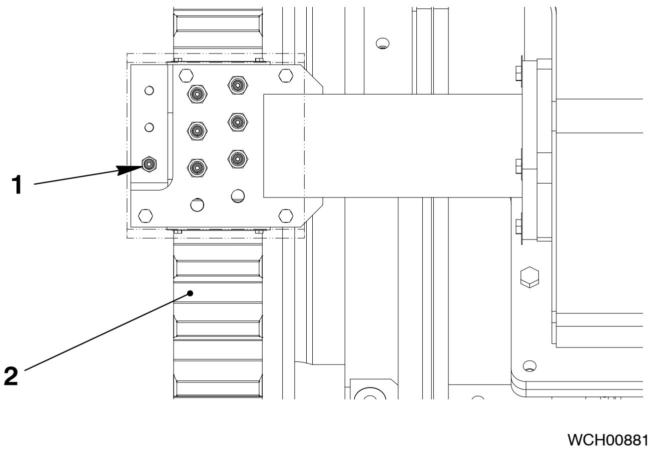
The proximity sensor 1 (see Fig. ’B’) gives indications to compare the measurement of the TDC position for the crank angle transmitters and is the reference point for the WECS−9520 (0 deg position of the cylinder 1 = TDC).

For more data, see 4628−1 Pick-up for Speed Measurement.

B



I



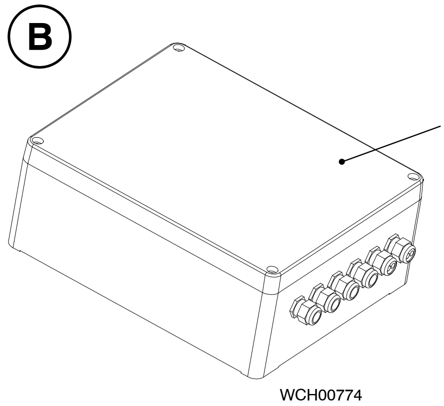
Key to Illustration: **’B’ Speed Pick-up Proximity Sensor**

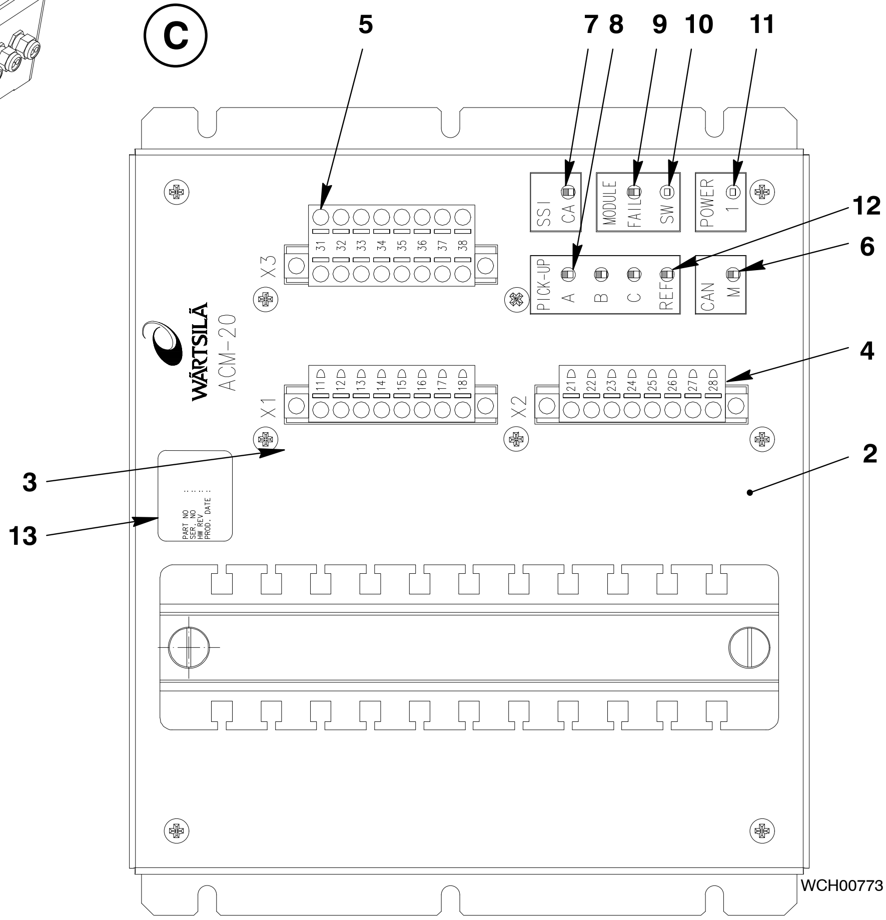
1 Proximity sensor ST5123C
2 Flywheel

2. ACM−20 module

The ACM−20 module is a microprocessor based control unit that has frequency inputs, which read the pick-up signals. The function of the ACM−20 module is to calculate the angle of the crankshaft.

The crank angle data is transmitted through the Synchronous Serial Interface (SSI).





Key to Illustration: **'B' Terminal box**
'C' ACM−20 module

1 Terminal box
2 ACM−20 module
3 Plug X1
4 Plug X2
5 Plug X3
6 CAN M LED
7 SSI CA LED
8 PICK-UP LEDs A, B, C
9 MODULE FAIL LED
10 MODULE SW LED
11 POWER LED
12 PICK-UP LED REF
13 Nameplate

2.1 LED indications

The LED indications are as shown below (see Fig. 'B' for more data).

LED	Indication	Function status
POWER LED 11	Shows green continuously	Power supply on (connected)
MODULE SW LED 10	Shows green continuously	Software application is in operation
	Flashes green	Boot loader is running
MODULE FAIL LED 9	Shows red continuously	Shows a failure on the module
	Yellow	Not used
PICK-UP A, B, C LEDs 8	Shows red continuously	No pick-up connected
	Flashes red (on for 0.2 sec, off for 0.2 sec)	No signal / incorrect signal sequence.
	Flashes red (on for 0.2 sec, off for 1.0 sec)	Overloaded – short circuit
PICK-UP REF LED (TDC or BDC) 12	Shows yellow continuously	Pick-up information: Shows a strong signal at the related input (tooth found)
SSI CA LED 7	Shows yellow continuously	Normal operation, no failure found. Absolute angle is transmitted
CAN M LED 6	Shows red continuously	No bus connection
CAN M LED 6	Shows yellow continuously	Normal operation

Pressure Switches and Pressure Transmitters

1. General

The pressure switches and transmitters are mounted on a 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.

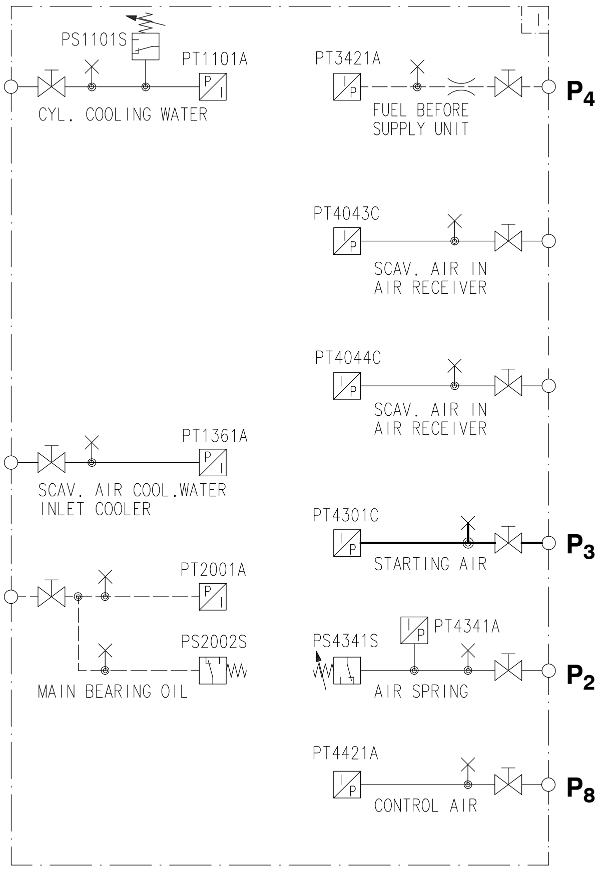
Their control signals effect the following commands:

- Alarm (ALM)
- Slow-down (SLD)
- Shut-down (SHD)

See Alarms and Safeguards at Continuous Service Power 0250−2.

Fig. 'A' shows a schematic diagram of the pressure switches and pressure transmitters I with the indications, as given in the control diagram 4003−2.

A



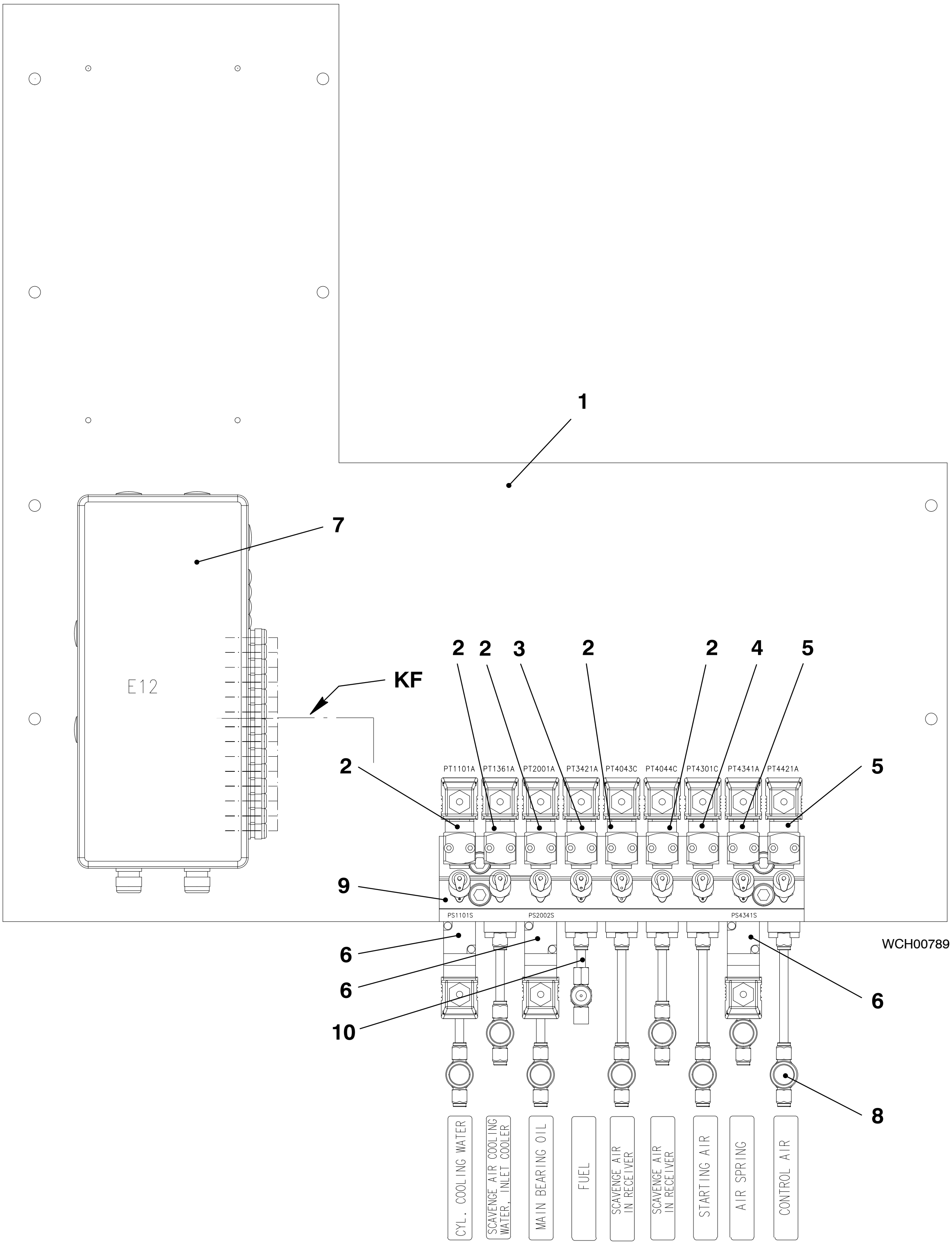
WCH00788

Key to Illustrations:

'A'	**Diagram of unit I** (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	Terminal box		
8	Regulating valve		
9	Teminal bar		
10	Throttle piece		
KF	Cable		

Pressure Switches and Pressure Transmitters

B



1. General

The engine is equipped with an oil mist detector. The oil mist detection system includes the control panel 1 located in the control room. The sensors 2 and junction box 3 are mounted 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.
Possible bearing damage 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 the fuel side of the engine provided for each cylinder of the divided crankcase, in the drive supply unit and supply housing (see Fig. 'B').

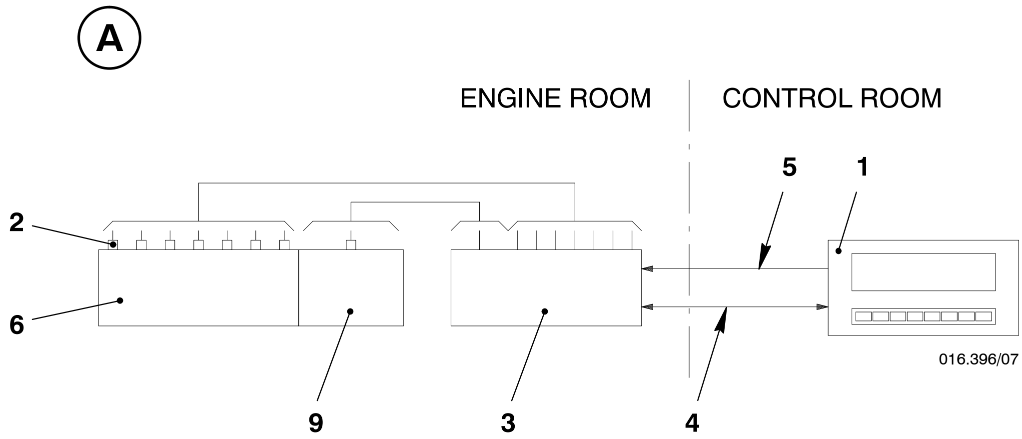
2. Function

Each sensor monitors optically the density of oil mist, and does a self-check for internal faults.
The data cable 4 enables communication between the junction box 3 and the control panel 1 (see Fig. 'A').

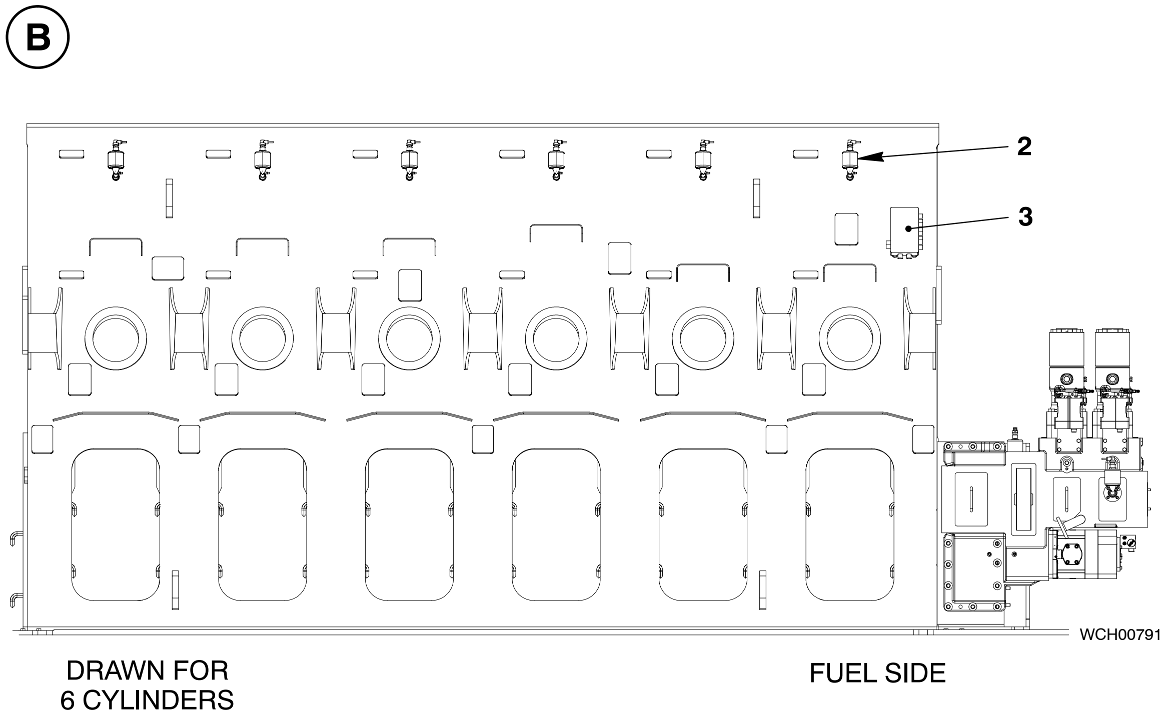
The adjustments can be programmed in the control panel.
The menu-driven software contains three user levels:

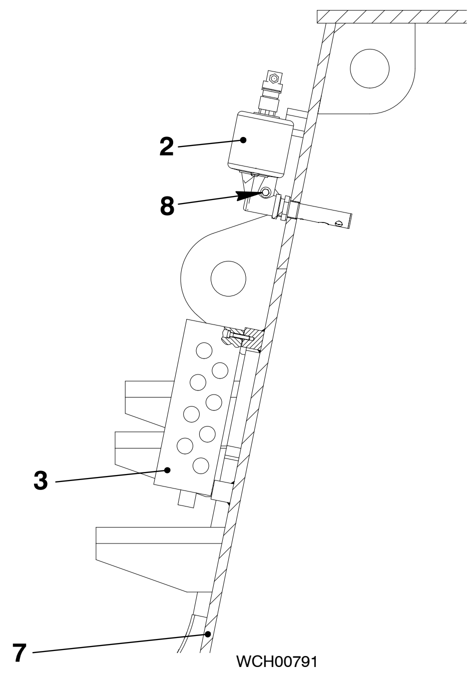
- USER: Data is read-only.
- OPERATOR: Password-protected level for access to most adjustments and functions.
- SERVICE: Password-protected level for authorized staff of manufacturer and service personnel.

Remark: For detailed instructions regarding adjustments, commissioning, fault detection and maintenance, see the related Manufacturer's manual.



Oil Mist Detector





Key to Illustrations: **'A' Schematic presentation**
'B' Arrangement of sensors

1 Control panel
2 Sensor
3 Junction box
4 Data cable
5 Power cable
6 Engine
7 Engine housing (column)
8 Test connection
9 Supply 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 on rail unit at the free end.

E95.01 to E95.08:

Control boxes (depending on number of cylinders) contain a FCM−20 module each.
Arranged on rail unit at every cylinder.

E41.01 to E41.08:

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.

E96.1 and E96.2:

Control boxes contain a ACM−20 module each for controlling the crank angle measuring system.

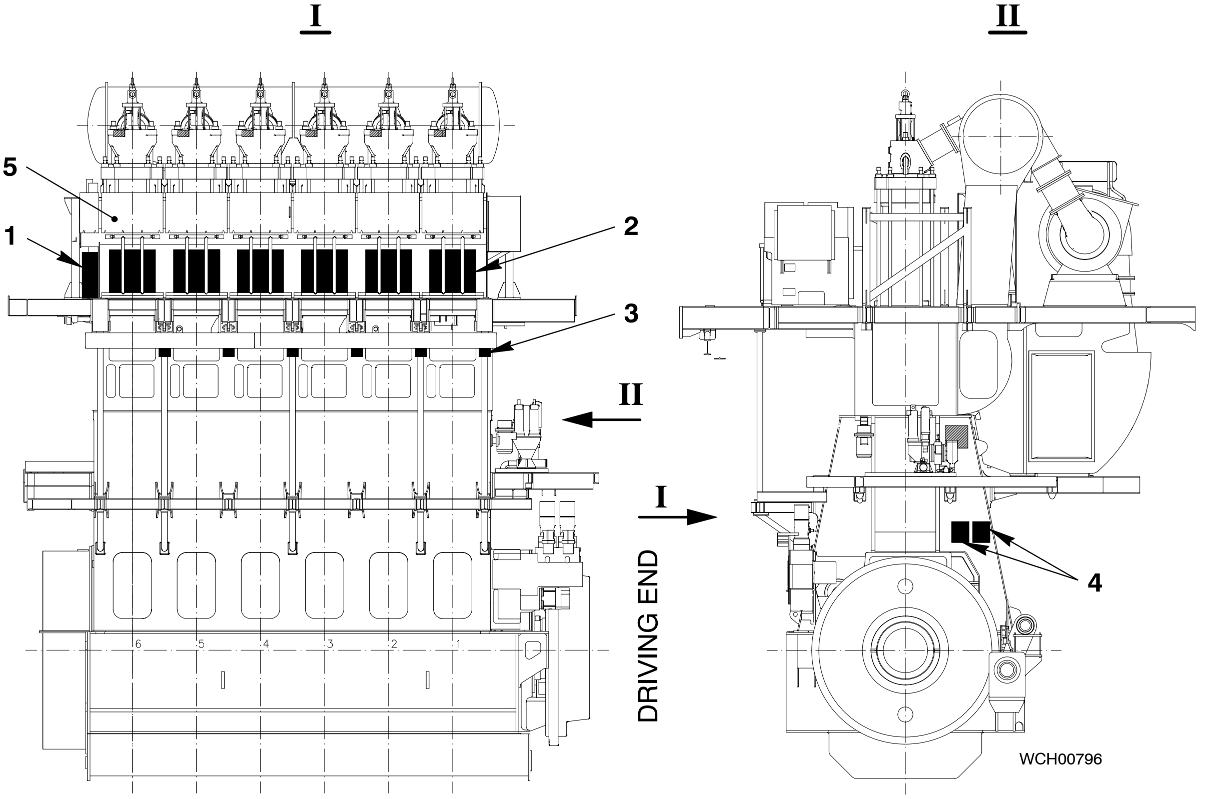
E85:

Power supply box for FCM−20 modules, fuel pump actuators, ALM−20 modules and ACM−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 and ACM−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

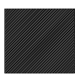
A



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 Control box E96.1, E96.2
5 Rail unit