Winterthur Gas & Diesel

X62

Operation Manual

"Marine"

Vessel:

Type:

Engine No.:

Document ID:

Winterthur Gas & Diesel Ltd.
Schützenstrasse 1–3
CH-8400 Winterthur
Switzerland

24hrs Support:
Wärtsilä Services Switzerland Ltd.
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W-X62				Summary for Operation Manual (OM)		
Page No.	Modification		Title	Subject	Page or Manual	
	Date	No.			new	exch.
	2014			**Operation Manual, Issue 2014**	x	
				Date of publication 2014-06-05		
OM_2015-03	2015-03		Cover Page and Disclaimer	New Layout WinGD; Disclaimer updated (WinGD and WSCH added);		x
0000-1/A1	2015-03		For Your Attention	Data updated (WinGD and WSCH added);		x
0010-1/A1	2015-03		Preface	Minor text changes; Data about Wärtsilä Service Switzerland Ltd added;		x
0020-1/A1	2015-03		Table of Contents	New chapters 4605-1/A2 and 7218-3/A1 added;		x
0030-1/A1	2015-03		Subject Index	New chapters 4605-1/A2 and 7218-3/A1 added;		x
0035-1/A1	2015-03		Abbreviations	New entries added		x
0110-1/A1	2015-03		Prepare for Engine Start after a Short Shut-down Period	page 1: Cooling Water inlet temperature changed from 60°C to 65°C (ALM L value TE1111A = 65°C); page 2: Reference to 0210-1 added (Warning);		x
0210/1-A1	2015-03		Safety Precautions and Warnings (General Data)	paragraph 2: Warning about oil mist detector added; paragraph 8: Warning about hot parts added; paragraph 9: Warning about injury hazards added; paragraph 13: Warning about air run added;		x
0220-1/A1	2015-03	Input Product Manager	Operation during Usual Conditions - Slow Turning	para 2: Warning added;		x
0250-1/A1	2015-03	EAAD085793 EAAD085660	Operating Data Sheet	Values for fresh water cylinder cooling (inlet) changed from min. 4.5 bar to 4.0 bar and max. from 5.5 to 5.0 bar; Data about thrust bearing removed; New data aobut high/low pressure lubricating oil system added; Document structure changed;		x
0250-2/A1	2015-03	Input from Bruno Frei 12/2015, E-Mail from licensee; new data for engines rated with CMCR speed less than or equal to 75 rpm; EAAD085793	Operating Data Sheet	PT2003A remark 'before injectors' added; Name of TE2011A (Crank Pin Bearing Oil, optional) changed to TE2201-08A; TE2101-10A (Outlet Bearing 1 to 10, optional) added; TE2501-08A and FS2521-28S moved to section 'Lubricating Oil - Bearings'; PT2021A (booster pump inlet) added; TE2301-08A (crosshead bearing oil outlet, optional) added; PT1101A ALM changed to 4.0 bar, SLD changed to 3.8 bar; PS1101S SHD changed to 3.5 bar;		x
0270-1/A1	2015-03	Service Bulletin RT-82; EAAD085468	Change-over from Diesel Oil to Heavy Fuel Oil and Back	para 3.1: Temperature gradient changed from 15°C/min to 2°C/min related to the Service Bulletin, paragraph 4; Data about the automatic change-over unit added; para 4.1: Data about the automatic change-over unit added; para 4.2: Caution updated; New references to fuel diagram;		x

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0410-1/A1	2015-03	E-Mails from Noah Mazenauer 05. Jun 2014 and 26. Jun 2014; Service Bulletin RT-161;	Running-in New Cylinder Liners and Piston Rings	Paragraph 1: Latest data from the Service Bulletin; Paragraph 1.2: Additional data about the HFR and LFR bushes added;		x
0530-1/A1	2015-03		Operation during Unusual Conditions - CCM-20 Failure	Fig. 1 and Fig. 2: Illustration updated, "Command 2" removed; para 1.3: Procedure changed;		x
0590-1/A1	2015-03		Operation during Unusual Conditions	paragraph 2.1: text engine output changed, Note added; paragraph 2.2: text engine output changed, paragraph about exhaust gas temperature added;		x
0620-1/A1	2015-03		Prepare the Engine for a Long Shutdown Period	para 2.2: Remark about auxilary blowers added;		x
0710-1/A1	2015-03	EAAD085468	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; 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 Switerland Ltd and WinGD added;		x
0720-1/A1	2015-03	EAAD085468	Operating Media - Fuel Treatment and Fuel System	Fig. 1: Schematic Diagram - Fuel System updated; para 3: minor text changes; para 4: text changed; Structure of the document changed;		x
0750/1A1	2015-03	Service Bulletins RT-138 (Version 4) RT-138_1 (Version 4)	Operating Media - Lubricating Oils	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
2303-1/A1	2015-03		Piston Rod Gland	paragraph 2: data about scraper rings updated;		x
3326-1/A1	2015-03		Crosshead and Guide Shoe	Position 8 added to illustration; Page 1: Remark about engines with a CMCR less than 106 rpm added; Illustrations: Remark added;		x
Group 4	2015-03	EAAD085778	Table of Contents	4605-1/A2 added to list		x
4002-1/A1	2015-03		Engine Control System UNIC	Chapter updated; new structure and latest data; Fig. 10: Latest data Signal Flow Diagram;		x

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4002-2/A1	2015-03		Local Control Panel / Local Display Unit (LDU-20)	Screenshots of the LDU-20 pages updated with latest data; LDU-20 card 'Temperature' added; LDU-20 card 'Perfomance Data' added; Paragraph 2.2: sentence removed; Paragraph 2.4: indication pressure control valve changed, references added; Paragraph 3.6: Changed the maximum value for the fuel command to 150%; Paragraph 3.7.1: data about hydraulic pump unit Tool 94845 removed; Several minor changes, new structure of the document;		x
4003-1/A1	2015-03		Engine Control	Updated with latest data, general minor changes; paragraphs 4.1 and 4.6: data about hydraulic pump unit Tool 94845 removed; Table 1: updated with latest data;		x
4003-2/A0	2015-03		Designations	para 6: CV7013C and CV7014C name changed to solenoid valve; para 5: PT2021A & PT2021C added;		x
4003-2/A1	2015-03	EAAD085710	Control Diagram	Control Diagram change to Revision C		x
4003-5/A1	2015-03	EAAD085670	Pipe Diagram - Oil Systems	Updated illustration		x
4003-6/A1	2015-03	EAAD085670	Pipe Diagram - Oil Systems	Updated illustration		x
4325-1/A1	2015-03		Shut-off Valve Starting Air	CV7013C and CV7014C name changed to solenoid valve		x
4605-1/A1	2015-03	EAAD085778	Control Air Supply	Fig. 1 replaced with updated version		x
4605-1/A2	2015-03	EAAD085778	Control Air Supply	Fig. 1 replaced, Air Tank position is different for engines with ELBA installed	x	
6420-1/A1	2015-03		Scavenge Air Receiver	Positon numbers and designations changed;		x
6545-1/A1	2015-03		Auxiliary Blower and Switch Box	para 1.1: Note added (auxiliary blower out of service for a long period);		x
6606-1/A1	2015-03		Scavenge Air Cooler - Operating Instructions and Cleaning	page 4: procedure changed		x
6735-1/A1	2015-03	EAAD085647	Scavenge Air Waste Gate	Pge 2 - Illustration change. Pge 3 - data changes in Table 1 and Table 2. Pge 4 - Pressure Check procedure changed		x
Group 7	2015-03		Group TOC	7218-3 added;		x
7218-1/A1	2015-03	EAAD084716	Cylinder Lubrication	Minor changes in the text; Fig. 3 new illustration (Pos. 3 added); New document structure; para 3.1: data related to PT3124A changed; para 6.4: New reference to 7218-3; para 8.4: new data, Data about the adjustment range removed;		x
7218-2/A1	2015-03	EAAD085313 E and EAAD085141 E	Cylinder Lubrication - LFR and HFR Bushes	Update of the document structure; Fig. 1, view I replaced with updated version;		x
7218-3/A3	2015-03	Service Bulletin RT-161	Feed Rate - Adjustment	New Chapter added, new data from the Service Bulletin; Minor text changes; Data about Wärtsilä Service Switzerland Ltd added;	x	
8016-1/A1	2015-03		Lubricating Oil System	Paragraph 5.1: data about hydraulic pump unit Tool 94845 removed; Fig. 2: Item 28 servo oil service pump added;		x

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8825-1/A1	2015-03	EAAD085176	Electrical Trace Heating	para 2.3: minor changes in the text; Page 5: Fig. 3 updated. New position of terminal boxes (E89.0X);		x
				Date of publication 2015-06-04		
0020-1/A1	2015-12		Table of Contents	New document 7722-1/A1 added;		x
0030-1/A1	2015-12		Subject Index	New document 7722-1/A1 added;		x
0035-1/A1	2015-12		Abbreviations	Abbreviations added;		
0210/1-A1	2015-12		Safety Precautions and Warnings (General Data)	paragraph 13: Warning text changed, Note added;		x
0250-1/A1	2015-12	EAAD086282 Circular to Licensees 7415 and 7415-1	Operating Data Sheet - Pressure and Temperature Ranges	Crosshead bearing (high pressure): min./max. value for different CMCR speed ranges added (additional crosshead lubricating pump); Piston cooling oil (high pressure): entry removed; Note 5 added;		x
0250-2/A1	2015-12	EAAD086282 Circular to Licensees 7415 and 7415-1	Operating Data Sheet - Alarms and Safeguards	Crosshead bearing oil (high pressure): New data for PT2021A added for different CMCR speed ranges (additional crosshead lubricating pump); Note 15 and Note 16 added;		x
0410-1/A1	2015-12	Service Bulletin RT-161_Issue2	Running-in New Cylinder Liners and Piston Rings	Data about running-in procedure removed, related to the new data in the Service Bulletin RT-161_Issue2; Additional data about feed rate adjustments added;		x
0720-1/A1	2015-12	EAAD085894	Operating Media - Fuel Treatment and Fuel System	Fig. 1: Schematic Diagram - Fuel System updated; Key to Fig. 1: Items 31, 32, 33 added; para 4: data about additional leakage collection tank added;		x
0750-1/A1	2015-12	Service Bulletins RT-161_Issue2	Operating Media - Lubricating Oils	document: style changed, minor text changes; para 2.1: data about automatic filter removed; table 3: data updated; para 2.3.1: recommend limits for particle count updated; para 3.1: data updated related to the changes in Fig. 1; Fig. 1: data updated; para 3.2: data updated; Fig. 2: new operating areas defined; para 3.4: Caution moved to the beginning of the paragraph;		x
4002−1/A1	2015-12	Software update; Review (Automation department);	Engine Control System UNIC	Document reviewed; Fig. 2: Illustration updated; Exhv. Ctrl Vlv Cyl#1 CV740nA changed to Exhv. Ctrl Vlv Cyl#n CV740nC para 2.3: Remark added; para 3.6: New section added (Angle Determination Algorithm); para 3.7.2: text changed; Fig. 8: Illustration updated; para 5.1: text changed;		x

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Page No.	Modification Date	Modification No.	Title	Subject	Page or Manual new	Page or Manual exch.
4002−2/A1	2015-12	Software update; Review (Automation department);	Local Control Panel / Local Display Unit (LDU−20)	Document reviewed; Structure of the document changed; para 2.2: Reference about control transfer added; Fig. 3 and Fig. 5: Illustration updated; para 3.3: Item 33 text added; Fig. 6: Illustration updated; New paragraph 3.5 added: Fuel System; para 3.6: Illustration updated; table entries added; para 3.5: Illustration updated; table text changed; para 3.8: Illustration updated; table text changed; para 3.9: Illustration updated; table text changed; para 3.10: Illustration updated; table text changed, table entries added; para 3.10.1: ADA Start from the LDU 20 Local Control Panel or LDU 20 ECR added; para 3.11: Illustration updated; table text changed, table entries added; para 3.12: Illustration updated; table text changed, table entries added; para 3.13: Paragraph added (Crank Angle); para 3.14: Illustration updated; para 3.17.1: Note added; para 3.21: Note added;		x
4003−1/A1	2015-12	Software update; Review (Automation department);	Engine Control	Document reviewed; para 2: Control transfer added; para 3.2: Note changed; para 3.5 added (Control transfer); para 4.3: Text changed; para 4.4: Text added; para 4.4.2: Text added; para 4.5.1: Procedure updated;		x
4003-3/A1	2015-12	EAAD085670	Pipe Diagram - Water Systems (Cylinder Cooling)	New air vent design		x
6500-1/A1	2015-12	Service Bulletin RT-162	Turbocharging	Caution added (new data related to the Service Bulletin RT 162, Issue 1)		x
6545-1/A1	2015-12	Review (Automation department)	Auxiliary Blower and Switch Box	para 2.2: Note about emergency operation added;		x
Group 7	2015-12		Group TOC	7722-1/A1 added;		x
7218-3/A1	2016-01	Service Bulletins RT-161_Issue2	Feed Rate - Adjustment	New procedure to set the feed rate (empirical data collection) related to the new data in the Service Bulletin; Structure of the document changed;		x
7722-1/A1	2015-12		Integrated Electric Balancer	New document added;	x	
				Date of publication 2016-01-12		
All pages	2017-10	Update WinGD	All documents	Engine brand changed from Wärtsilä to WinGD X62		x
0250-1/A1	2017-10	Update WinGD; EAAD086595	Operating Data Sheet Pressure and Temperature Ranges	Torisional vibration damper (damper inlet): Min. pressure value changed from 1.5 bar to 2.8 bar; max. pressure 5.0 bar (value added); Note added;		x

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0250-2/A1	2017-10	Update WinGD	Operating Data Sheet Alarms and Safeguards	PT2711A: ALM value changed from 1.5 bar to 2.2 bar; Medium name changed to 'Torsional vibration damper oil (steel spring damper)'; Note added; Crosshead bearing oil, PT2021A SLD setting value changed from 6.0 bar to 6.5 bar		x
0750-1/A1	2017-10	Update WinGD	Lubricating Oil	Update according to Service Bulletin (Text changes, Particle Count; new Tables 4 and 5, updated Figures 1 and 2, updated Tables 6 and 7)		x
				Date of publication 2017-10-27		

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Operating Descriptions Group 0

For Your Attention

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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Preface

1. Technical Documentation Set

The technical documentation set for this diesel engine type includes the following publications:

1.1 Operation Manual

The operation manual contains data about engine operation, the necessary operating media (oil, water and fuel) and descriptions of the components and systems. The manual also gives troubleshooting procedures.

1.2 Maintenance Manual

The maintenance manual contains data about disassembly / assembly procedures that are necessary for the engine maintenance and the maintenance schedule. This manual gives more data about the masses (weight) of components, a clearance table, tightening values for important screw connections and a tool list.

1.3 Code Book (spare parts catalogue)

In the code book all parts of the engine are marked with a unique code number. The code number is necessary to order spare parts from Wärtsilä Services Switzerland Ltd. or the engine supplier. The spare parts can only be ordered with the code number from the code book.

1.4 External Supplier Documentation

The documentation from external suppliers gives data about the parts of the engine that are not supplied by Winterthur Gas & Diesel Ltd. or Wärtsilä Services Switzerland Ltd., such as turbocharger, automatic filter, torsional or vibration damper. Most of this documentation also contains data about spare parts.

1.5 Records and Drawings

The setting tables, shop trial documents, schematic diagrams and survey certificates of the related engine are given with the first supply of the documentation.

2. Manual Structure

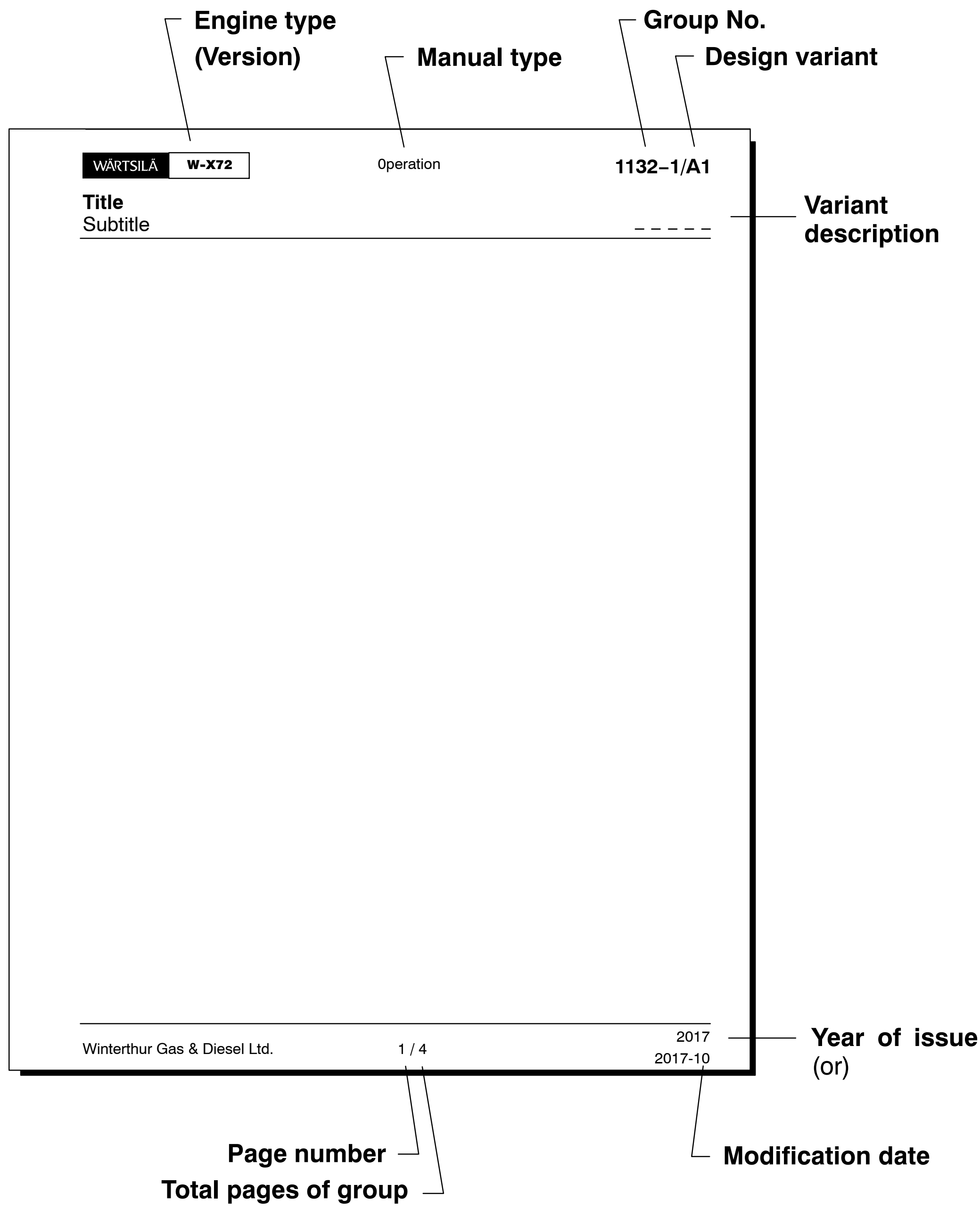
The manual is divided into different groups. Each group contains data about components or systems referred to in the design groups.

The manuals give data about the standard engine with all cylinder numbers, alternative designs and special equipment.

The documentation for alternative engine designs are separated into different chapters with the related design name.

2.1 Structure of the Manual

The groups with their illustrations are divided into the design groups.



2.2 Symbols

WARNING
This symbol shows that the text is safety related. The signal word WARNING is used to show a hazardous condition. If ignored, these conditions could cause serious injury or death to personnel.

CAUTION
This symbol shows that the text is safety related. The signal word CAUTION is used to show a potentially hazardous condition. If ignored, these conditions could cause minor injury to personnel, or damage to engine components.

Note: Notes give more data to help you do a task, or give you data about the engine. Notes come immediately before or after the related paragraph.

3. Technical Documentation

Because of the continuous development of the engine, the technical documentation also changes and is regularly updated. The modification service leaflet on the first page of the manual shows all changes.

Important data and changes are given directly to the customer in the service bulletins.

To order more technical documents, the data that follows is necessary:

- Engine type, year of manufacture and engine manufacturer
- Name of vessel or site of installation
- Cylinder or engine number
- Special equipment
- Document type (printed manuals or CD).

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Operating Descriptions Group 0

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Abbreviations

See the table below for the the abbreviations used in this manual. Unit of measures are not shown in the list.

Abbreviation	Word(s) in Full
ADA	Crank Angle Determination Algorithm
AHD	Ahead
ALM	Alarm
AMS	Alarm and Monitoring System
AST	Astern
ASTM	American Society for Testing and Materials
BDC	Bottom Dead Center
BN	Base Number
BSFC	Brake Specific Fuel Consumption
CAN	Controller Area Network
CCAI	Calculated Carbon Aromaticity Index
CMCR	Contract Maximum Continuous Rating
CCM	Cylinder Control Module
COC	Cleveland Open Cup
DENIS	Diesel Engine CoNtrol and OptImizing Specification
ECA	Emission Control Area
ECR	Engine Control Room
ECS	Engine Control System
ELBA	Electrically-driven second-order balancer
FQS	Fuel Quality Setting
FZG	Gear Research Center
HFO	Heavy Fuel Oil
HFR	High Feed Rate
ICC	Intelligent Combustion Control
IOM	Input Output Module
IMO	International Maritime Organisation
ISO	International Standard Organisation
LDU	Local Display Unit
LED	Light Emitting Diode
LFR	Low Feed Rate
LLT	Low-load Tuning
MARPOL	International Convention for the Prevention of Pollution from Ships
MCM	Main Control Module
Modbus	Gould-Modicon Fieldbus
MCR	Maximum Continuous Rating
MDO	Marine Diesel Oil
mep	Mean effective pressure
MGO	Marine Gas Oil
OPI	Operator Interface (user interface in the control room)

Abbreviation	Word(s) in Full
PMCC	Pensky Martens Closed Cup method
RCS	Remote Control System
SAE	Society of Automotive Engineers
SCS	Speed Control System
SHD	Shut Down
SLD	Slow Down
SOI	Start of Injection
TDC	Top Dead Center
UNIC	Unified Controls
VEC	Variable Exhaust valve Closing
VEO	Variable Exhaust valve Opening
VIT	Variable Injection Timing

How to Use the Operation Manual

1. Contents

The Operation Manual, contains data and indications about:

- The servicing of the engine during operation
- The necessary media (oil, water, air, fuel)
- The functions of components and systems.

Note: The maintenance and overhaul instructions are found in the Maintenance Manual.

2. Abbreviations

Some of the abbreviations used in the Operation Manual are given in 0035−1. Other abbreviations are shown in the related text and the keys to related illustrations.

3. Where to find Data

You can find the group titles in the Table of Contents 0020−1. You can also look in The Subject Index 0030−1.

In the cross section and longitudinal section illustrations (Fig. 1 and Fig. 2), important components are shown with their group numbers. These group numbers have hyperlinks to the different groups in the manual, which give more data about the engine.

For the cross section and longitudinal section illustrations, see pages 2 and 3.

The cross section and longitudinal section illustrations shown can have small differences because of different engine revisions.

If you have a PDF version of this manual, you can use the Previous View and Next View buttons on the taskbar to navigate.

4. Cross section

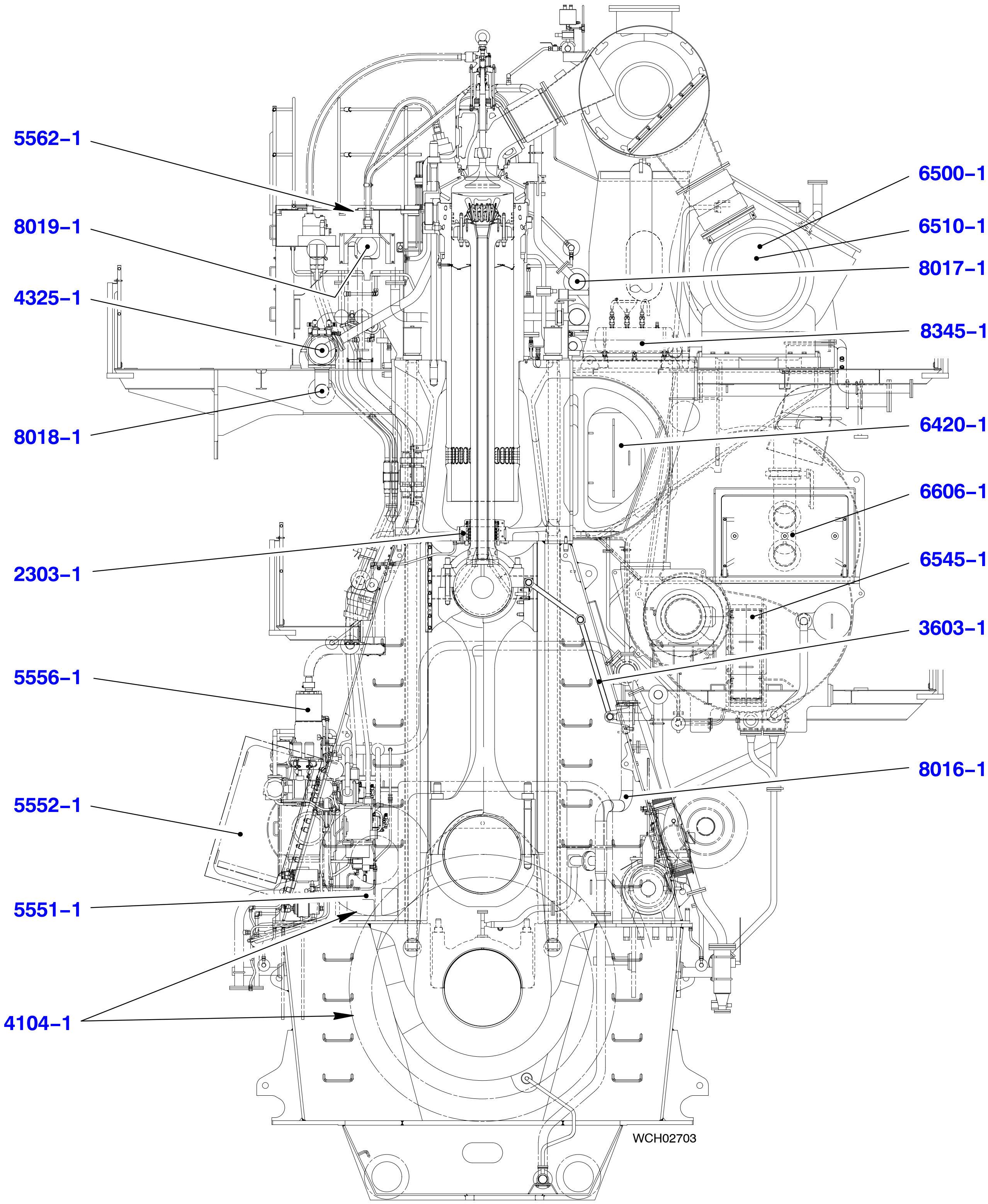

Fig. 1: Cross Section

5. Longitudinal section

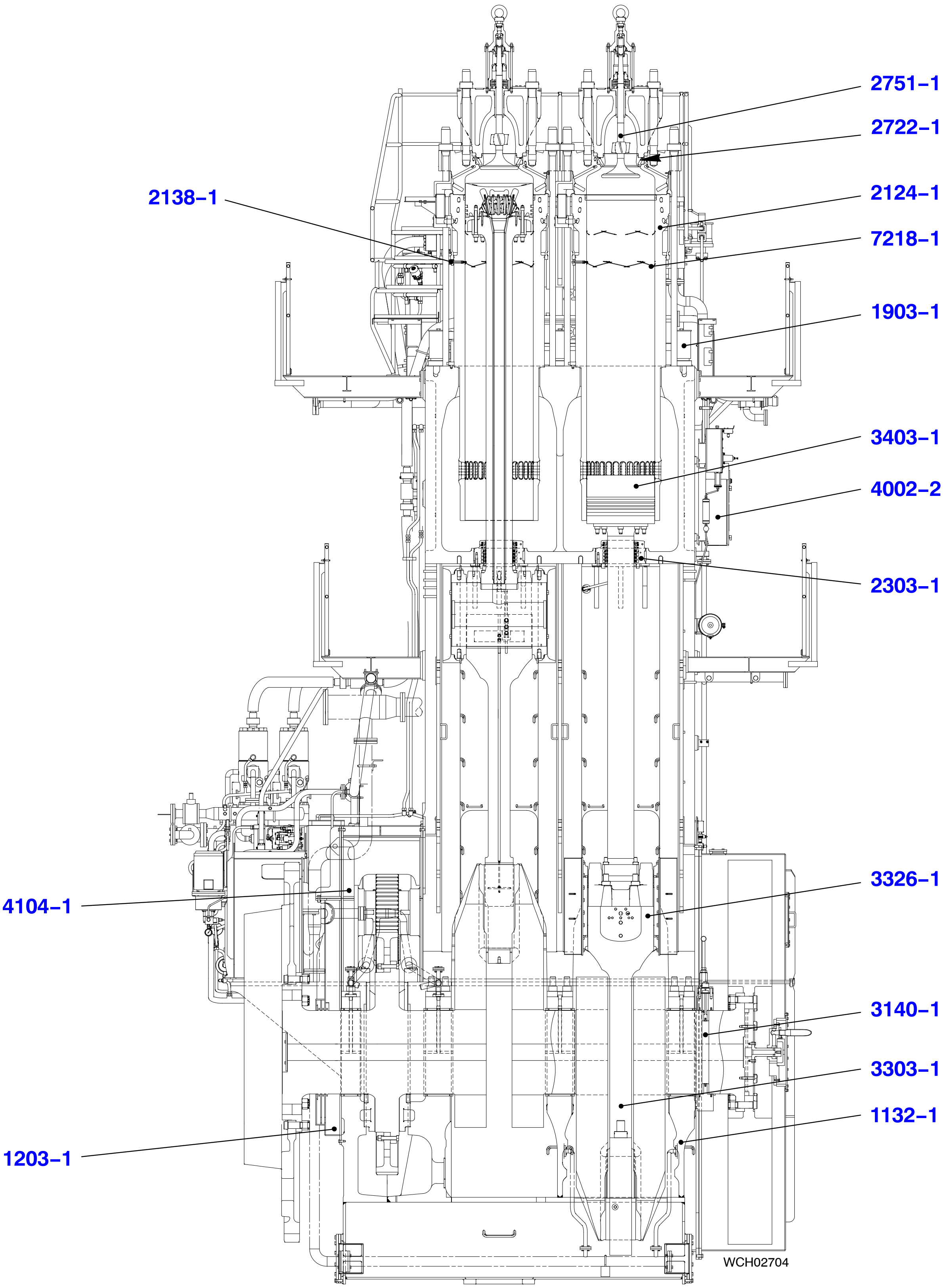

Fig. 2: Longitudinal Section

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Short Description of the Engine

1. General

General data about the engine are given as follows:

- The W−X engine is a single acting, two-stroke diesel engine of crosshead design with exhaust gas turbocharging and uniflow scavenging.
- The engine is reversible and is directly connected to the propeller.
- The W−X concept is based on the Wärtsilä Common Rail, with full electronic control of the fuel injection system and the exhaust valve operation.
- The engine control can have different remote controls, which are related to our specifications, from recommended manufacturers.
- If the remote control has a failure, the engine can be controlled with the emergency control from the local control panel.
- Tie rods hold the bedplate, columns and cylinder block together.
- A partition isolates the crankcase from the cylinder block. This partition includes the piston rod glands for the piston rods.
- The thrust bearing and turning gear are installed on the driving end of the engine.
- The engine control system (ECS) controls the exhaust valve operation, electronic fuel injection and cylinder lubricating system.
- The lubrication oil, coolant water, fuel supply, booster pumps and air compressors are parts of the engine room installation (ancillary systems).

2. Systems

General data about the systems are given as follows:

- The servo oil system opens the exhaust valves hydraulically. The exhaust valves are closed pneumatically.
- Servo oil pumps in the supply unit, supply bearing oil at the necessary pressure through two high pressure (HP) oil pipes to the servo oil rail.
- Bearing oil cools the pistons.
- The fuel pumps in the supply unit, supply high pressure fuel through the HP fuel pipes to the fuel rail. The fuel rail supplies high pressure fuel to all the injection valves.
- Fresh water cools the cylinder liners and cylinder covers.
- A single-stage fresh water (closed−circuit) cooler keeps the scavenge air cool.
- The ECS controls the engine start sequence. Compressed air flows through the starting valve into the cylinders to start the engine.

- The exhaust gases flow from the cylinders through the exhaust valves into the exhaust gas manifold.
- The turbocharger constantly charges the gas pressure from the manifold.
- The scavenge air from the turbocharger flows through the air cooler and water separator into the air receiver. This air then flows through air flaps and scavenge ports when the pistons are almost at BDC.
- At low loads, independently operated auxiliary blowers supply air to the scavenge air space.

Two-stroke Diesel Engine – Operation

1. Piston Movement

1.1 First Stroke (Compression)

The sequence of piston movements during the compression stroke is as follows:

- The piston is at BDC (see Fig. 1).
- The scavenge ports and exhaust valve are open.
- Scavenge air flows into the cylinder and pushes the exhaust gas through the exhaust valve into the exhaust gas manifold and then to the turbocharger.
- The piston moves up.
- At ES, the piston covers the scavenge ports.
- At AS, The exhaust valve closes and compression starts, which heats the air.

1.2 Second Stroke (Ignition – Combustion – Expansion – Exhaust – Scavenging)

The sequence of piston movements during the second stroke is as follows:

- When the piston is almost at TDC, fuel is injected into the cylinder.
- The fuel ignites in the compressed, heated air and combustion starts.
- The gases expand and push the piston down.
- At AO, the exhaust valve opens. Exhaust gas flows out of the cylinder into the exhaust gas manifold.
- At EO, the piston continues to move down to let air in through the scavenge ports.
- Scavenge air flows into the cylinder and pushes the exhaust gas through the exhaust valve into the exhaust gas manifold and then to the turbocharger.

See also the schematic diagram in 6500–1 Turbocharging.

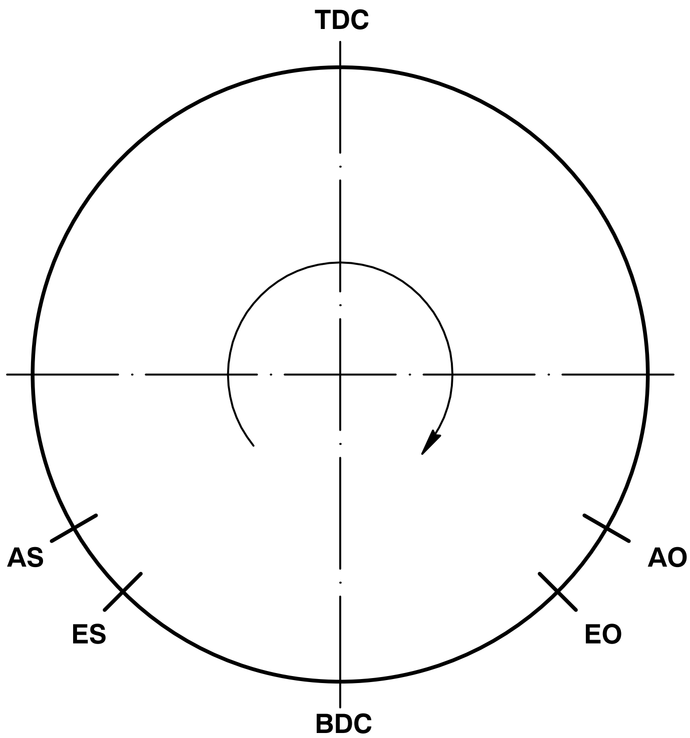

Fig. 1: Schematic of Engine Operation

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The Relation between Engine and Propeller

1. General

There is a specified relation between the propeller speed and the absorbed power in ships that have fixed pitch propellers. The relation is between the propeller and the speed at which it turns.

The formula that follows (where P = power and n = speed) gives an approximate result, which is sufficient for conventional vessels:

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

The graph from this formula is known as the propeller characteristic.

If the engine is in good condition, correctly supplied with air (i.e. turbocharger(s) are in good condition and the resistance of the air and exhaust lines is in the specifications) and the fuel injection quantity is correctly adjusted (see the shop test protocol), then the mean effective pressure (mep) developed during service conditions (in accordance with the specified load indication), is related to the approximate mep for this position on the test bed.

In the diagram (see paragraph 2), the propeller property line through the CMCR point (100% power at 100% engine speed) is known as the nominal propeller characteristic. Engines which are to be used for the propulsion of vessels with fixed propellers have a load applied on the test bed in accordance with this propeller characteristic. However, during sea trial of a new ship with a smooth and clean hull, the power requirement is lower and the operation point is below the nominal propeller characteristic.

During service, a higher torque will be necessary for the propeller to keep its speed than at the time of the sea trial (sea margin) because:

- There are changes in wake flow conditions because of marine growth on the hull.
- The cargo load has an effect on the depth of the vessel in the water.
- The propeller has a rough surface or has mechanical damage.
- The vessel operates in bad sea and weather conditions.
- The vessel operates in shallow water. The mep of the engine (and thus the fuel injection quantity) will increase. In such a condition, the operating point will then be at the left of the initial propeller curve which was calculated during sea trials.

A hull that was cleaned and painted will help to decrease the resistance as the vessel moves through the water. It is not possible, to get the hull back to its initial condition.

Because the thermal load of the engine is related to the mep, the position of the operating point is also important. The air supply to the engine and the operating conditions will become unsatisfactory if the operation point is far above the propeller curve.

To get the best conditions, the operation point of the engine for service range must be on or below the nominal propeller characteristic.

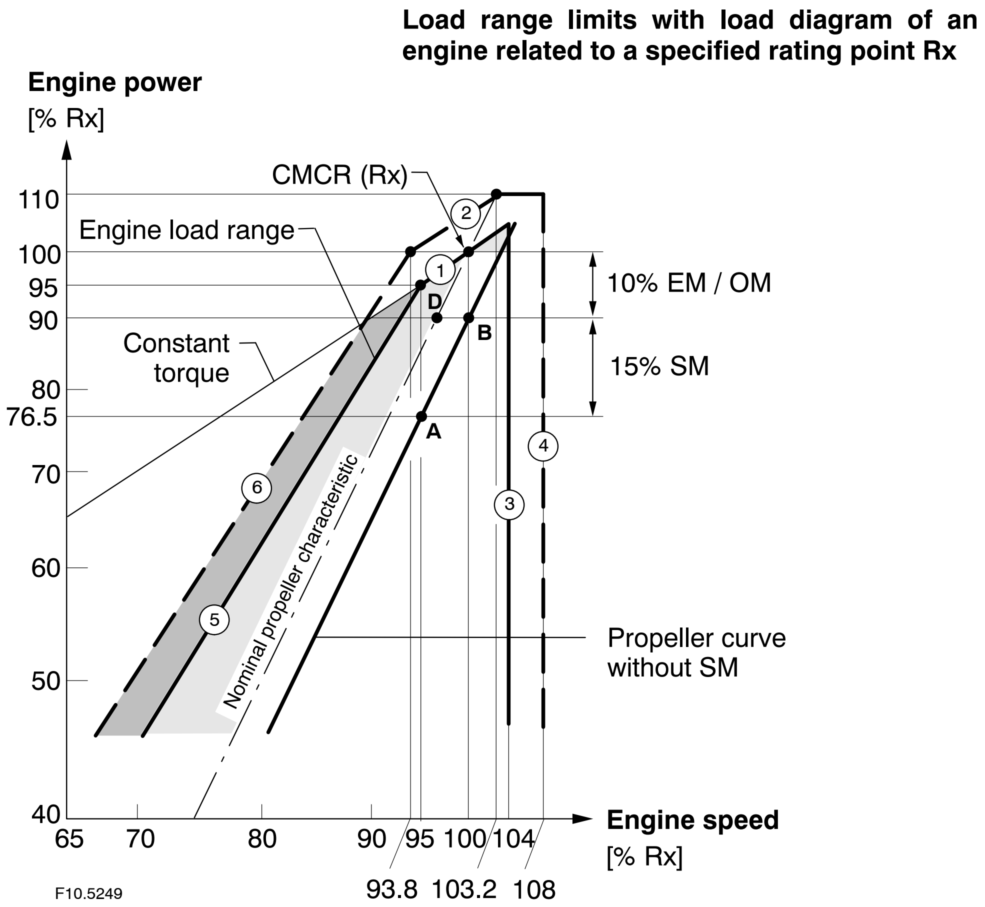
2. Fixed Pitch Propeller (FPP)

2.1 Continuous Service Rating (CSR)

Point A (see Fig. 1) shows the power and speed of a ship that operates at contractual speed in calm seas with a new clean hull and propeller. A power / speed combination at point D is necessary for the same ship at the same speed during service conditions with aged hull and average weather. Point D is then the CSR point.

2.2 Engine Margin (EM) / Operational Margin (OM)

Most owners specify the contractual loaded service speed of the ship at 85% to 90% of the contract maximum continuous rating (CMCR). The remaining 10% to 15% of power can be used to catch up with changes in schedules or for the timing of dry-dock intervals. This margin is usually subtracted from the CMCR. Thus, to get the 100% power line, you divide the power at point D by between 0.85 to 0.90.



EM Engine Margin
OM Operational Margin
SM Sea Margin

Fig. 1: Schematic Diagram of Speed / Power Relation (FPP)

2.3 Load Range Limits

When the engine has the best values at CMCR (Rx), the limits that follow give the load range of the engine:

- Line 1 is a constant mep or torque line through CMCR from 100% speed and power down to 95% speed and power.
- Line 2 is the overload limit. This is a constant mep line from 100% power and 93.8% speed to 110% power and 103.2% speed. 103.2% speed is the intersection point between the nominal propeller property and 110% power.
- Line 3 is the 104% speed limit where an engine can operate continuously. For Rx with decreased speed ($N_{CMCR} \leq 0.98\ N_{MCR}$) this limit can be extended to 106%, but, the torsional vibration must not be more than the specified limits.
- Line 4 is the overspeed limit. The overspeed range between 104 (106) and 108% speed is only permitted during sea trials if necessary. This is to demonstrate the speed of the ship at CMCR power with a light running propeller in the presence of authorized representatives of the engine builder. The torsional vibration must not be more than the specified limits.
- Line 5 is the permitted torque limit from 95% power and speed to 45% power and 70% speed. This shows a curve defined by the equation: $P_2/P_1 = (N_2/N_1)^{2.45}$. When the engine speed and power is near the data in Line 5 there will be a decrease in scavenge air, which has an effect on the engine. The area between Lines 1, 3 and 5 show the range in which the engine must be operated. The area in the nominal propeller characteristic, 100% power and Line 3 is recommended for continuous operation. The area between the nominal propeller property and Line 5 must be reserved for acceleration, shallow water and usual flexibility of operation.
- Line 6 gives the equation: $P_2/P_1 = (N_2/N_1)^{2.45}$ through 100% power and 93.8% speed and the maximum torque limit in transient conditions. The area above Line 1 is the overload range. You must only operate the engine in this range for a maximum of one hour during sea trails in the presence of authorized representatives of the engine builder. The area between Lines 5 and 6 and the constant torque line (shown as a dark area) must only be used for transient conditions, i.e. during fast acceleration. This range is known as the service range with operational time limit.

3. Controllable Pitch Propeller (CPP)

3.1 Load Ranges

After engine start, the engine is operated at an idle speed of up to 70% of the rated engine speed with zero pitch. From idle speed, the propeller pitch must be increased with constant engine speed to the minimum at point E, the intersection with Line 9.

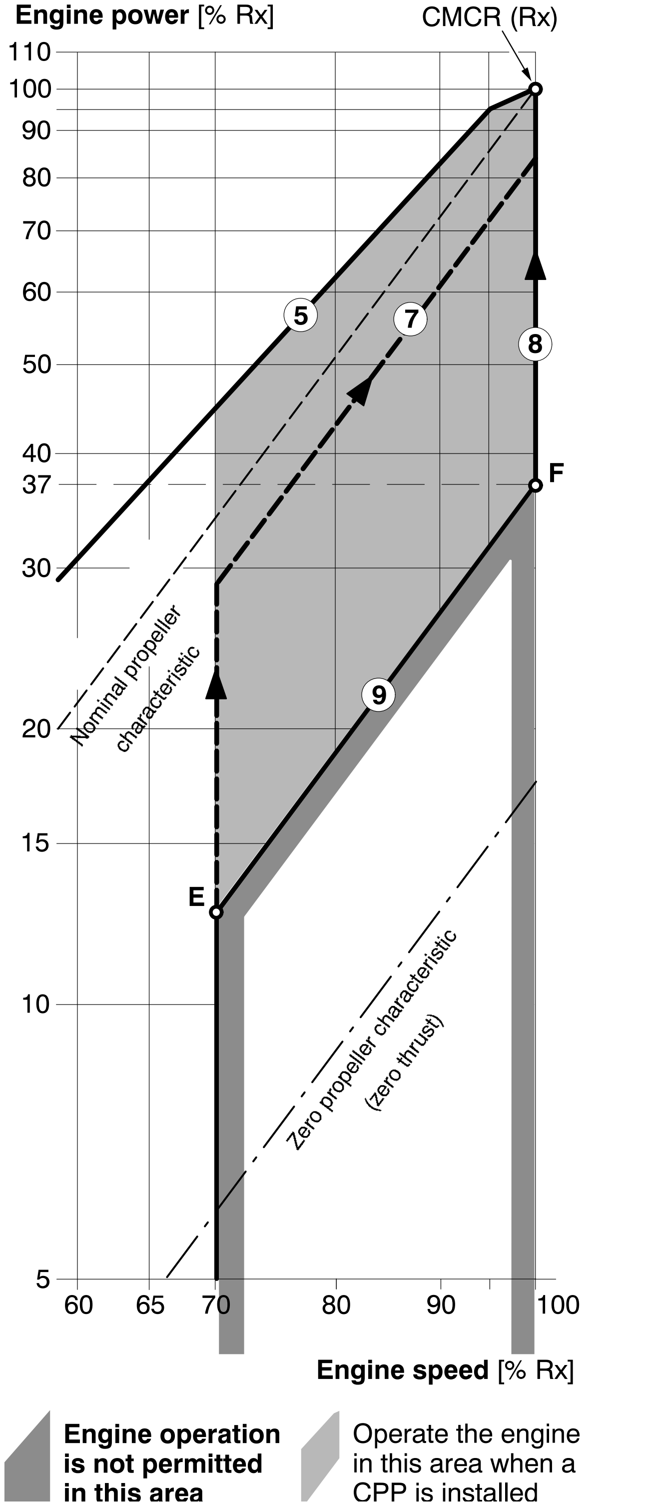


Fig. 2: Schematic Diagram of Speed / Power Relation (CPP)

- Line 9 is the bottom load limit between 70% and 100% speed, with a pitch position that at 100% speed, the minimum power at point F is 37%. The formula shown in paragraph 1 is used for this calculation.
- Along Line 8 the power increase from 37% (point F) to 100% power (CMCR) at 100 % speed is the constant speed mode for shaft generator operation
- Line 5 is the top load limit and relates to the permitted torque limit.
- The area between 70% and 100% speed and between Line 5 and Line 9 shows the area that an engine with a CPP must be operated.

Line 7 shows a typical combinator curve for variable speed mode.

Maneuvering at maximum speed with low or zero pitch is not permitted. Thus, installations with main engine-driven generators must have a frequency converter when electrical power is to be supplied (e.g. to thrusters) at constant frequency during manoeuvring. As an alternative, power from auxiliary engines can be used for this purpose.

For test purposes, the engine can be operated at rated speed and low load during a one-time period of 15 minutes on the testbed (e.g. NO_x measurements) and 30 minutes during dock trials (e.g. shaft generator adjustment) when there are an authorized representatives of the engine builder on board. More requests must be agreed from Winterthur Gas & Diesel Ltd.

3.2 Control System

The CPP control functions are usually part of the engine control system and include the functions in the paragraphs that follow.

3.2.1 Combinator Mode 1

Combinator mode for operation without a shaft generator. A combinator curve that includes an applicable light running margin can be set in the permitted operation area, Line 7 (see Fig. 2).

3.2.2 Combinator Mode 2

An optional mode used in connection with shaft generators. During maneuvering, the combinator curve follows the Line 9. At sea the engine is operated between point F and 100% power (Line 8) at constant speed .

For manual and/or emergency operation, different setpoints for speed and pitch are usually supplied.

An alarm is also usually given in the main engine safety system, or the alarm and monitoring system when the engine operates for more than three minutes in the operation area that is not permitted. If the engine operates for more than five minutes in the operation area that is not permitted, the engine speed must be decreased to idle speed (less than 70%).

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Basic Engine Data

1. General

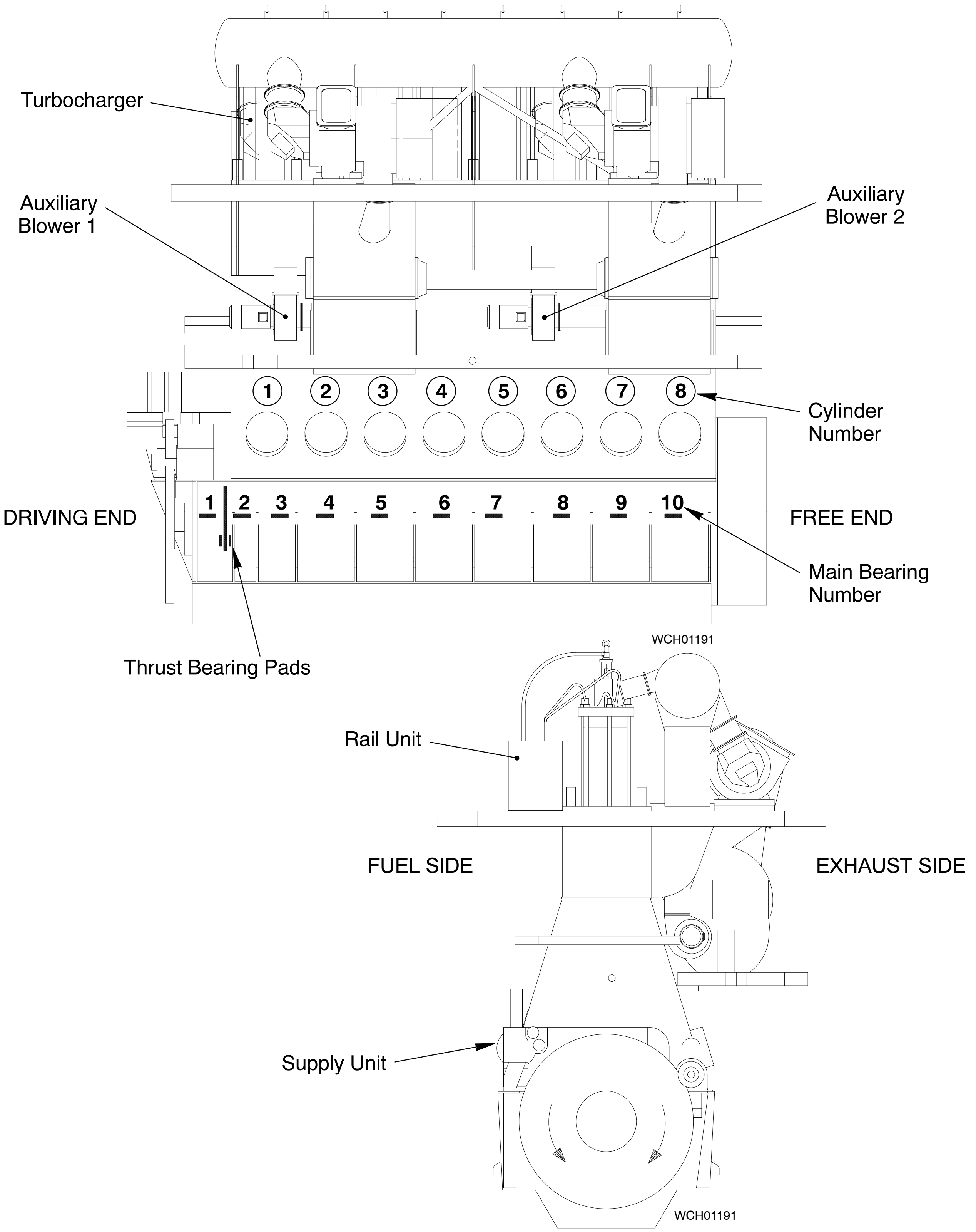
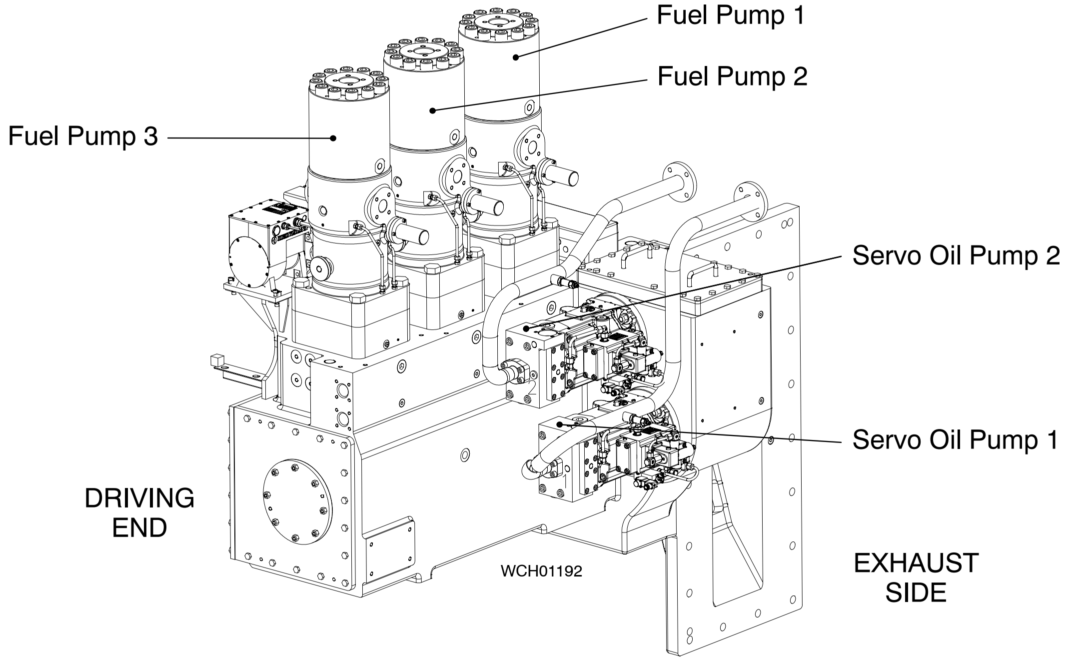


Fig. 1: Outline View

2. Flex Parts



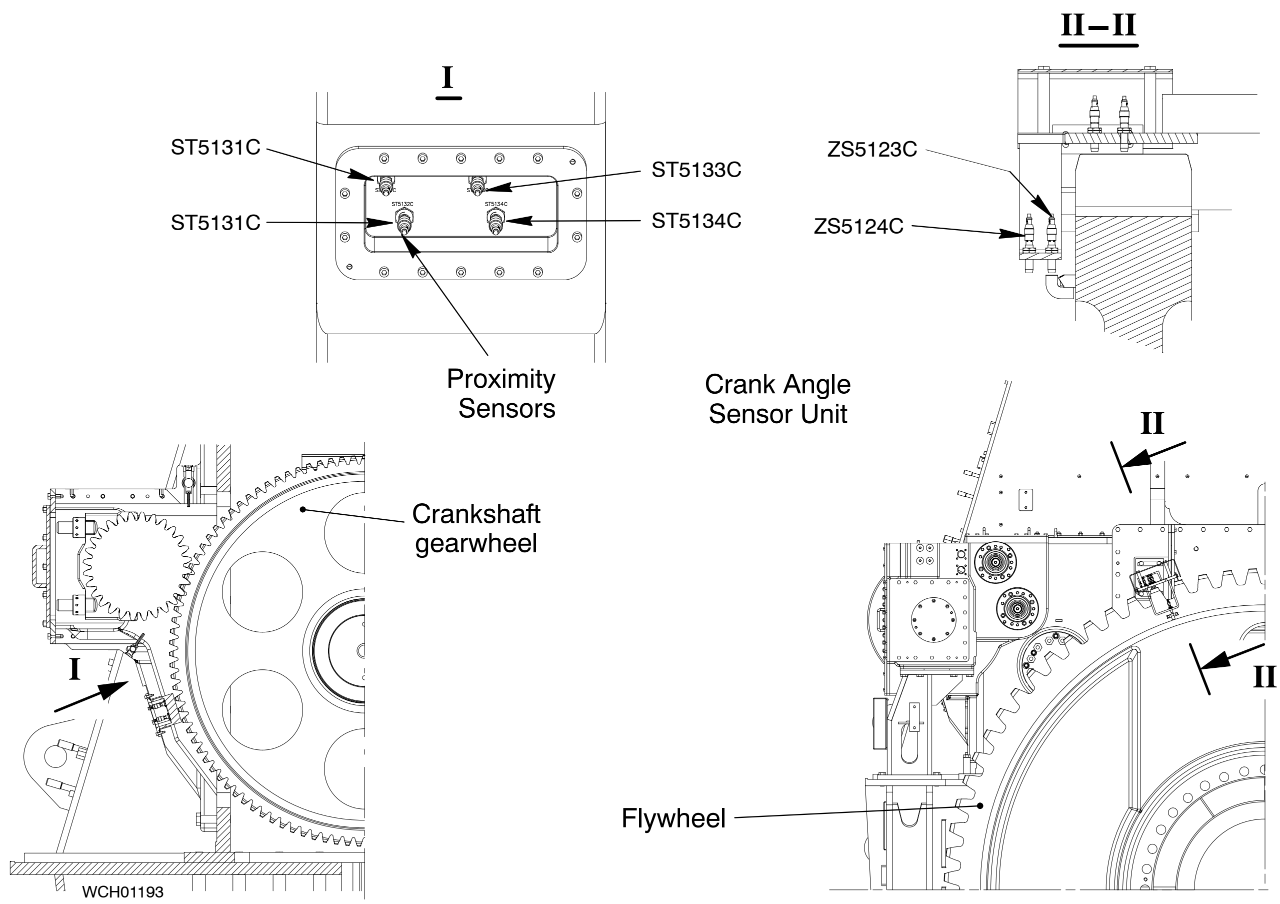


Fig. 2: Flex Parts

Prepare for Engine Start after a Short Shut-down Period (One or More Days)

1. Start Position

For the start position, the engine must be in the condition that follows:

- All components that had an overhaul are correctly assembled and installed. All components that had an overhaul have had tests or checks to make sure that they operate correctly.
- All devices, tools and materials are removed from the engine.

CAUTION

Damage Hazard: The ball valves 30-8605_E0_6 and 30-8605_E0_7 in the start air line must be open when the starting air shut-off valve 30-4325_E0_1 is in the position CLOSED (see the Control Diagram 4003–2).

2. Prepare for Operation

1) Do a check of the fluid levels of all the tanks in the engine systems (and the leakage drain tanks).
2) Make sure that all the shut-off valves for the coolant water system and lubrication oil system are in the correct position.
3) Open the air supply from the shipboard system to the control air supply **A**.
4) Open the 3/2-way valve 35-36HB at connection A1 and put the 3/2-way valve 35-36HA to the operation position (see Control Air Supply 4605–1).
5) Heat the lubrication oil to approximately 35°C (through the lube oil separator or heaters in oil drain tank if installed).
6) Heat the cylinder coolant water to a minimum of 65°C.
7) Set to on the ECS.
8) In the power supply box E85, set all circuit breakers to on.
9) Prepare the servo oil system (see 0130–1).
10) Start the pumps for the cylinder coolant water and bearing oil. Set the pressures to their usual values (see the Operating Data Sheet 0250–1).
11) Prepare the cylinder lubrication system (see 0140–1).
12) Prepare the fuel system (see 0120–1).
13) Make sure that you correctly release all air from all systems.
14) In the LDU–20 (on the local control panel), get the MAIN page.
15) Get the EXHAUST VALVES page (see 4002–2, paragraph 3.1 and paragraph 3.8).
16) Make sure that there is an air spring supply and make sure that all exhaust valves are closed.
17) Manually open and close all exhaust valves until all air is released in the hydraulic actuators as follows:
    - In the column Exh. Valve pos., enter 1 in all the fields to manually open all the exhaust valves.
    - In the column Exh. Valve pos., enter 2 in all the fields to manually close all the exhaust valves.

Note: You cannot start the engine if the exhaust valves are not fully closed.

18) Open the indicator valve on all cylinder covers.

WARNING
Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel. Obey the data given in 0210–1 Safety Precautions and Warnings.

19) Use the turning gear to turn the engine a minimum of one full turn to make sure that all the running gears will operate correctly.

Note: Oil, water or fuel must not come out of the indicator valves.

20) If water oil or fuel comes out of the indicator valves, do a check of the related cylinder liner, cylinder cover, piston or injection valves.

21) Set the cylinder lubrication to on.

22) Close the indicator valves on all cylinders.

23) Make sure that all the clamps lock the crankcase doors.

24) Make sure that the starting air bottles have the correct pressure.

25) Open the drains of the starting air bottles 930_B001 and 930_B002 to drain possible condensate water.

26) Open the ball valve 35_8353_E0_2 until no more water comes out.

27) Close the ball valve 35_8353_E0_2.

28) Close the ball valves 30_8605_E0_6 and 30_8605_E0_7.

29) Open the primary shut-off valves on the starting air bottles.

30) Turn the handwheel of the starting air shut-off valve 30_4325_E0_1 to the position AUTOMAT.

31) Open the 3/2-way valve 34-36HC at connection A2 (see 4605–1 Control Air Supply).

32) In the LDU–20, MAIN page (on the local control panel), (see 4002–2, paragraph 3.3) make sure that the Control Air field and the Start Air field show a pressure indication.

33) Make sure that a pressure indication shows on the pressure gages for the control air supply.

The different circuits are:

- Air spring air
- Control air.

Note: The air supply from the control air board supply and the back-up supply from the starting air system flow through the pressure reducing valve 35–19HA.

For the necessary pressures, see the Operating Data Sheet 0250–1.

34) In the LDU–20 MAIN page (on the local control panel), select the tab AUX. to operate the the auxiliary blowers.

35) Disengage the turning gear and lock the lever.

36) Open the ball valve 35_8353_E0_2 momentarily. Make sure that you can hear the valve open.

37) Close the ball valve.
38) In the LDU−20 MAIN page (on the local control panel), get the USER PARAMETERS page.
39) Select the tab SLOW TURN. The engine will slowly turn one time (see Slow Turning 0220−1, paragraph 3).
40) Make sure that at the location where you want to start the engine, the related LDU−20 has control (e.g. the control room or the local control panel.
41) Tell personnel on the bridge that the engine is prepared for operation.

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Prepare the Fuel System for Operation

1. Prepare the Fuel System

1.1 Diesel Operation

1) See 0720−1, Fig. 1.
2) Set the three-way valve 4 in the suction line of the low pressure pump 7. This lets diesel oil flow from the daily tank 3 to the pump and to the mixing unit 8.
3) Make sure that the shut-off valves upstream and downstream of the engine are open.
4) Set the low pressure pumps 7 and the booster 10 to on.
5) Drain the daily tanks 2, 3 and the mixing unit 8.
6) Use the pressure regulating valve 5 to set the pressure in the fuel oil system.

Note: When the engine operates with diesel oil (and low fuel temperature) a small over-pressure is sufficient. If a change-over to heavy fuel oil is necessary, the setting of the usual pressure is recommended from the start.

7) Use the pressure retaining valve 17 to set the fuel oil pressure at the fuel pump return (see 0250−1 Operating Data Sheet, column Medium, row Fuel, downstream of pressure retaining valve).

1.2 Heavy Fuel Operation

1) See 0720−1, Fig. 1.

Note: The fuel system is not ready for operation until the heavy fuel upstream of the fuel pumps is at the necessary temperature (see 0710−1 Viscosity-Temperature Diagram).

After a shut-down period of more than 24 hours heat the high pressure circuit on the engine for a minimum of four to six hours. Do not try to start the engine on heavy fuel before you heat the fuel.

2) Set to on the heating for the daily tank 2, mixing unit 8, end-heater 11 and fuel filter 12.
3) Set to on the heating for the fuel system on the engine (fuel rail 10, HP fuel pipes 8 and the fuel leakage system (see 8019−1, Fig. 1).
4) Make sure that the steam pipes are tight. If leakages are found, repair them before the first commissioning or after maintenance on the fuel system.
5) Set the three-way valve 4 in the suction line of low pressure feed pump 7 to let heavy fuel flow from the daily tank 2 to the pump and to the mixing unit 8 (See 0720−1, Fig. 1.
6) Drain the settling tank 1, daily tank 2 and mixing unit 8.
7) Make sure that the shut-off valves upstream and downstream of the engine are open.
8) Start the pumps 7 and 10.
9) Heat the heavy fuel. This is necessary to bring the heavy fuel to the necessary viscosity (see 0270−1 Change-over from Diesel Oil to Heavy Fuel Oil).
10) Use the pressure regulating valve 5 to set the pressure in the fuel oil system.
11) Use the pressure retaining valve 17 to set the fuel pressure at the fuel pump return (see 0250−1 Operating Data Sheet, column Medium, row Fuel downstream of pressure retaining valve).

2. High pressure circuit

1) See 8019–1 Fuel System Fig. 1).
2) Make sure that the ball valve 43 is open.

Prepare the Servo Oil System

1. Servo Oil System – Checks

See 8016–1 Lubricating oil system, Fig. 2 and Fig. 5.

1) Do the checks that follow:
   a) Make sure that the ball valve 20-8423_E0_2 (26, Fig. 2) upstream of the injector valve is closed (see 4003-2).
   b) Make sure that the screw plug (1) on servo oil rail (2) is tight (see Fig. 5).
2) Make sure that the service pump (Tool 94845) is disconnected.

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Prepare the Cylinder Lubricating System

See 7218–1 Cylinder Lubrication Fig. 1).

1) Make sure that the engine is in the condition that follows:
   - The engine control system (ECS) and remote control systems are set to on.
   - The primary switches in the control box E44 (engine room) are set to on and the ECS has selected cylinder lubrication.
2) Do the checks that follow:
   a) Make sure that the ball valves are open.
   b) Make sure that there is no air in the cylinder lubrication pumps (25_7230_C1_1 to 25_7230_C#_1).
   c) Make sure that there is no air in the lubricating pipes to the lubricating quills.

You must only do the air removal procedure:

- Before the first commissioning
- After maintenance
- After a long shut-down period
- When there are operation problems (operation pressure, supply rate).

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General

The data that follow are about engine operation during usual conditions e.g. all cylinders operate correctly:

- 0210−1 Safety Precautions and Warnings
- 0220−1 Slow Turning
- 0230−1 Starting
- 0240−1 Usual Operation.

During maneuvering, it is possible to operate the engine from the control room, the bridge or the local maneuvering stand.

Operation includes all maneouvers from the first start at cast off until the last maneuver when the vessel is moored.

The engine is designed to operate with heavy fuel oil (HFO) from pier to pier, i.e. without a change-over to diesel oil.

When the engine is stopped, the fuel flows through the fuel pumps if the booster pump operates.

The necessary conditions of HFO before operation are as follows:

- The HFO is correctly treated.
- The HFO is kept at the correct temperature during the full in-service period, which includes manoeuvring and stand-by.

For more data, see 0710−1 Diesel Engine Fuels and 0720−1 Fuel Treatment and Fuel System.

For operation during unusual conditions, see 0500−1.

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Safety Precautions and Warnings (General Data)

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

WARNING

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.

WARNING

Injury Hazard: If an oil mist detector activates an alarm, keep away from engine. There is a risk of explosion. Do not go into the areas adjacent to the explosion relief valves (see 0460–1 Instructions about the Prevention of Crankcase Explosions).

WARNING

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.

WARNING

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.

Make sure that you read the maintenance instructions for the related parts.

3. Lighting

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

4. Clean Areas

CAUTION

Damage Hazard. Do not use water or cleaning fluids to clean the ECS 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 ECS 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

CAUTION

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

CAUTION

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 ECS 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 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

WARNING

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.

WARNING

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

9. Temperature

WARNING	
⚠	**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.**

WARNING	
⚠	**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:

- The starting air to the engine is blocked and the ball valves 30-8605_E0_6 and 30-8605_E0_7 are open (see Control Diagram 4003–2).
- The turning gear is engaged (see the Maintenance Manual 0011–1 Precautionary measures before you start maintenance tasks).

Note: 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

WARNING	
⚠	**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 CO_2 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

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

WARNING
Injury Hazard: After an air run the crankshaft can turn suddenly when the pressurized air in the cylinder releases. There is a risk of death, serious injury or damage to components.

Note: Before you do maintenance on the engine, engage the turning gear, or start the Crank Angle Determination Algorithm (ADA) a second time:

1) **Make sure that there is no pressurized air in the cylinder and the starting air pipes.**

2) **Make sure that you open the relief valves on all cylinder covers to release the pressure.**

WARNING
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.

Note: 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 3/2-way valve (35-31HA) can prevent engine start (see 4003–2 Control Diagram).

14. Instruments

Calibrate 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 operation, it is possible that water in the engine, pumps, coolers and piping system will freeze. To prevent this, drain the systems or increase the temperature in the engine room.

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Slow Turning

1. General

To make sure that the running gear turns freely, it is recommended (as long as the classification society did not make more primary specifications) to turn the crankshaft a minimum of one full turn before start-up.

Note: This does not apply if the engine was stopped during a maneuvering period.

2. Turning Gear

WARNING

Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel. Obey the data given in 0210−1 Safety Precautions and Warnings.

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

A controlled quantity of starting air is released to turn the running gear at approximately 5 rpm to 10 rpm.

The engine control system (ECS) has the command SLOW TURNING for this operation (see 4002−2, paragraph 3.10, User parameters).

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.

3.1 Conditions

Note: The numbers e.g. 30-4325_E_01 refer to items in 4003–2 Control Diagram.

1) Before you start the SLOW TURNING operation, do the steps that follow:
   a) Make sure that the turning gear is disengaged.
   b) Make sure that the ECS is set on.
   c) Make sure that the oil pumps operate (bearing oil and crosshead oil).
   d) Make sure that the related control stand has control.
   e) Make sure that the indicator valves are closed.
   f) Make sure that the handwheel on the starting air shut-off valve 30-4325_E_01 is in the position AUTOMAT..
   g) Make sure that the shut-off valves on the starting air bottles are open.
   h) Make sure that the air pressure for the air spring is correctly set (see 0250–1 Operating Data Sheet)
   i) Make sure that the cylinder lubrication is set to on.

Note: If there is a pressure decrease during this procedure, see 8019–1 paragraph 4.4.

3.2 Function

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

- The 2/2-way valve 35-4325_E0_5 opens the starting air shut-off valve 30-4325_E_01 and starting air flows to the starting air valves 30-2728_CX_1 in the cylinder covers.
- The CCM–20 control the 3/2-way solenoid valves upstream of the starting valves. The starting valves open and close for short intervals only.
- You can use the remote control to change the timing of the starting valves (open / close) to get the best slow turning speed.

Engine Start

1. General

Before you start the engine (also, before trials and using starting air to turn the engine) see:

- 0110–1 Prepare the Engine for Engine Start
- 0120–1 Prepare the Fuel Oil System for Operation
- 0130–1 Prepare the Servo Oil System
- 0140–1 Prepare the Cylinder Lubricating System.

You can start the engine from the locations that follow:

- The bridge or control room with remote control.
- At the LDU–20 in the control room.
- At local control panel on the engine.

2. Engine Start – Control Stand in Control Room

Prepare the engine as follows:

1) At the local control panel, push the button CTRL. TR on the LDU–20 for transfer to ECR remote (see 4002–2, paragraph 3.4 Control Locations).
2) At the control room console, make sure that the remote control has control.

For more procedures to start using the remote control, see the documentation of the remote control manufacturer.

If you move the telegraph from STOP to a different position, a start signal is released automatically.

3. Engine Start – at the Local Control Panel

You use this mode if e.g. the electronic speed control system or the remote control becomes defective.

CAUTION
Damage Hazard. The operator must not leave the local maneuvering stand. The operator must regularly monitor the speed indication to immediately adjust the fuel supply if the speed changes.

3.1 Preparation

1) At the local control panel, push the button CTRL. TR. on the LDU–20 for transfer to Local.

3.2 Engine Start Procedure

1) In the LDU, MAIN page push the button ON/OFF to start the auxiliary blowers. Make sure that Running shows in the Auxiliary Blowers field (see 4002–2, paragraph 3.3 MAIN page).
2) Use the rotary button to select the Fuel command button.
3) Turn the rotary button to set the fuel injection quantity to approximately 30%.
4) Push the button START AHD or START AST until the engine operates.
5) Slowly turn the rotary button to adjust the fuel injection quantity until the engine operates at the applicable speed. You can see the related value on the display and speed indicator.
6) Read the instructions to increase the speed/power (see 0260–1 Maneuvering) and monitor the data (see 0250–1 Operating Data Sheet).

You can also do the engine start procedure above from the ECR manual control panel.

Note: You can use the buttons and rotary button only at the related active control stand (see 4002–2, paragraph 3.4 Control locations).

Usual Operation

1. General

To get the best performance, operate the engine at constant power. You must only change the engine load and / or speed slowly, unless there are unusual conditions.

2. Checks and Precautions

During usual operation, you must do regular checks and use precautions. This lets you operate the engine without problems. The most important of these regular checks and precautions are given below:

- You must do regular checks of pressures and temperatures. You must obey the limits (see 0250–1 Operating Data Sheet).
- You must compare the values of the instruments with those given in the acceptance records and include the engine speed and power values. This gives a good indication of engine performance. If there are differences in the values, these must be identified.
- If there is no risk to the engine, replace instruments that are possibly defective. Feel the pipes to compare temperatures.

1) Do a check of the values that follow:
   - Fuel injection quantity
   - Fuel rail pressure
   - Servo oil rail pressure
   - Engine speed
   - Turbocharger speed
   - Scavenge air pressure
   - Exhaust gas temperature upstream of the turbine.

Other important data are the values of the fuel that is used each day and the lower calorific value.

2) Do a check to make sure that all shut-off valves in the cooling and lubricating system are in the correct position.

3) Make sure that the shut-off valves for the cooling inlets and outlets on the engine are always fully open during operation. These shut-off valves are used only to isolate cylinders from the cooling water system during overhauls.

If there are unusually high or low temperatures at a water outlet, the temperature must must be gradually adjusted to the usual value. Sudden temperature changes can cause damage (see also 2124–1 Cylinder Liner and 8017–1 Cooling Water System).

The maximum permitted exhaust temperature at the turbine inlet must not be more than the limit given in 0250–1 Operating Data Sheet.

4) Compare the exhaust gas temperature indications at the cylinder outlet with the related values in the acceptance records. If larger differences between the cylinders are shown, you must find the cause.

5) Look at the colors of the exhaust gases from the funnel. No dark smoke must come out.

6) Keep the correct scavenge air temperature downstream of the air cooler with the usual water flow (see 0250−1 Operating Data Sheet). A higher scavenge air temperature will give an unsatisfactory quantity of scavenge air in the cylinder. This will cause more fuel to be used and higher exhaust gas temperatures.

7) Do a check of the scavenge air pressure decrease through the air cooler. Too much resistance will cause a decrease of air to the engine.

Note: The fuel must be carefully cleaned before use. See the recommendations in 0720−1 Fuel Treatment, Fuel System and the documentation of the separator manufacturer.

8) Open the drain valves of all fuel tanks and and fuel filters regularly for short periods to drain possible sludge or water.

9) Keep the fuel pressure correct downstream of the low pressure feed pump and the inlet of the mixing unit (see the 0250−1 Operating Data Sheet and 0720−1, paragraph 4 Configuration of the Fuel System).

10) Use the pressure retaining valve in the fuel return pipe to adjust the pressure at the fuel pump inlet. The fuel will flow in the low pressure circuit of the engine at the usual supply capacity of the booster pump.

The heavy fuel oil (HFO) must be sufficiently heated to make sure that its viscosity upstream of the inlet to the fuel pumps is in the limits given in 0710−1, Viscosity paragraph 3.1).

11) Do regular checks of the cylinder lubricating oil quantity that is used. Continuous service will give the best cylinder lubricating oil quantity. Do not lubricate the cylinders too much.

The cooling water pumps must operate at their usual flow capacity i.e. the supply head is related to the given system configuration. The result of the flow rate and temperature difference between the inlet and outlet will approximately relate to the values given in 0250−1 Operating Data Sheet . If the temperature difference is too much, repair or replace the related pump as soon as possible.

To adjust the correct supply head of the cylinder cooling water pump, the supply rate must be controlled in the engine outlet manifold. There must always be positive pressure at the suction side of the pump to prevent air flow through the stuffing box.

12) Make sure that the vents at the top of the cooling water spaces are kept constantly open to release the air.

13) Do a check of the level in all water and oil tanks, and all the drainage tanks of the leakage pipes. Look for unusual changes.

14) Look at the cooling water. If there is contamination or oil in the cooling water, the cause must be found and the defect repaired.

15) Regularly examine the sight glasses of the condensate collectors to do a check of the water flow (see 8345−1 Drainage System and Wash-water Piping System Fig. 1, item 12).

16) If there is a pressure decrease, do a check of the oil filters. Clean the oil filters if necessary.

17) You must monitor for a period, bearings that are replaced or bearings that are installed after an overhaul. You must obey the precautions to prevent crankcase explosions (see 0460−1).

18) Make sure that the covers of the rail unit are kept closed when the engine operates.

When you listen to the engine, unusual noises will show that there is a possible defect.

Hand-drawn diagrams give data about the combustion process and pressures in the cylinder (see 0420−1 Indicator Diagrams).

When the quality of the fuel used changes (diesel oil, HFO from different bunkerings), the maximum pressure in the cylinder at service power must be found as soon as possible. You must compare this pressure to the pressure measured during the related shop trial (speed, power).

If there are large differences in the firing pressures (i.e. too high or too low), adjust the fuel quality setting (FQS) to change the firing pressures (see 4002−2 paragraph 3.10 User Parameters).

19) Put the lubricating oil through a centrifuge. Get samples at regular intervals and compare these samples with the values given in 0750−1 Lubricating Oils.

20) Do a check of the dirty oil drain pipes from the piston underside to make sure that there are no blockages. Use your hand to touch each drain pipe to feel for a temperature difference. A pipe is blocked when there is a temperature difference along its length. You must clear all blockages as soon as possible.

21) Examine regularly the lubricating and fuel oil systems for leaks (see 8016−1, paragraph 4 Servo Oil Leakage and 8019−1 paragraph 4 Fuel Leakage System). To find leakages in the rail unit, open the related hinged covers and casings. You must repair leaks as soon as possible.

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Pressure and Temperature Ranges at Continuous Service Power MCR

Medium	System	Location of Measurement	Gage Pressure [bar]		Temperature [°C]		
			Min.	Max.	Min.	Max.	Diff.
Fresh Water	Cylinder cooling	Inlet	4.0	5.0	65	–	max.
		Outlet each cylinder	–	–	85	95	15
	SAC, low temperature circuit LT (single-stage scavenge air cooler)	Inlet	2.0	4.0	25	36	Note (3)
		Outlet	–	–	–	80	
Crosshead lubricating oil (see Note 5)	Crosshead bearing (for engines rated in the speed range: 66.0 rpm ≤ CMCR speed ≤ 70.5 rpm	Inlet	11.0	13.0	40	50	–
		Outlet	–	–	–		–
	Crosshead bearing (for engines rated in the speed range: 70.5 rpm < CMCR speed ≤ 75.0 rpm	Inlet	7.0	9.0	40	50	–
		Outlet	–	–	–		–
Lubricating Oil	Servo oil	Pumps inlet	–	–	–	–	–
	Main bearing oil	Inlet	4.0	5.0	40	50	–
	Piston cooling oil	Inlet	4.0	5.0	40	50	max.
		Outlet	–	–	–	80	30
	Torsional vibration damper (steel spring damper)	Supply	4.0	5.0	–	–	–
		Damper inlet	2.8 Note (6)	5.0 Note (6)	–	–	–
	Axial vibration damper (chamber pressure)	Supply	4.0	5.0	–	–	–
		Monitoring	1.7	–	–	–	–
	Turbocharger bearing oil (ABB, A100L type) (with internal oil supply)	Inlet	1.0	2.5	–	–	–
		Housing outlet	–	–	–	110	–
	Turbocharger bearing oil (MHI, MET type)	Inlet	0.7	1.5	–	–	–
		Housing outlet	–	–	–	85	–
Fuel	Supply unit	Inlet (fuel pump)	7.0 Note (1)	10.0 Note (2)	–	150	–
	Downstream of pressure retaining valve	Return (fuel pump)	3.0	5.0	–	–	–
Scavenge Air	Scavenge air cooler (SAC)	Downstream of SAC			25	80	–
	Intake from engine room (pressure decrease)	Air filter / silencer	max. 10 mbar		–	–	–
	Intake from outboard (pressure decrease)	Ducting and filter	max. 20 mbar		–	–	–
	SAC (pressure decrease)	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	–	–	–
			Usual 6.5		–	–	–
	Air spring of exhaust valve	Main distributor	6.0	7.5	–	–	–
			Usual 6.5		–	–	–

Medium	System	Location of Measurement	Gage Pressure [bar]		Temperature [°C]		
			Min.	Max.	Min.	Max.	Diff.
Exhaust Gas	Receiver	Downstream of each cylinder	–	–	–	515	Tolerance ±50 Note (4)
		Turbocharger inlet	–	–	–	515	–
	Manifold downsteam of turbocharger	new	max. 30 mbar		–	–	–
		fouled	max. 50 mbar		–	–	–
TC Bearing Oil	A100 (on engine lube oil system)	Inlet	1.0	2.5	–		–
		Outlet			–	110	–
	A100 (with independent lube oil system)	Inlet	1.3	2.5	–	85	–
		Outlet			–	130	–
	MET	Inlet	0.7	1.5	–		–
		Outlet			–	85	–

For the limits of the alarm, slow-down and shutdown signals see 0250–2.

Notes:

(1) At 100% engine load.

(2) At stand-by condition; during commissioning of the fuel system, the fuel pressure at the inlet of the fuel pumps is adjusted to 10 bar.

(3) The water flow must be in the specified limits (scavenge air cooler specification).

(4) Maximum temperature difference between the cylinders

(5) This data is applicable only to engines with a CMCR in the range between:

- more than or equal to 66.0 rpm (CMCR speed ≥ 66.0 rpm) and less than or equal to 70.5 rpm (CMCR speed ≤ 70.5 rpm)
- more than 70.5 rpm (CMCR speed > 70.5 rpm) and less than or equal to 75.0 rpm (CMCR speed ≤ 75.0 rpm)

For these engines an external crosshead lubricating oil booster pump is installed. For more data, see also Technical Circular to Licensees 7415 and Technical Circular to Licensees 7415–1.

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

Alarms and Safeguards at Continuous Service Power

Media	Unit	Location	Signal No. (1)	Function (2)	Type of signal (3)	Setting value [bar or °C]	Time Interval [sec]
Cylinder Cooling Water	Pressure	Engine inlet	PT1101A	ALM	L	4.0 bar	0
				SLD	L	3.8 bar	60
			PS1101S	SHD	L	3.5 bar	60
	Temperature	Engine inlet	TE1111A	ALM	L	65°C	0
		Outlet each cylinder	TE1121–28A	ALM	H	95°C	0
				SLD	H	97°C	60
Scavenge Air Cooling Water	Pressure	Cooler inlet	PT1361A	ALM	L	2.0 bar	0
Single stage SAC (4) Fresh water	Temperature	Cooler inlet	TE1371A	ALM	L	25°C	0
		Cooler outlet	TE1381A	ALM	H	80°C	0
Lubricating oil – Bearings	Pressure	Engine inlet	PT2001A	ALM	L	4.0 bar	0
				SLD	L	3.8 bar	60
			PS2002S	SHD	L	3.3 bar	10
		before injectors	PT2003A	ALM	L	2.6 bar	0
	Temperature	Engine inlet	TE2011A	ALM	H	50°C	0
				SLD	H	55°C	60
	Temperature	Outlet Bearing	TE2101–10A	ALM	H	65°C	0
		1 to 10	(Optional)	SLD	H	70°C	60
Crank Pin Bearing Oil	Temperature	Outlet	TE2201–08A	ALM	H	65°C	0
			(Optional)	SLD	H	70°C	60
Piston Cooling Oil	Temperature	Outlet each cylinder	TE2501–08A	ALM	H	80°C	0
				SLD	H	85°C	60
	Flow	Inlet each cylinder	FS2521–28S	SHD	H / L	no flow	0
Crosshead Bearing Oil	Pressure	Booster Pump–Inlet (for engines rated in the speed range: 66.0 rpm ≤ CMCR speed ≤ 70.5 rpm)	PT2021A see Notes (14), (15)	ALM	L	11 bar	0
				SLD	L	10 bar	60
		Booster Pump–Inlet (for engines rated in the speed range: 70.5 rpm < CMCR speed ≤ 75.0 rpm)	PT2021A see Notes (14), (16)	ALM	L	7 bar	0
				SLD	L	6.5 bar	60
	Temperature	Outlet	TE2301–08A	ALM	H	65°C	0
			(Optional)	SLD	H	70°C	60
Oil Leakage Monitoring	Level	Oil supply unit (7)	LS2055A	ALM	H	maximum	0
Thrust Bearing	Temperature	Thrust bearing	TE4521A	ALM	H	80°C	0
		Pads (ahead)		SLD	H	85°C	60
			TS4521S	SHD	H	90°C	0

Media	Unit	Location	Signal No. (1)	Function (2)	Type of signal (3)	Setting value [bar or °C]	Time Interval [sec]
Oil mist	Concentration	Crankcase	AS2401A	ALM	H	–	0
			AS2401S	SLD	H	–	60
	Failure	Detection unit	XS2411A	ALM	F	–	0
Turbocharger Oil (TC ABB A100)	Pressure	Inlet	PT2611−12A	ALM	L	1.0 bar	5
			See Note (13)	SLD	L	0.8 bar	60
			PS2611-12S	SHD	L	0.6 bar	5
	Temperature	Housing outlet	TE2601-02A	ALM	H	110°C	0
				SLD	H	120°C	60
Turbocharger Oil (TC ABB A100) (independent TC lube oil supply)	Pressure	Inlet	PT2611-12A	ALM	L	1.3 bar	5
			See Note (13)	SLD	L	1.1 bar	60
			PS2611-12S	SHD	L	0.9 bar	5
	Temperature	Housing outlet	TE2601-02A	ALM	H	130°C	0
				SLD	H	140°C	60
Turbocharger Oil (TC MET MHI)	Pressure	Inlet	PT2611-12A	ALM	L	0.7 bar	5
			See Note (13)	SLD	L	0.6 bar	60
			PS2611-12S	SHD	L	0.4 bar	5
	Temperature	Housing outlet	TE2601-02A	ALM	H	85°C	0
				SLD	H	90°C	60
Torsional vibration damper oil (steel spring damper)	Pressure	Damper inlet	PT2711A	ALM	L	2.2 bar Note (17)	0
Axial vibration damper oil	Pressure	Chamber rear	PT2721A	ALM	L	1.7 bar	60
		Chamber front	PT2722A	ALM	L	1.7 bar	60
Cylinder Lubricating Oil	Pressure	Servo oil pressure − free end	PT2041A	A	L	40.0 bar	3
				A	H	75.0 bar	3
Fuel	Temperature (4)	Upstream of the supply unit	TE3411A	ALM	H	50°C to 160°C	0
				ALM	L	20°C to 130°C	0
(see 0710−1 Viscosity-Temperature Diagram)	Pressure	Upstream of the supply unit	PT3421A	ALM	L	7.0 bar	0
	Viscosity (4)	Upstream of the supply unit	(5)	ALM	H	20 cSt	0
				ALM	L	13 cSt	0
	Temperature	Downstream of the fuel pump (12)	TE3431−32A	ALM	D	±30°C	30
Fuel Leakage Monitoring	Level	Rail/supply unit (7)	(7)	ALM	H	max.	0

Media		Unit	Location	Signal No. (1)	Function (2)	Type of signal (3)	Setting value [bar or °C]	Time Interval [sec]
Exhaust Gas		Temperature	Downstream of each cylinder	TE3701–08A	ALM	H	515°C	0
					ALM	D	±50°C	0
					SLD	H	530°C	60
					SLD	D	±70°C	60
			Upstream of each TC (6)	TE3721-22A	ALM	H	515°C	0
				(10)	SLD	H	530°C	60
			Downstream of each TC (6)	TE3731–32A	ALM	H	480°C	0
				(10)	SLD	H	500°C	60
Scavenge Air		Temperature	Air receiver	TE4031-32A	ALM	L	25°C	0
			Downstream of 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
Condensation Water		Level	Water separator	LS4071–72A	ALM	H	max.	0
					SLD	H	max.	60
			Upstream of the water separator	LS4075–76A	ALM	H	max.	0
					SLD	H	max.	60
Starting Air		Pressure	Engine inlet	PT4301–02C	ALM	L	12.0 bar	0
Air Spring Air (8), (9)		Pressure	Distributor	PT4341A	ALM	H	7.5 bar	0
					ALM	L	5.5 bar	0
					SLD	L	5.0 bar	60
				PS4341S	SHD	L	4.5 bar	0
Leakage Oil Of Air Spring Air		Level	Exhaust valve air spring	LS4351–52A	ALM	H	max.	0
Control air	**Usual supply** (8)	Pressure	Engine inlet	PT4401A	ALM	L	6.0 bar	0
				PT4411A	ALM	L	5.5 bar	0
	Safety supply (9)	Pressure	Engine inlet	PT4421A	ALM	L	5.0 bar	0
ECS Control System		Power failure	Power supply box E85	XS5056A	ALM	F	–	0

Engine Data	Unit	Location	Signal No. (1)	Function (2)	Type of signal (3)	Setting Value [%]	Time Interval [sec]
Engine Performance Data Overspeed	Speed	Crankshaft	ST5111–12S	SHD	H	110%	0

Notes:

(1) Signal number shows the interface to the remote control (see 4003–2).

(2) Function:
SLD = Slow down
SHD = Shut down
ALM = Alarm.

(3) Type of signal:
D = Difference in value
F = Failure
H = High
L = Low.

(4) Alternative design.

(5) Not included in standard engine supply range.

(6) Abbreviations:
TC = Turbocharger
SAC = Scavenge Air Cooler.

(7) For the location of measurements and signal numbers, see 8016–1, paragraph 4 Servo Oil Leakage and 8019–1, paragraph 4 Fuel Leakage System.

(8) Supply from the board system for control and air spring air through the pressure reducing valve 35–23HA.

(9) Supply from starting air pipe upstream of the shut-off valve (from starting air bottles 930-B001 and 930-B002) for control and air spring air through the pressure reducing valve 35–19HA.

(10) Signal designation changes downstream of the amplifier (on the engine) from TExxxxA to TTxxxxA.

(11) Alarm has an effect only above 30% engine power.

(12) Alarm has an effect only above 40% engine power.

(13) The alarm and slow-down values shown are the minimum settings permitted (from the TC manufacturer). To get a warning in a shorter time, the ALM and SLD values can be increased up to 0.4 bar below the minimum effective pressure (measured in the full operation range). The last ALM/SLD setting is found during commissioning / sea trial of the vessel.

(14) Alarm has an effect only above 40% engine power.

(15) This data is applicable only to engines with a CMCR in the range between:

- more than or equal to 66.0 rpm (CMCR speed ≥ 66.0 rpm) and less than or equal to 70.5 rpm (CMCR speed ≤ 70.5 rpm)

For these engines an external crosshead lubricating oil booster pump is installed. For more data, see also Technical Circular to Licensees 7415 and Technical Circular to Licensees 7415–1.

(16) This data is applicable only to engines with a CMCR in the range between:

- more than 70.5 rpm (CMCR speed > 70.5 rpm) and less than or equal to 75.0 rpm (CMCR speed ≤ 75.0 rpm)

For these engines an external crosshead lubricating oil booster pump is installed. For more data, see also Technical Circular to Licensees 7415 and Technical Circular to Licensees 7415–1.

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

Manoeuvring

1. General

Correct maneuvering, with a subsequent increase in engine load up to service power and a decrease in load from service power, is very important.

Engine loads in the higher power ranges that are changed too quickly can cause increased wear and contamination, specially on piston rings and cylinder liners.

Slow load changes let the piston rings adapt to the new conditions and therefore make sure of the best sealing.

There must always be sufficient power available in a short time for safe manoeuvring in ports and waterways.

2. Maneuvering

Maneuvering is the operation between leaving port and release to sea speed and from the approach to port until finished with engine. This also includes all changes during usual service e.g. changes of direction.

The manoeuvring range is the speed range between FULL AHEAD and FULL ASTERN. This range is usually divided into four manoeuvring steps with related given speeds in each direction.

Note: Because of torsional vibration, it is possible that the engine has more than one barred speed range. Also, it is possible that the engine has a barred speed range if the axial damper becomes defective. Data about the barred speed range can be found near the telegraph on the bridge, and/or near the local control panel.

Usually, the full maneuvering speed, for engines that have fixed pitch propellers, is related to approximately 70% of the maximum rated engine speed. This is approximately 35% of the maximum power. This means that when sailing straight ahead, the ship will be at approximately 66% of its maximum speed.

A fully serviceable engine can be manoeuvred in the range given above with no time or performance limits. Fuel and scavenge air necessary for engine operation are controlled electronically.

With controllable pitch propellers the speed and torque can be freely selected. During maneuvering, the limits are the same as for fixed pitch propellers. The time period to change the propeller pitch position from zero pitch to full, must be a minimum of 20 seconds.

If the engine is increased quickly to full maneuvering speed (or the propeller blades move to full pitch), the engine load is momentarily higher when the vessel has no movement. When the vessel is at sea speed, the engine load is decreased.

You can do maneuvering operations from the bridge (if the remote control is installed), from the engine control room or at the local control panel on the engine.

Make sure that you know the special precautions for maneuvering operations from the local control panel.

Heavy fuel oil or diesel oil can be used during maneuvering, but heavy fuel oil is recommended (see 0270−1, paragraph 1 General).

The fuel used must have sufficient treatment (see 0720−1 Fuel Treatment, Fuel Oil System).

The data given in 0250−1, Operating Data Sheet is also applicable during manoeuvring.

When HFO is used for maneuvering, the fuel must be heated sufficiently. This keeps the viscosity at the fuel pump inlets in the range given in 0710−1, Fig. 1 Viscosity-Temperature Diagram.

The heating of the fuel oil system must stay set to on. Keep the temperature of the cooling media as close as possible to the higher limits given for usual service (see 0250−1 Operating Data Sheet).

3. Usual Operation

3.1 Control Room Maneuvering Stand

To start the engine in speed mode with a fixed pitch propeller do as follows:

1) Make sure that the MCM−11 module is set to on.
2) In the LDU−20 MAIN page, select the Speed Setpoint button.
3) Set the applicable speed.
4) Push the the START AHD or START AST button.

3.2 Local Control Panel

See also 4003−1, Engine Control, paragraph 3.

3.3 Transfer and Accept Control from ECR Remote to Local

1) At the ECR console LDU−20, get the CONTROL LOC. Page (see 4002−2, paragraph 3.4).
2) Push the button Local for control to the local manual control.
3) At the local control panel LDU−20, push the button CTRL. TR. to get control.
4) Get the MAIN page.
5) Use the rotary button to select the Fuel Command button to between 12% and 30%.

Note: The recommended range for the start fuel setting is between 12% and 30%. A setting of less than 12% will not be sufficient for engine start. A setting of more than 30% will cause too much smoke.

You can also use the Speed Setpoint button to operate the engine.

Use this operation mode for long periods only when necessary e.g. until defects in the speed control system, or other defects in the remote control can be repaired.

In installations with controllable pitch propellers or clutch couplings, more precautions are necessary. There must be good communication between the bridge and the local manoeuvring stand.

Note: The speed control is part of the engine control system (ECS). An engineer must stay at the local manoeuvring stand. The engineer can then make changes immediately if necessary.

3.4 Reversing

1) In the LDU−20, get the MAIN page.
2) Turn the rotary button to select 30% fuel injection quantity.
3) Push the button START AHD or START AST until the engine operates in the applicable direction.

Note: On ships under way, this procedure can be some minutes, because the flow of water has an effect on the propeller.

You can also use the ECR manual control panel to do the reversing procedure given above.

You can use the buttons and rotary button only at the related active control stand.

3.5 Installations with Controllable Pitch Propeller

For data about installations with controllable pitch propellers, refer to the documentation of the propeller manufacturer.

3.6 Installations with Clutch Couplings

You must not disengage clutch couplings while the engine operates.

You must make sure that the couplings are engaged before you start the engine.

4. Increase Power after Release to Sea Speed and Decrease

You must only increase and decrease the engine load during a given time period. This time period is usually between 40 minutes to 45 minutes between full maneuvering and service power. The time period must not be less than that given as follows:

- For an increase in engine load, not less than 30 minutes
- For a decrease in engine load, not less than 15 minutes.

You use the related devices in the engine room to manually increase and decrease the engine load as follows:

For fixed pitch propeller installations:

- Speed setting.

For controllable pitch propeller installations:

- Speed setting
- Propeller pitch setting lever
- Speed and propeller pitch setting lever (combinator).

The time limits given above for speed and power are not applicable if a faster decrease of engine load is necessary when:

- There are critical alarm conditions in the engine room
- A shut-down or slow-down signal is activated.

5. Emergency Maneuver

The safety of the vessel is very important. If an emergency manoeuvre is necessary, all the limits specified in paragraphs 2, 3 and 4 are not applicable, i.e. you can use the the full power of the engine.

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Change-over from Diesel Oil to Heavy Fuel Oil and Back

1. General

Continuous operation with heavy fuel oil (HFO) is recommended for engines and plants. You must only change from HFO to marine diesel oil (MDO) if necessary, for example when:

- The engine is flushed before maintenance
- The heating plant is set to off in the dry dock
- There are environmental conditions.

To make sure that the change-over is safe, see the paragraphs that follow:

2. 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 the 0710−1 Diesel Engine Fuels, paragraph 3.1, Viscosity / Temperature Diagram.

A viscosimeter controls the temperature increase of the fuel.

Note: While the engine has stopped, fuel flows through the fuel pumps, fuel rail and fuel pressure control valve and then flows back to the fuel system.

3. Change-over from MDO to HFO

See 0720−1 Fuel Treatment and Fuel System, Fig. 1 Schematic Diagram – Fuel System.

3.1 Plant Side

To change from marine diesel oil MDO to HFO, you must make sure that the automatic change-over unit (16) is in the correct position. When the position of the automatic change-over unit (16) is changed, HFO and MDO are mixed in the mixing unit (21).

The viscosimeter controls the end-heater (23), which keeps the fuel temperature at the necessary viscosity. You must make sure that the fuel temperature increases slowly (i.e. the temperature increase must be a maximum of 2°C each minute).

Note: It is possible that sudden temperature changes can stop the movement of the fuel pump plungers.

1) Make sure that the heating for the fuel filter (24), fuel supply and fuel return pipes is set to on until the fuel is at the necessary temperature.

Note: The temperature is shown on the thermometer upstream of the inlet to the fuel pumps

2) Do a check of the fuel pressure downstream of the low pressure feed pump and at the fuel pump inlet (see Operating Data Sheet 0250−1).

3.2 Engine Side

The trace heating on the engine (fuel pressure pipes and fuel rail) must be set to on when there is a change-over from MDO to HFO in the plant. All covers of the rail unit must be closed.

If the engine room is cold, you must set to on the trace heating approximately one hour before the change-over.

Before you stop the engine, the change-over procedure must be fully completed. This prevents a mixture of MDO and HFO in the fuel rail, which can cause viscosity problems during the next engine start.

It is recommended that for the change-over, the fuel is at the necessary temperature and the CMCR load is not more than 75%.

4. Change-over from HFO to MDO

See 0720–1 Fuel Treatment and Fuel System, Fig. 1 Schematic Diagram – Fuel System.

4.1 Plant Side

To change from HFO to MDO, you must first change the position of the automatic change-over unit (16). HFO and MDO is mixed in the mixing unit (21). The viscosity of the fuel mixture decreases quickly at a specified temperature, which is related to an increased proportion of MDO to HFO. After a short period the heating can be set to off.

4.2 Engine Side

CAUTION
Damage Hazard: If you operate the engine with marine diesel oil and the electrical trace heating is set to on, damage to the engine will occur. Set to off the electrical trace heating (see 4002–2 Local Control Panel/Local Display Unit LDU–20, paragraph 3.10 User Parameters and 8825–1 Electrical Trace Heating System).

The trace heating on the engine (fuel pressure pipes and fuel rail) must be set to off during change-over from HFO to MDO in the plant.

Note: The time to complete a change-over will be longer if the engine operates at low load.

Before you stop the engine, the change-over procedure must be completed. This will prevent a mixture of MDO and HFO in the fuel rail which can cause viscosity problems during the next engine start.

It is recommended that the CMCR load is less than 50% CMCR power for the change-over from HFO to MDO.

Operation at Low Load

1. General

See the data that follow:

- 0240–1 Usual Operation, paragraph 2 Checks and Precautions
- Trace heating of the fuel system during operation
- Temperature of the cooling medium in the usual range (see 0250–1 Operating Data Sheet)
- Careful treatment of the fuel (see 0720–1, Fuel Treatment and Fuel System)
- 0750-1 Operating Media, paragraph 3 Cylinder Lubricating Oil.

The cylinder lubricating oil quantity automatically adapts to the lower engine load. The engine control system (ECS) controls the lubricating oil quantities related to the engine load.

2. ECS Injection Control

At low load the ECS automatically cuts out one of the three injection valves in each cylinder. This makes sure that the engine has the best fuel mist and combustion properties, thus decreasing smoke and fuel consumption.

The ECS cuts out a different injection valve at regular intervals to get an equal thermal load in the combustion chamber.

There is no time limit to operate the engine at low load.

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Operation at Overload

1. General

Usually, the engine is only operated at overload (110% of CMCR power) during sea trials when there is an authorized representative of the engine builder on board the ship.

The limit for operation of the engine at overload is a maximum of one hour each day (see also 0070−1 The Relation between Engine and Propeller).

During operation at overload, you must carefully monitor the engine. If there are unusual indications, you must decrease the load (power).

The load indication (fuel injection quantity) and the exhaust gas temperature upstream of the turbine show the engine load (see 0250−1 Operating Data Sheet, and the Acceptance Records).

The coolant temperatures must stay in their usual ranges.

In usual service, the full load position of the load indication (fuel injection quantity) must stay in the limits given (see the Acceptance Records).

The maximum permitted position of the load indication (fuel injection quantity) is given in the Acceptance Records. The adjustments are only permitted to show the CMCR power during sea trials with an overspeed of 104% to 108% of CMCR power.

The conditions given below affect the speed of the ship:

- Sailing into strong head winds
- Sailing in heavy seas
- Sailing in shallow water
- When there is unwanted heavy growth on the hull.

The governor increases the fuel quantity to keep the speed of the ship constant. The increase in the fuel injection quantity shows on the FUEL INJECTION page in the LDU−20 (see 4002−2, paragraph 3.7).

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General

1. Engine Load Decrease

When possible, it is recommended that the engine load is decreased slowly, see 0260–1 Maneuvering.

2. Engine Stop

2.1 Usual Procedures

2.1.1 Engine Stop from the Control Room – Remote Control

Because different types of remote control can be connected to the engine controls, the operation procedure from the manoeuvring stand in the control room is not given. For this procedure, see the applicable documentation of the remote control manufacturer.

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

2.1.2 Engine Stop from the Control Room – ECR Manual Control Panel

See 4003–2 Control Diagram and 4002–2, Local Control Panel / Local Display Unit.

When you push the STOP button on the LDU–20, the engine control system (ECS) shuts down the engine after the engine speed/power decreases.

2.1.3 Engine Stop from the Local Control Panel

When you push the STOP button on the LDU–20 (see 4002–2 paragraph 3.2), the ECS shuts down the engine after the engine speed/power decreases.

Note: You can use the buttons and rotary button only at the related active control stand.

2.2 Emergency Stop

To stop the engine immediately, push the EMERGENCY STOP button in the control room (control console) or on the local control panel. The 3/2-way valve 10-5560_E0_3 then releases the pressure in the fuel rail. At the same time, the fuel pump supply decreases to 0 (zero).

2.3 Last Option

CAUTION
Damage Hazard. Do this emergency procedure only as a last option. Damage to the engine can occur.

You can also set to off the electrical power to the ECS in the power supply boxes E85.1 to E85.x to stop the engine

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Procedures after Engine Stop

1. Procedures for Short Service Breaks (some days to some weeks)

1.1 Engine is Maneuverable

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

- The engine control system (ECS) 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.
- The cylinder cooling water must be kept at the correct temperature.
- The temperature of the lubricating oil must not decrease.
- The fuel must be kept at the applicable temperature in accordance with 0710–1, Fig. 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. The temperatures of these media must not decrease below their usual inlet temperatures. Thus, the sea-water pump can usually be stopped immediately.
- If the engine was shut down during operation with HFO, 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 of 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 a Long Period).
- The low pressure supply pump and booster pump can be stopped if the engine was shut down during operation with diesel oil (see 0720–1, paragraph 4 Configuration of the Fuel System).
- After the engine has stopped, the starting air supply must be closed.

1) Close the shut-off valves on the starting air bottles.
2) Turn the handwheel of the starting air shut-off valve 30-4325_E0_1 to the position CLOSED.
3) Open the ball valves 30-8605_E0_6 and 30-8605_E0_7 to release the pressure (see 4003–2 Control Diagram and 4003–9 Air Systems).
4) Open the indicator valves in the cylinder covers.
5) Engage the the turning gear.

Note: Make sure that you know the safety precautions before you do repair work or overhauls (see the Maintenance Manual 0011–1 and 0012–1).

6) If necessary, release the pressure from the fuel system.

1.3 Post-lubrication of the Cylinders

Post-lubrication starts automatically during the slow-down of the engine.

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

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

Where possible, keep the cooling water warm to prevent too much of a decrease of the engine temperature. The cooling water pump thus, continues to operate unless it is necessary to stop the pump for maintenance.

2) At frequent intervals and with the indicator valves open, use the turning gear to turn the engine as necessary (you can do this 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 this procedure is completed, make sure that the piston stops in a different position each time.

3) Repair all the defects found in service (leaks, etc).

2. Procedures for Service Breaks for a Longer Period (weeks or months)

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

Running-in New Cylinder Liners and Piston Rings

1. General

It is not necessary to do a special running-in procedure after new components of the piston running system are installed. But, you must obey the data given in paragraph 2.

2. Feed Rate Adjustments

After new components of the piston running system are installed, it is necessary to adjust the cylinder lubrication feed rate. This makes sure of sufficient lubrication which prevents damage to the cylinder liner and the piston rings. See Fig. 1 for the applicable running-in cylinder lubrication feed rates with their related running hours.

Wärtsilä Services Switzerland Ltd recommends the inspection of the cylinder liner and piston rings after 24 running hours and after 72 running hours (see the indications 1 in Fig. 1).

After 72 running hours, set the cylinder lubrication feed rate to the usual values. For more data, see 7218–3 Feed Rate – Adjustment.

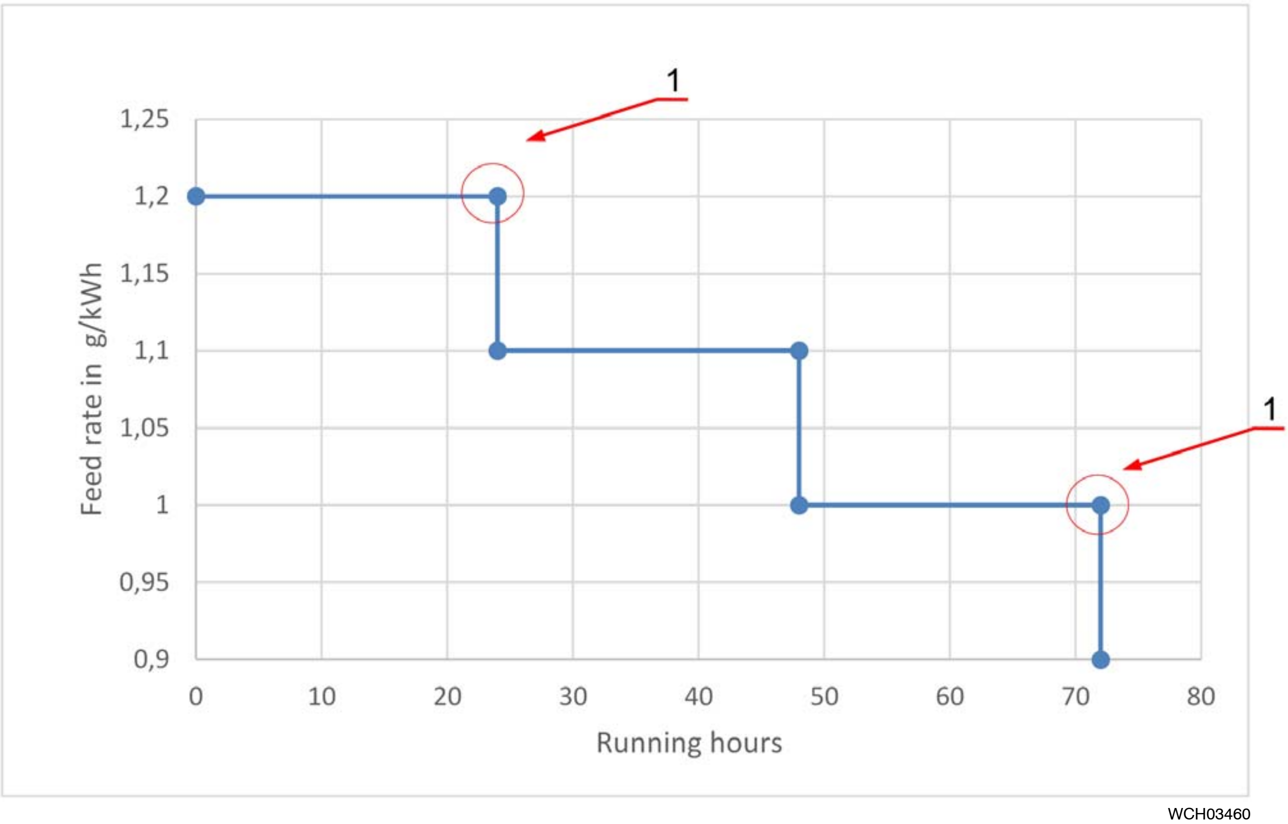

Fig. 1: Feed Rate Adjustments – Running-in

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Indicator Diagrams

1. General

Indicator diagrams must only be drawn with a serviceable indicator at constant power and speed, and ships sailing in calm sea and deep water.

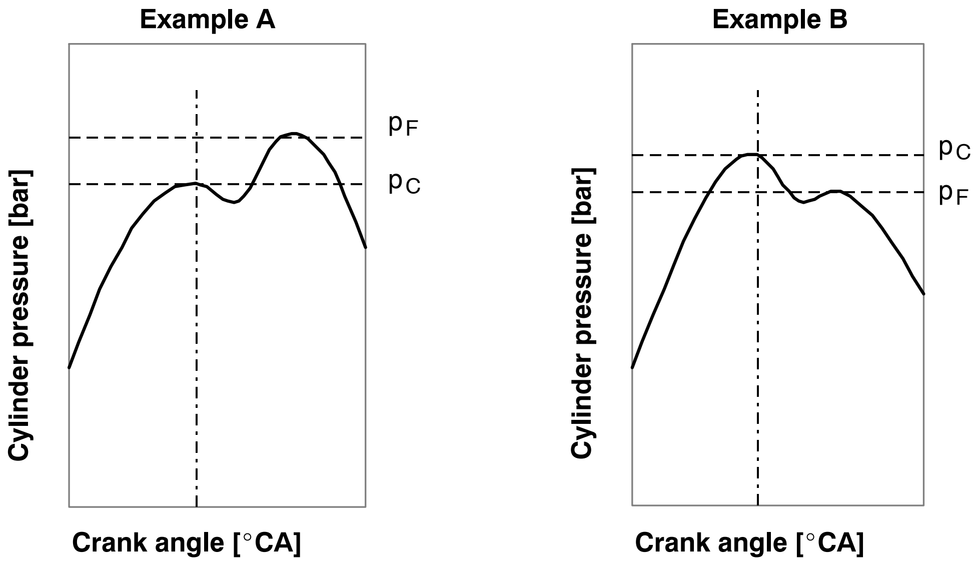
To give you data about the indication diagrams, record the related cylinder number, engine speed, the positions of the load indicator and VIT.

2. Description of Cylinder Pressures

Higher compression ratio and fuel injection delay are used to decrease the NO_x value for engines so that the IMO rules are obeyed.

The ratio of the maximum firing pressure to the compression pressure is in the range of 0.90 to 1.25 at 100% load.

The engine rating is related to IMO tuning. This means that the curves in the diagram can be different in the two examples that follow:

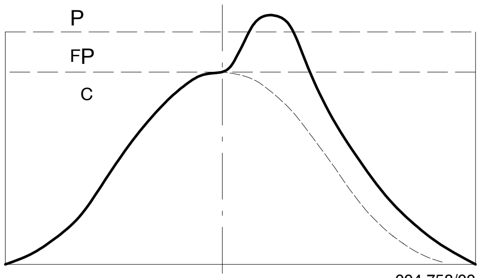


P_C = Compression pressure at TDC **P_F = maximum firing pressure**

Fig. 1: Compression Ratios

3. Indicator Diagrams and Related Engine Adjustments

The diagrams, which were made during the acceptance trial, must be used as references. For reference values about compression and maximum firing pressures for the related load and speed, refer to the trial reports and performance curves.



Example A

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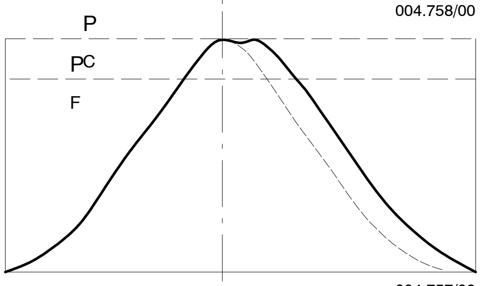

Example B

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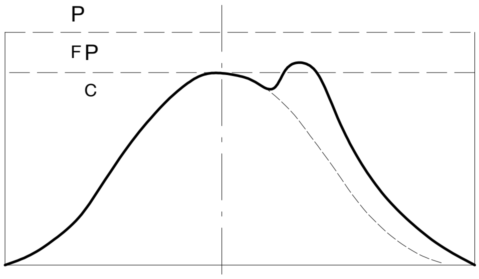

Example A

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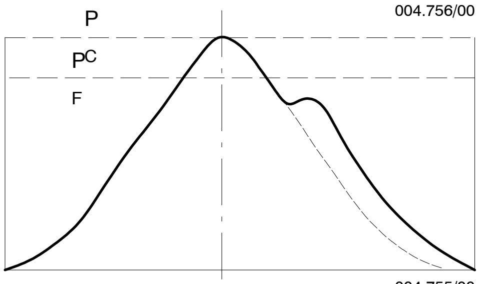

Example B

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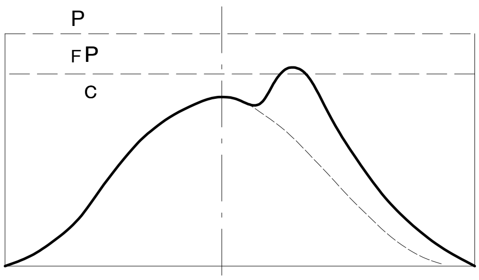

Example A

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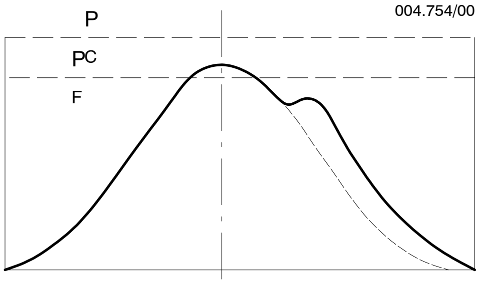

Example B

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3.1 Maximum Firing pressure Too High at Correct Compression Pressure

Possible causes:

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

You must adjust the FQS as follows:

1) In the LDU−20, get the USER PARAMETERS page (see 4002−2, paragraph 3.10).
2) In the FQS field, enter a positive (+) setting to correct the the ignition pressure.

You can only do a correction of the FQS if all cylinders show the same pressure difference.

3.2 Maximum Firing Pressure Too Low at Correct Compression Pressure

Possible causes:

- Unsatisfactory combustion: The nozzle tip has trumpets or is worn.
- Ignition (start of injection) too retarded for the fuel type in use.

1) Do a check of the injection nozzles.
2) In the LDU−20, get the USER PARAMETERS page (see 4002−2, paragraph 3.10).
3) In the FQS field, enter a negative (−) setting to correct the the ignition pressure.

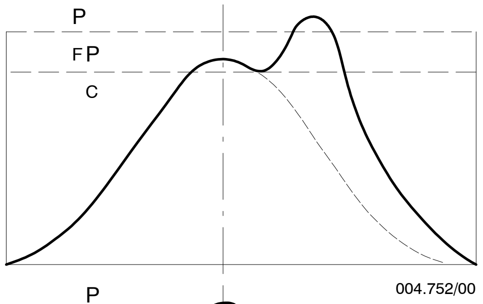
You can only do a correction of the FQS if all cylinders show the same pressure difference.

3.3 Compression and Maximum Firing Pressure Too Low

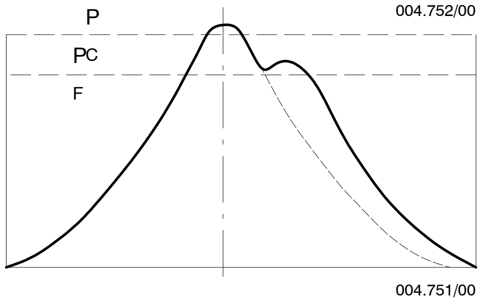
Possible causes:

- The load is less than you think.
- The exhaust valve has a leak.
- The scavenge air pressure is too low.
- The suction temperature is too high.
- VEC timing is incorrect i.e. exhaust valve closing time too late (parameter in the ECS).

1) Do a check of the exhaust valve.
2) Clean the turbocharger or scavenge air cooler (see 6510−1 and 6606−1, paragraph 3).



Example A



Example B

3.4 Compression Pressure and Maximum Firing Pressure Too High

Possible causes:

- Engine has too much load.
- VEC timing is incorrect.

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Procedures to Prevent Contamination and Fire in the Scavenge Air Spaces

1. General

The primary cause of contamination is when combustion materials are blown between the piston and cylinder into the scavenge air spaces (blow-by). The contamination will be more if the fuel is not fully burned, causes exhaust smoke.

2. Causes and Procedures

2.1 Unsatisfactory Combustion

The causes of unsatisfactory combustion are as follows:

- The injection valves do not operate correctly (the nozzle tip has trumpets or is worn).
- The fuel is too cold, specially at low load.
- Operation with a temporarily low air supply during large differences in engine load and the scavenge air pressure fuel limiter set too high.
- Too much load
- Low air supply because the ventilation in the engine room is not sufficient.
- The silencer and diffuser on the air side of the turbocharger has contamination.
- The wire mesh and nozzle ring upstream of the turbocharger has contamination.
- The exhaust gas boiler, the air cooler and water separator, the air flaps in the scavenge air receiver and the scavenge ports have contamination.

2.2 Blow-by

The causes of blow-by are as follows:

- Worn piston rings, broken piston rings or piston rings that cannot move.
- Worn cylinder liner.
- Incorrect operation of a lubricating quill.
- The running surface of the cylinder liners are damaged.

If there are one or more of these conditions, the remaining particles will collect at the areas that follow:

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

2.3 Fires

The causes of fires are as follows:

- Combustion gases and sparks, that bypass the piston rings between the piston and cylinder liner running surface, go into the piston underside.
- If sealing rings of the piston rod gland leak and drain pipes from the piston underside are blocked, system oil and cylinder lubricating oil will collect. This is a primary fire risk.

You must do periodic checks of the bottom of the cylinder block and scavenge air receiver. If necessary clean the cylinder block and scavenge air receiver.

2.4 Indications of a Fire

- You can hear the related temperature alarms.
- A large increase in the exhaust gas temperature of the related cylinder and an increase in piston underside temperature.
- In some conditions the turbocharger can surge.

2.5 Fire-fighting Procedures

It is recommended that you do the procedures that follow:

1) Decrease the engine power.
2) Cut out the injection of the related cylinder as given in steps a) and b):
   a) In the LDU−20, get the FUEL INJECTION page (see 4002−2, paragraph 3.7 Fuel injection).
   b) In the Inj. cutoff field for the related cylinder(s), set the parameter to 0.
3) Although there is high temperature in the cylinder(s), increase the feed rate of lubricating oil to maximum as given in steps a) and b):
   a) In the LDU−20, get the CYL. LUB. page (see 4002−2, paragraph 3.9).
   b) In the Manual Lub. To Cyl # field, set the parameter to the related cylinder number.
4) In the Adjustment column, set the parameter to 150%.

Note: This will make sure that the cylinder(s) is (are) lubricated (see 7218−1 paragraph 6.4).

If the plant has a specified fire extinguisher system, (CO_2 gas) the containers can be attached to the applicable connections on the scavenger air receiver. The related shut-off valve must be fully leak-proof.

5) If you think there is a fire, shut down the engine and fill the scavenge space with CO_2 gas.

Note: Make sure that you read 0210−1 Safety Precautions and Warnings, paragraph11 Carbon Dioxide (CO_2 gas).

If steam is used to extinguish a fire, you must do the procedures to prevent corrosion.

It is possible that after approximately 5 minutes to 15 minutes, a fire will be extinguished.

6) To make sure that a fire is extinguished, do a check of:

- The exhaust gas temperatures
- The temperatures of the doors to the piston underside space.

After the procedures above, you must stop the engine as soon as possible and find the cause of the fire.

7) Do steps a) to e):
   a) Do a check of the cylinder liner running surface, piston and piston rings.
   b) Do a check of the air flaps in the scavenge air receiver (replace if necessary).
   c) Do a check of for possible leakages.
   d) Do a check of the piston rod gland as much as possible.
   e) Do a check of the injection nozzles.

8) After a careful check, or if necessary a repair, do the procedure given in steps a) to c):

   a) Start the engine.

   b) Start the injection and slowly increase the load.

   c) Set the lubricating oil feed rate to the applicable value.

9) If the engine must stay in operation and the fire is extinguished, do the procedure given in steps a) and b):

   a) Cut in the injection and slowly increase the load.

   b) Set the lubricating oil feed rate to the applicable value.

Note: Do not operate the engine for long periods with a high cylinder lubrication setting.

2.6 Procedures to Prevent Fire

Good engine maintenance will help to prevent a fire in the scavenge air spaces. The data that follow will also help to prevent fire:

1) Make sure that the injection nozzles are serviceable (i.e. the spray from the nozzles must come out correctly).
2) Do regular inspections of the air and gas pipes.
3) Regularly clean the the air and gas pipes.
4) Dirty oil from the piston underside must always drain through the dirty oil outlet.
5) Make sure that the oil pipes are clean.
6) Use your hand to feel the drain pipes. If there is a blockage, a drain pipe will have a temperature difference. You must clean the related drain pipe as soon as possible.

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Prevention of Crankcase Explosions – Instructions

1. General

Examples of crankcase explosions in diesel engines have shown that they can only occur in special conditions,and thus do not occur frequently.

The cause of crankcase explosions is oil mist. Oil mist comes from components that have become unusually hot.

Engines have oil mist detectors , which continuously monitor the concentration of oil mist in the crankcase. If there is a high oil mist concentration the oil mist detector activates an alarm. For more data about the oil mist detectors, see 9314–1.

Correct engine maintenance will help prevent explosions in the crankcase.

2. Procedure

If an oil mist detector activates an alarm, do the procedures given below:

WARNING

Danger: If an oil mist alarm is activated, keep away from the engine. There is a risk of explosion.

1) Decrease the engine speed (power) immediately.
2) Stop the engine when possible and let the engine temperature decrease for a minimum of 20 minutes.
3) Find the cause (see 0840–1 Operation Problems).

WARNING

Danger: Do not open the crankcase doors or the covers for a minimum of 20 minutes. If air goes into the crankcase, an explosion can occur.

The crankcase doors have relief valves. To prevent accidents no person must be in the areas of gases that can come out of these relief valves.

If no fire-extinguishing system is installed or not in use, a portable fire extinguisher must be kept ready when the crankcase doors are opened.

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General Data

1. General

The data below give the procedures for engine operation when:

- The parts cannot be immediately repaired
- The engine must continue to operate, or
- When engine operation must continue as soon as possible.

2. Decreased Power Output

In an emergency, when the engine must operate (with one or more cylinders out of operation, turbochargers out of operation or decreased coolant flow etc) the power must be decreased to prevent damage to the engine.

The load indication must always be less than the full load position (fuel injection quantity). The gas temperature at the turbocharger inlet must always be less than the maximum temperature (see 0250–1 Operating Data Sheet). If necessary decrease the engine speed and power.

Because of torsional vibration, it is possible that the engine has more than one barred speed range. Also, it is possible that the engine has a barred speed range if the axial damper becomes defective. You can find data about the barred speed range near the telegraph on the bridge, and/or near the local control panel.

The exhaust smoke must be monitored because the engine must not operate with dark exhaust smoke. The speed and power must be decreased until the exhaust smoke is satisfactory.

3. Cylinders Out of Operation

When one or more cylinders are out of operation the turbocharger can surge. This makes a loud sound. Large differences in the scavenge air pressure will show on the pressure gage.

If the turbocharger surges for short periods or continuously, you must decrease the speed sufficiently.

Note: When cylinders are out of operation, it is possible (when an engine has only e.g. five cylinders) that the engine will stop in a position from which it cannot start. This is because none of the serviceable pistons are in the correct position to start the engine again.

Start the engine momentarily in the opposite direction to get the crankshaft to a different position. It is possible that the engine will not reverse correctly and you must do related precautions together with the bridge.

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Operation with Injection Cut Out (One or More Cylinders)

1. Cut Out the Injection

If the injection of one or more cylinders must be cut out, do the procedure give in steps 1) to 5).

1) In the LDU–20, get the FUEL INJECTION page (see 4002–2, paragraph 3.7 Fuel Injection).

2) In the Inj. Cutoff column, set the parameter for the applicable cylinder to 1 to isolate the injection.

Note: If there is a defect in the injection system (injection valve, high pressure pipe, etc) only cut out the injection of the related cylinder. If possible, the exhaust valve must always operate.

3) Disconnect the plug (3, Fig. 1) from the injection valve (1).

If it is necessary to operate the engine with the injection cut out for an extended period, do steps 4 and 5.

4) Record the settings of the lubricating oil feed rate.

5) Decrease the lubricating oil feed rate for the related cylinder to the minimum setting (see 4002–2, paragraph 3.9 Cylinder lubrication).

2. Injection Start

Replace the defective injection valve (see the Maintenance Manual 2722–1 Injection valve).

WARNING

Injury Hazard: You must put on gloves and safety goggles when you do work on hot components. Oil can come out as a spray and cause injury.

2.1 Defective High Pressure Pipe

Replace the defective high pressure pipe to the fuel injection valve as given in steps 1) to 3):

1) Stop the engine.

2) Disconnect the plug (3) from the injection valve (1).

3) Replace the defective high pressure pipe (2) (see the Maintenance Manual 8733–1 Fuel Pressure Pipes).

Note: If an HP fuel pipe between the fuel pumps and the fuel rail has a leak, do the procedures given in 8019–1, paragraph 4 to find the leak.

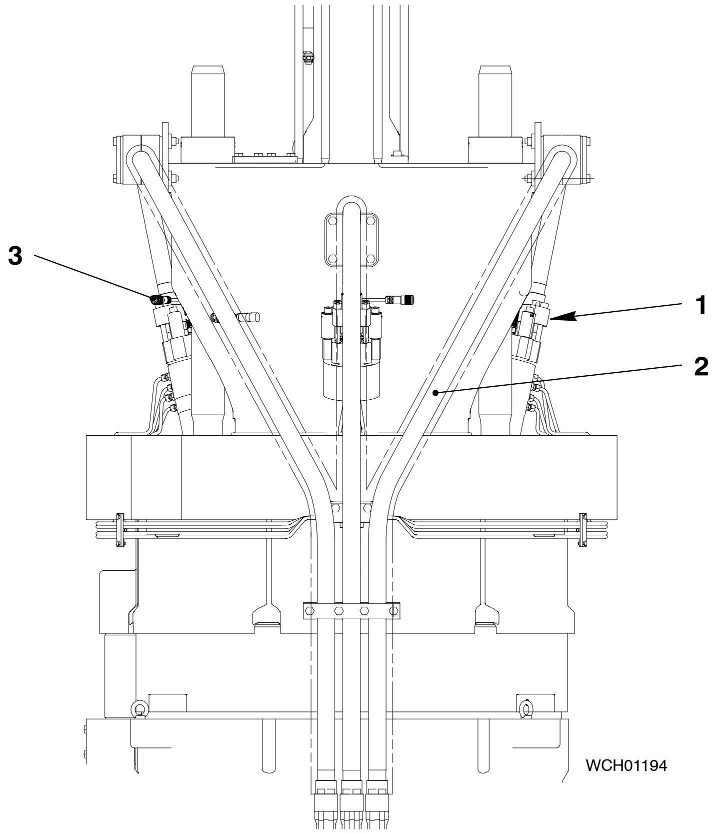

Fig. 1: High Pressure Pipes

1 Injection valve
2 High pressure pipe
3 Plug to control valve

Faults in High Pressure Fuel System

1. Defective Fuel Pump

1.1 Fault Identification

Fault identification is as follows:

- Failure indication in engine control system (ECS) (see 4002−2, LDU−20, paragraph 3.15 Log Messages).
- Unusual noises e.g. knocks, scrapes and rings.
- The level switch LS3446A shows an alarm (see 8019−1, paragraph 4).

1.2 Causes

The causes of the defects are given below:

- The fuel pump is blocked.
- The safety device on the driving wheel is broken (see fuel 5556−1 Fuel Pump and the Maintenance Manual 5556−2).
- Failure of the fuel pump.

1.3 Procedure

You must replace the defective fuel pump or high pressure (HP) fuel pipe as soon as possible (see 5556−1 Fuel Pump, 5556−2 Supply Unit and the Maintenance Manual 8752−1 Fuel Pressure Pipes).

2. Defective Fuel Pump Actuator

2.1 Fault Identification

If an actuator becomes defective, its output stays the same or changes slowly to zero supply. The toothed rack does not change when the load changes.

A failure message shows in the ECS (see 4002−2, paragraph 3.15 Log Messages).

The fuel pumps stay in their last position when no control signal is received.

At high engine load, the remaining serviceable fuel pump actuators control the fuel quantity.

At low engine load, the pressure control valve (PCV) 10-5562_E0_5 controls the fuel pressure control function.

Note: The fuel quantity released from the pressure control valve flows into the fuel return.

Operation with these control functions must be prevented if possible, or kept for only a short time (see 5562−1 Pressure Control Valve).

If there is an overpressure in the HP fuel system (i.e. the PCV becomes defective), the pressure relief valve (which is part of the PCV) opens and the level switch LS3426A activates an alarm.

2.2 Causes

The causes of a defective fuel pump actuator are as follows:

- Electrical interference (defective cable connections, broken cable etc.).
- A fuel pump actuator is defective.

2.3 Procedure

1) Connect the correct cable connections between the related CCM−20 and the fuel pump actuator as soon as possible.

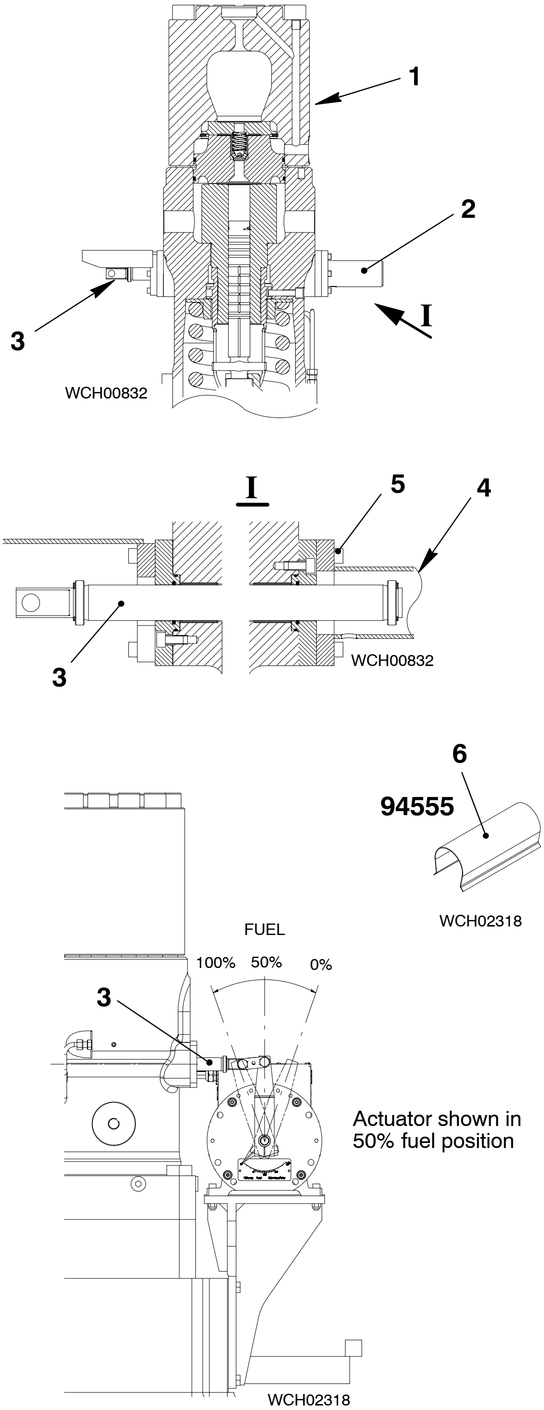

Fig. 1: Fuel Pump Actuator

2.3.1 One Actuator is Defective

1) Do a check of the control signals from the ECS and the electrical cables. If necessary, replace the electrical cables.
2) Make sure that the toothed rack (3) moves freely (see Fig. 1).
3) Move the toothed rack (3) to the 0% fuel position.
4) Install two distance pieces (6, tool 94555) to the toothed rack (3) on the fuel pump (1) that has the defective actuator.
5) Replace the defective actuator as soon as possible (see the Maintenance Manual, 5801−1 Regulating Linkage).
6) If different power outputs are necessary, you can lock the actuator in other positions (50% fuel, or 100% fuel) see step 7 to step 9.
7) Remove the six screws from the cover (2) then remove the cover.
8) For 50% fuel, do steps a) and step b):
   a) Move the toothed rack (3) to the 50% fuel position.
   b) Install one distance piece (6) on each end of the toothed rack (3).
9) For 100% fuel, do step a) and step b):
   a) Move the toothed rack to the 100% fuel position.
   b) Install two distance pieces (6) on the toothed rack.

Note: Fuel pressure control through the PCV must be prevented if possible.

2.3.2 All Actuators are Defective

1) To install the distance pieces (6, Fig. 1) to the toothed racks (3), see steps a) and b):

   a) For engines with two fuel pumps, install the distance pieces (6) to get:

      - One fuel pump in the 0% fuel position and the other fuel pump in the 100% position.

   b) For engines with three fuel pumps, install the distance pieces (6) to get:

      - One of the fuel pumps in the 0% fuel position and the other two fuel pumps in the 100% position.

Note: For higher loads, set more fuel pumps to the 100% position.

3. Defective Injection Valve

During engine operation, the open/short circuit of the injector is monitored.

When you manually activate the Injector Analysis Mode, only one injector operates in the related cylinder (this is done in cylinder balancing in an engine load range of between 20% and 30%).

When there is an external change command from the cylinder balancing function, the next injector operates. See the data that follows:

- When the Injector Analysis Mode = 0, all injectors operate
- When the Injector Analysis Mode = 1, injector No.1 operates until the next change command, then
- When the Injector Analysis Mode = 2, injector No.2 operates until the next change command, then
- When the Injector Analysis Mode = 0, all injectors operate again.

The command change occurs after a specified time. The cylinder balancing function records the firing pressure and exhaust gas temperature data.

3.1 Fault Identification

- Failure indication in the ECS (see 4002−2 LDU−20, paragraph 3.15 Log messages).
- The fuel injection is cut out automatically (Inj. CUT OFF) on the related cylinder, which activates a SLOW DOWN signal.
- The level switch LS3446A shows an alarm because of leakage of the high pressure fuel pipes to the injection valve (see 8019−1, paragraph 4 Fuel Leakage System).

3.2 Causes

- Electrical interference (cable connections defective, parting of a cable etc).
- The solenoid valve is defective.
- The needle cannot move from the closed position.
- The needle cannot move from the open position.
- The injection valve is defective.
- Leakage from the sealing surfaces on each side of the high pressure pipe.

3.3 Procedures

3.3.1 Injection Valve

1) The fuel injection must be cut out immediately (if not automatically cut-out). See 0510–1, paragraph 1 Cut Out the Injection.

Note: When the injection is cut out (Inj. CUT OFF) the engine can only be operated at decreased load.

2) Replace the defective injection valve as soon as possible (see 0510–1, paragraph 2 Injection start and the Maintenance Manual 2722–1 Injection valve).

3.3.2 Injection Pipe

1) If an HP fuel pipe to the injection valve breaks, cut out the injection (see 0510–1 Operation with Injection Cut Out).

2) Replace the defective high pressure fuel pipe as soon as possible (see 0510–1, paragraph 2 and the Maintenance Manual 2733–1 Injection Valve).

CAUTION

Damage Hazard: If the rail pressure continues to decrease because of the leak, replace the high pressure fuel pipe immediately.

4. Defective Flow Limiter Valve

The flow limiter valve prevents a pressure release in the fuel rail if an HP fuel pipe to the fuel injectors breaks.

The flow limiter valve does not shut off the fuel flow when smaller problems cause an increase in fuel injection to the cylinder (e.g. one fuel injector closes incorrectly, or the nozzle is damaged). To make sure that the engine can continue to operate, the related cylinder must be cut out (see 0510–1, paragraph 1 Cut Out the Injection).

If the in-cylinder pressure and exhaust gas temperature of a cylinder have large differences when compared to other cylinders, the indications show that:

- The injector does not close
- The injection nozzle is damaged.

In this condition, you must cut out the related cylinder.

If the exhaust gas temperature and in-cylinder pressure continues to have large differences (after the injection is cut out), there is leakage from the injector into the cylinder.

To prevent fuel flow through the defective injector, manually select the flow limiter valve. All injectors of the related cylinder will inject the maximum fuel quantity at a specified late injection start (e.g. energize time at 20% load). This manual check is only possible below e.g. 20% load.

5. Defective Pressure Control Valve

5.1 Fault Identification

Fault identification of a defective pressure control valve (PCV) is as follows:

- The engine load decreases or the engine stops.
- The fuel system pressure is too low (alarm).
- The fuel pump supply is higher than usual or at maximum.
- You can hear a sound like a whistle when the engine operates.

5.2 Causes

The causes are as follows:

- The PCV is defective.
- The PCV has opened or has a leak.

5.3 Procedure

CAUTION

Damage Hazard: Replace the PCV only when the engine has stopped. The fuel rail must have zero pressure.

1) Stop the engine.
2) Replace the defective PCV (1, Fig. 2) as soon as possible.
3) Make sure that there is no pressure in the fuel rail (4) as follows:
    a) In the plant, set to off the fuel booster pump.
    b) Close the shut-off valves to the fuel inlet and return.
    c) Operate the button on the PCV.
    d) On the fuel rail (4), loosen the drain screw (9) a maximum of two turns.
4) Replace the defective PCV (see the Maintenance Manual 5562–1).

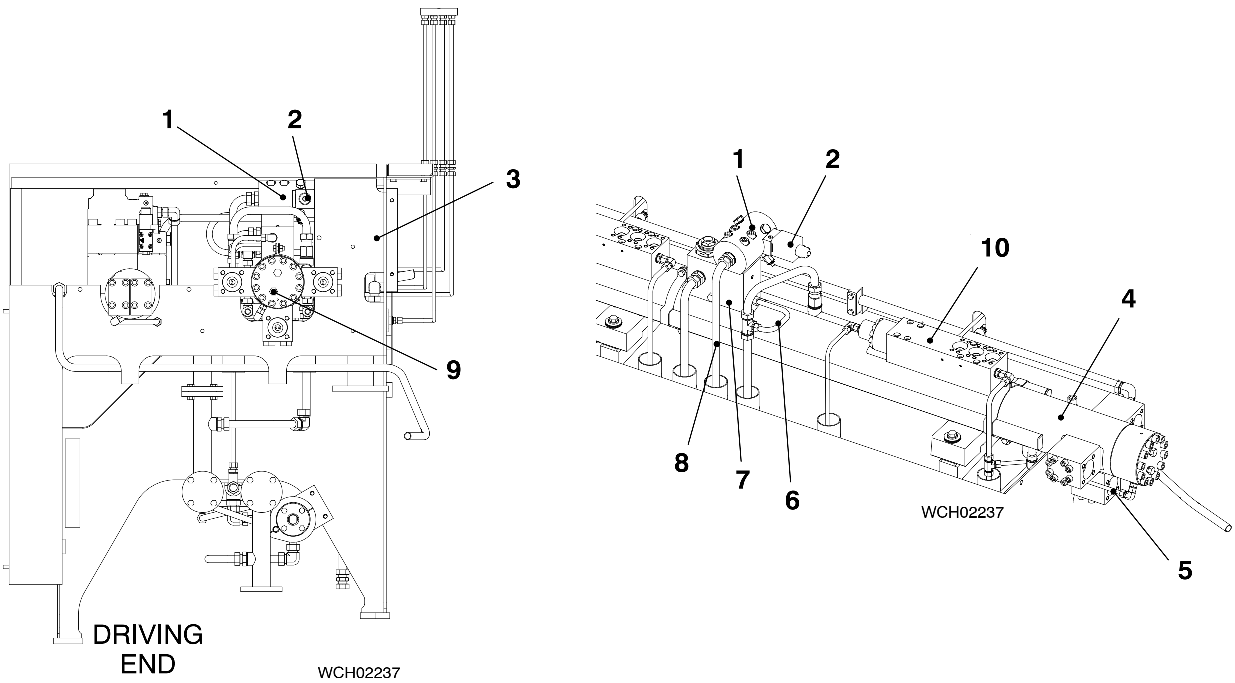

Fig. 2: Location of Pressure Control Valve

1	Pressure control valve 10-5562_E0_5	6	Fuel supply pipe
2	Solenoid valve (ZV7061S)	7	Valve block
3	Rail unit	8	Fuel return pipe
4	Fuel rail	9	Drain screw
5	Drain pipe	10	Flow limiter valve

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Operation with Exhaust Valve Control Unit Cut Out

1. General

If there is a defect in an exhaust valve control unit (VCU), on the hydraulic pipes or on an exhaust valve, you must repair the defective item immediately.

If this is not possible because the engine must continue to operate, do the procedures that follow for the related cylinder.

2. Emergency Operation with Exhaust Valve Closed

2.1 Cut Out the VCU

If the exhaust valve is defective or there is a large difference between the closing or opening time, cut out the VCU.

The exhaust valve stays closed in the emergency operation that follows:

1) Cut out the injection (see 0510−1 paragraph 1).
2) In the LDU−20 get the EXHAUST VALVES page (see 4002−2, paragraph 3.8 Exhaust valve).
3) In the column Exh. Valve pos., select 0 to set the related cylinder to automatic.
4) Disconnect the electrical connection (7, Fig. 1) from the 4/2-way valve (8) of the related cylinder.

2.2 Operation with the VCU Cut Out

After the procedure in paragraph 2.1 above is completed, the engine can operate again.

Note: With one or more VCUs cut out, you can operate the engine only at decreased load. Read and obey the data in 0500−1. Also, the exhaust gas temperature on the cylinders must not be more than the maximum limit of 515°C.

Replace the defective VCU or hydraulic pipe as soon as possible (see the Maintenance Manual 5612−1 Servo Oil Rail and 8460−1 Hydraulic Pipe for Exhaust Valve Drive).

2.3 Replace the Defective VCU or Hydraulic Pipe

1) Stop the engine.
2) Make sure that the servo oil service pump is set to off.
3) Set to off the main bearing oil supply.
4) Carefully open the screw plug (3) to release the pressure in the servo oil rail (2) (see Fig. 1).
5) Close the screw plug (3).
6) Loosen the screws (6) on the flange (5) to drain the hydraulic pipe (4) through the check bore (9) in the housing of the VCU (1).
7) Set to on the main bearing oil supply.
8) Replace the defective VCU or the hydraulic pipe (see the Maintenance Manual 5612−1 and 8460−1).

9) Connect the electrical connection (7, Fig. 1) to the 4/2-way valve (8).
10) Start the injection (see 0510–1).
11) Do a visual check for leaks.

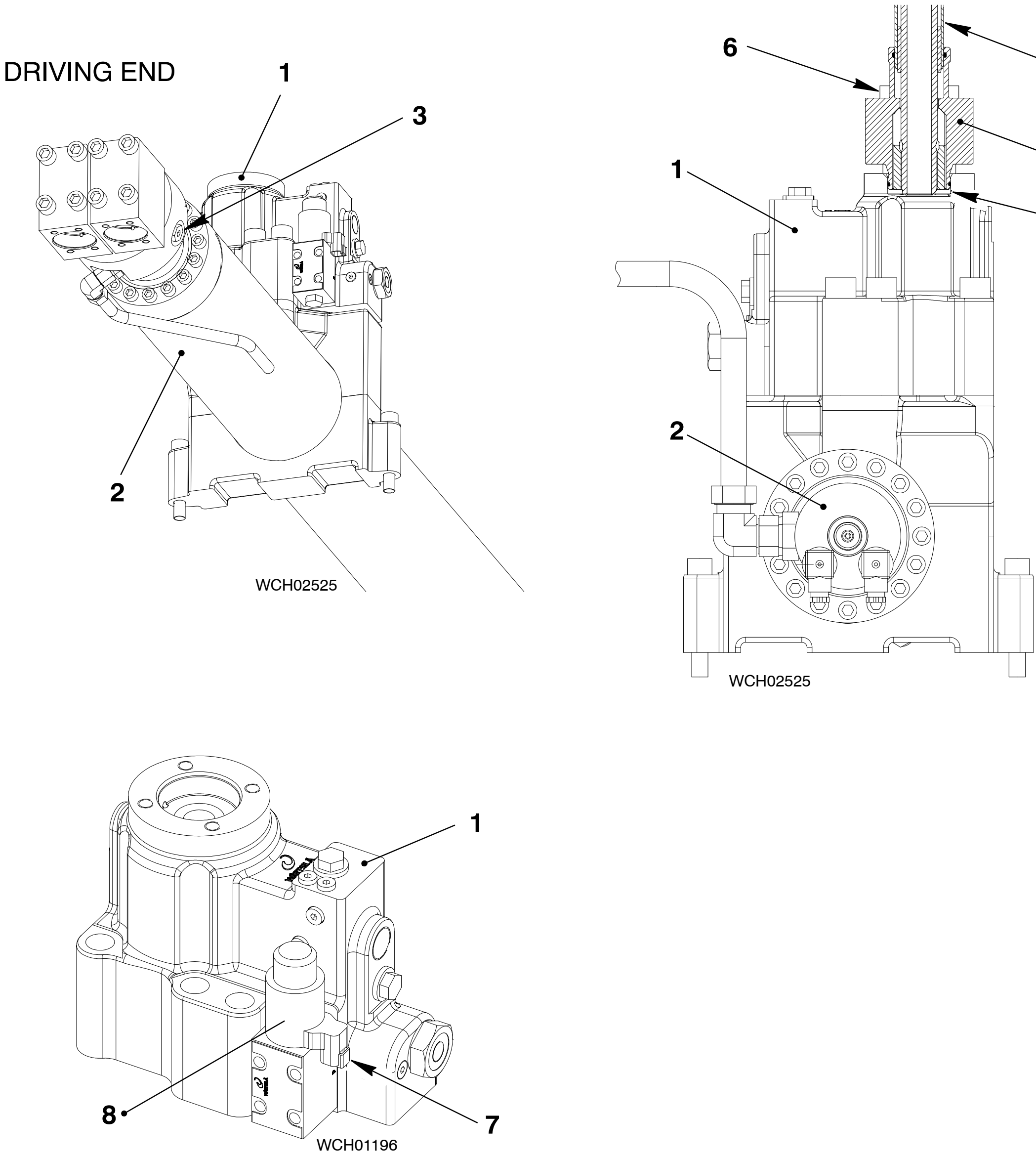

Fig. 1: Exhaust Valve Control Unit

1 Exhaust valve control unit (VCU)
2 Servo oil rail
3 Screw plug
4 Hydraulic pipe
5 Flange
6 Screw (on flange of hydraulic pipe)
7 Electrical connection
8 4/2-way valve
9 Check bore

3. Emergency Operation with Exhaust Valve Open

This mode of operation is only necessary if there is water leakage into the combustion chamber (see also 0545−1).

3.1 Exhaust Valve – Stop Operation

1) Stop the engine.
2) Make sure that the servo oil service pump is set to off.
3) Set to off the main bearing oil supply.
4) Remove the damper (1, Fig. 2) from the top housing (4).
5) Close the 3/2-way valve 35-36HA in the control air supply **A**. This releases the pressure in the air pipe to the exhaust valves and the exhaust valve stays open.
6) Apply a thin layer of oil to the thread of the pressure element (2, tool 94259).
7) Install the pressure element (2).

Note: Make sure that you do not lose the shim(s) (3). The shim(s) must stay in position when the pressure element (2) is installed.

For safety, the pressure element (2) must also be installed if an exhaust valve is caught in the open position.

8) Disconnect the electrical connection (7, Fig. 1) from the 4/2-way valve (8) of the related VCU (1).
9) Open the 3/2-way valve 35-36HA to the operation position.
10) Set to on the main bearing oil supply.
11) Disconnect the control signal connection from the starting air valve 30-2728_CX_1.

Note: The same conditions are applicable for the engine load as those given in paragraph 2.2.

12) Make sure that the faces of the valve seat and the valve head are in perfect condition (no hard dirt particles).

Note: If there are hard dirt particles on the faces of the valve seat and valve head, an overhaul is necessary. See the Maintenance Manual, 2751−3 and 2751−4.

3.2 Cut In the VCU

1) Make sure that the servo oil service pump is set to off.
2) Set to off the main bearing oil supply.
3) Close the 3/2-way valve 35-36HA in the control air supply **A** (see 4003−2 Control Diagram). This removes all of the air from the air pipe to the exhaust valves. The exhaust valve stays open.
4) Remove the pressure element (2, Fig. 2). Make sure that you do not lose the shim(s) (3).
5) Apply a thin layer of oil to the thread of the damper (1).
6) Install the damper (1).
7) Open the 3/2-way valve 35-36HA to the operation position.
8) Connect the electrical connection to the 4/2-way valve (8, Fig. 1).
9) Start the injection (see 0510−1, paragraph 2)
10) Set to on the servo oil pump.
11) Connect the control signal connection to the starting air valve 30-2728_CX_1.
12) Set to on the main bearing oil supply.

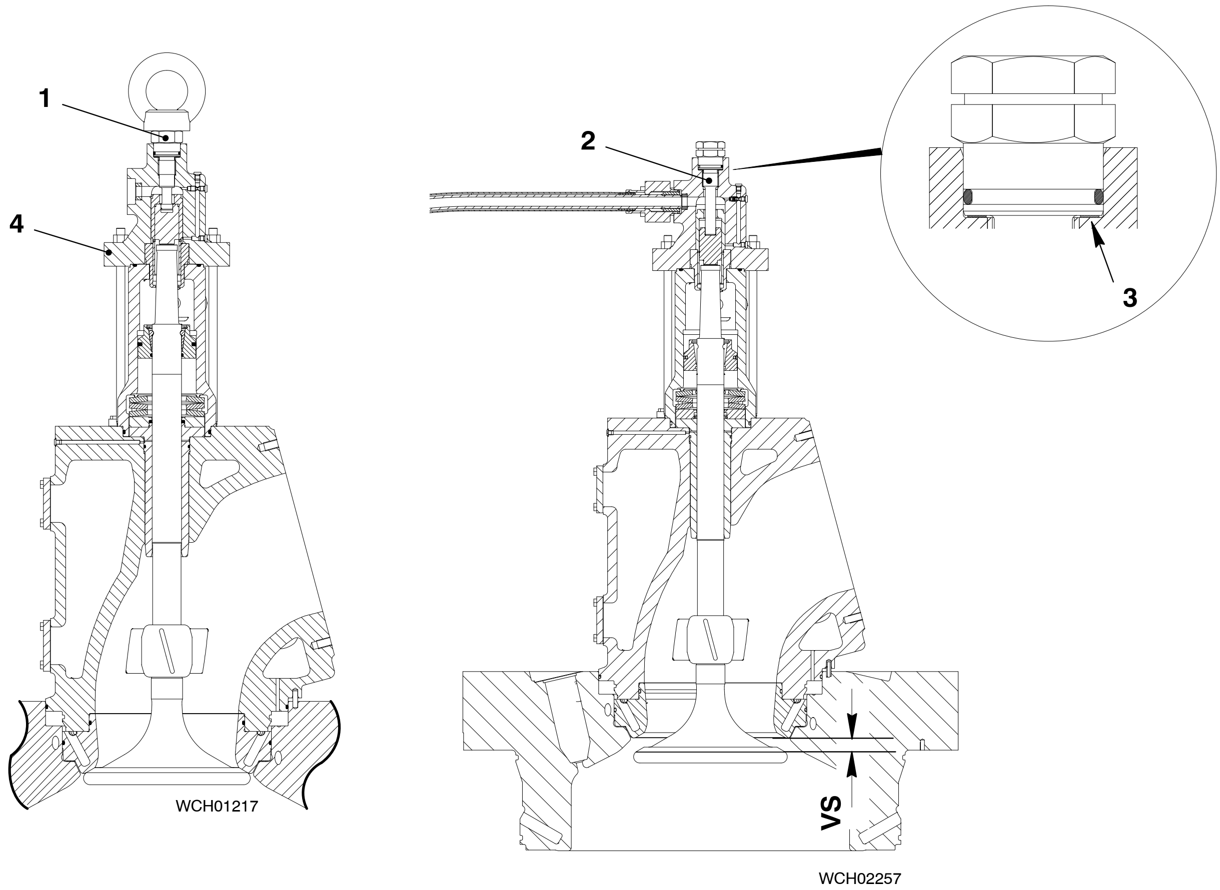

Fig. 2: Exhaust Valve / Pressure Element

1 Damper
2 Pressure element (tool 94259)
3 Shim
4 Top housing

VS Maximum exhaust valve stroke

Faults in Servo Oil System

1. Defective Servo Oil Pump

1.1 Identification

The flow sensors FS2061A and FS2062A show that a servo oil pump does not supply oil, i.e. an alarm is activated in the alarm and monitoring system (Servo oil pump No. 1 or No. 2 no flow).

1.2 Causes

- The servo oil pump has damage.
- The safety device on the pump drive has sheared.
- The actuators CV7221C and CV7222C are defective.
- There is no control current (the cable coupling is defective).

1.3 Procedure

If one servo oil pump becomes defective, the engine can operate through the full load range.

CAUTION

Damage Hazard: Do not operate the engine with one unserviceable servo oil pump for a long period. If the other servo oil pump becomes defective, damage can occur and the engine cannot operate.

1) Replace the defective servo oil pump as soon as possible (see the Maintenance Manual 5551–2 Supply Unit).

2. Defective Exhaust Valve Control Unit

2.1 Identification

- The engine control system (ECS) gives an alarm indication (see 4002–2, paragraph 3.15 Log Messages).
- The fuel injection is cut out automatically (Inj. CUT OFF) on the related cylinder, and a slow down signal is released.
- The level switch LS3444A activates an alarm because there are leakages in the hydraulic pipes to the exhaust valves (see 8016–1 Lubricating oil system, paragraph 4 Servo Oil Leakage).

2.2 Causes

- The 4/2-way valve on the exhaust valve control unit (VCU) is defective.
- The piston in the VCU, or the valve cannot move.
- A hydraulic pipe to the exhaust valve is broken.

2.2.1 4/2-way Valve – Replace

Replace the defective 4/2-way valve on the VCU as soon as possible.

1) Stop the engine.
2) Make sure that the servo oil service pump is set to off.
3) Set to off the main bearing oil supply.
4) Carefully open the screw plug (3, Fig. 1) to release the pressure in the servo oil rail (2). Make sure that the servo oil rail has no pressure.
5) Disconnect the electrical connection (7).
6) Remove the four screws (5) together with the 4/2-way valve (6).

7) In the new 4/2−way valve (6, Fig. 1), make sure that the correct new O-rings are installed.
8) Make sure that the mating surfaces of the 4/2-way valve (6) and the VCU (1) are clean.
9) Make sure that the small M6 orifice is installed in one of the four ports (P-port) in the VCU (1).
10) Put the 4/2−way valve (6) in position. Make sure that the bores are correctly aligned.
11) Tighten the four screws (5).
12) Close the screw plug (3).
13) Connect the electrical connection to the 4/2-way valve. Make sure that the connection is tight.
14) Set to on the main bearing oil supply.

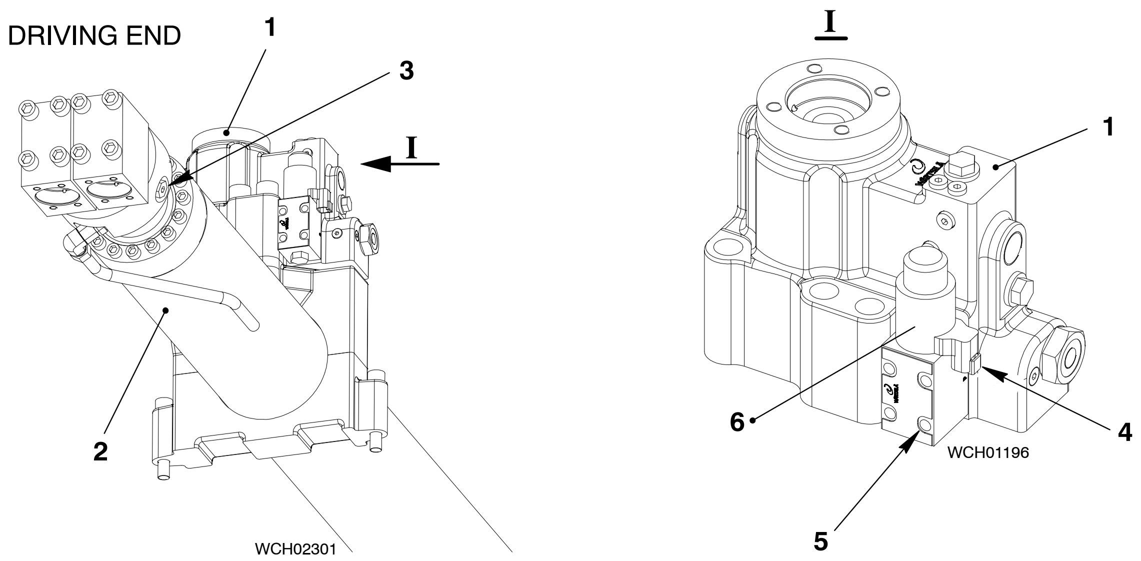

Fig. 1: Servo Oil Rail and VCU

1 Exhaust Valve control unit (VCU)
2 Servo oil rail
3 Screw plug
4 Electrical connection
5 Screw
6 4/2-way valve

2.2.2 Defective Exhaust Valve Control Unit

If the piston, or the slide rod in the VCU cannot move, shut off the VCU immediately.

See 0520−1, paragraph 2 Emergency Operation with Exhaust Valve Closed.

Note: With one or more VCU cut-out, you can operate the engine only at decreased load.

1) Replace the defective VCU as soon as possible (see 0520−1 Start the VCU and the Maintenance Manual 5612−1).

2.2.3 Hydraulic Pipe to Exhaust Valve

1) If a hydraulic pipe to the exhaust valve is broken, cut out the injection to the related cylinder (see 0510−1, paragraph 1 Cut Out the Injection).

2) Replace the defective hydraulic pipe as soon as possible (see 0520−1, paragraph 2.3. See also the Maintenance Manual 8460−1).

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CCM-20 Failure

1. CCM-20 Failure

1.1 Identification

The alarm Module Fail CCM#X shows in the engine control system (ECS). Fig. 1 shows a schematic diagram of the CCM-20 in usual configuration.

1.2 Cause

The CCM-20 of cylinder X is defective, thus the related cylinder has no lubrication.

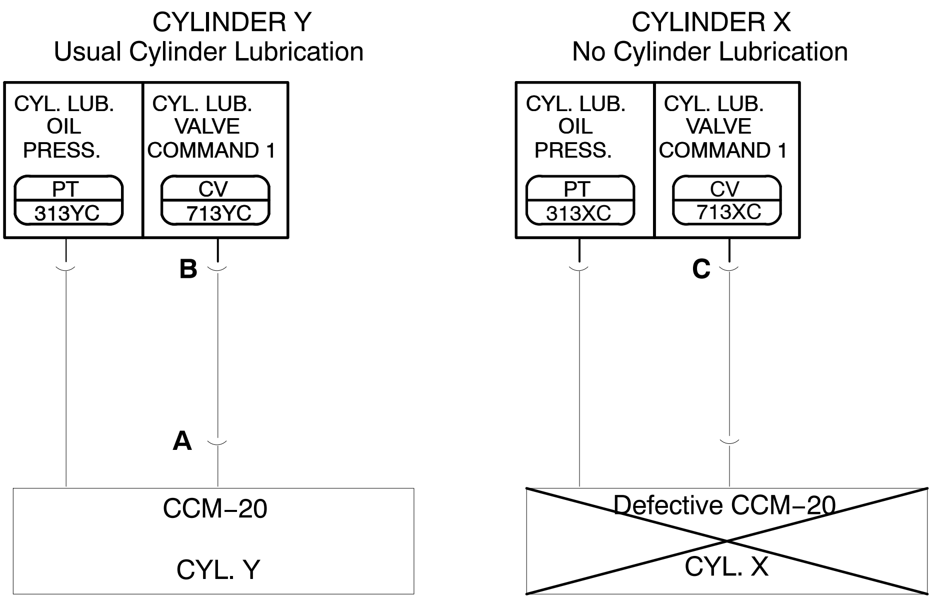


Fig. 1: Schematic Diagram − Usual Configuration

1.3 Procedure

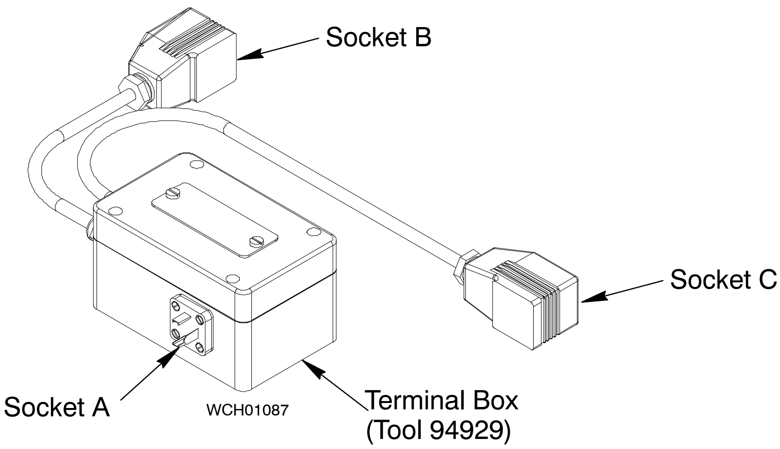
If a CCM-20 has a failure, you use the terminal box (tool 94929) to bypass the defective CCM-20 and give emergency lubrication to the related cylinder.

Do steps 1) to 7) to install the terminal box (see Fig. 1 and Fig. 2).

1) Attach the terminal box to the cylinder block near the applicable cylinder lubrication pump. The terminal box has magnets installed in the base.
2) Disconnect the connection A (from the valve CV713YC) on the cylinder lube pump on Cylinder Y.
3) Connect Socket A on the terminal box, to the connection A (valve CV713YC).
4) Connect Socket B on the terminal box to to the connection B (valve CV713YC) of the cylinder lube pump on Cylinder Y.
5) Disconnect the connection C (from the valve CV713XC) on Cylinder X.
6) Connect Socket C on the terminal box to the connection C (valve CV713XC) of the cylinder lube pump of Cylinder X.

Note: The piston that has emergency lubrication will operate, but will not fire.

7) If the defective CCM-20 operates correctly again, disconnect the terminal box and connect all valves to their related CCM-20 modules.



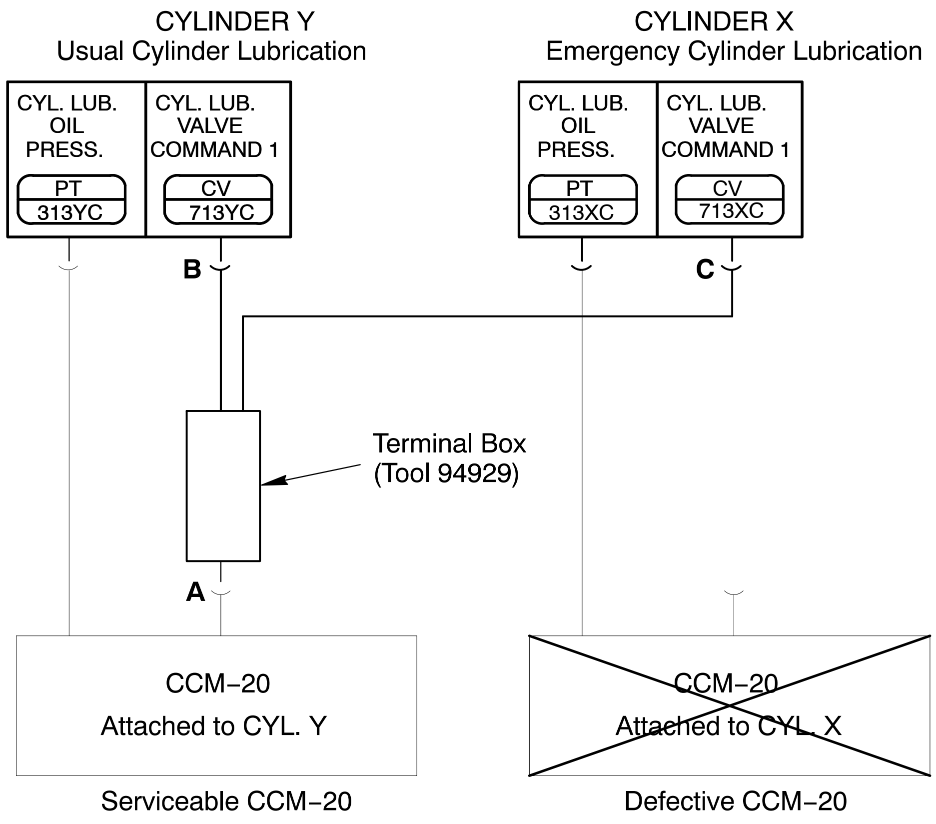
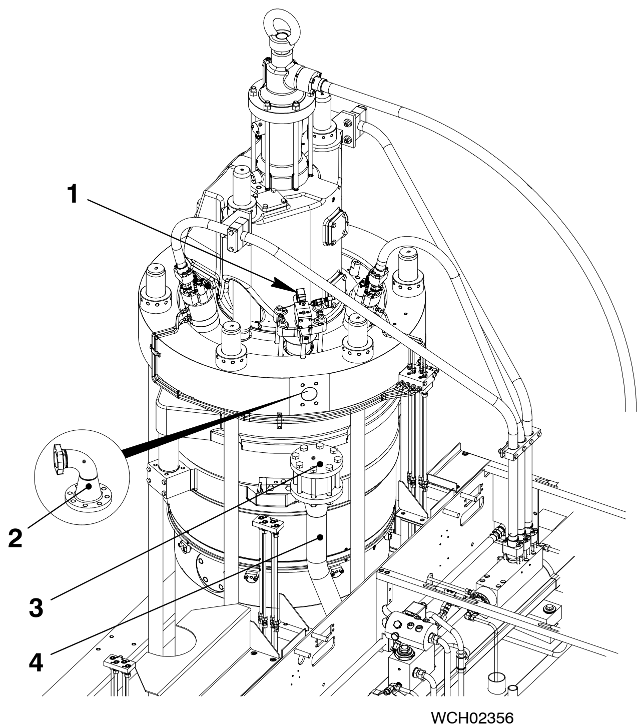


Fig. 2: Schematic Diagram − Emergency Lubrication

Operation with Running Gear Partially or Fully Removed



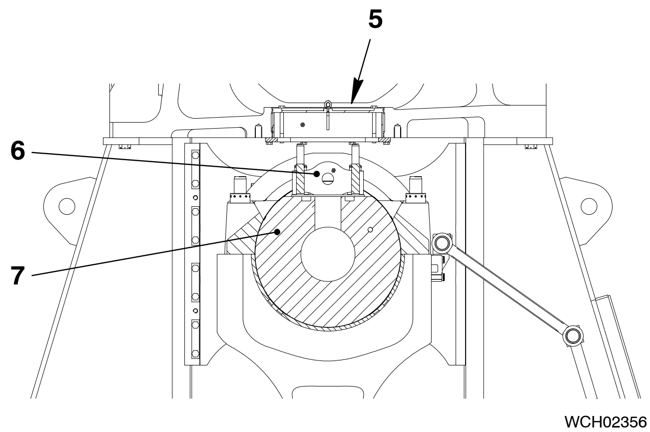


Fig. 1: Tools 9486−01 and 9423−01

1. General

If the engine must operate with a defect in the running gear, which cannot be immediately repaired, do the procedures given in paragraph 3 to paragraph 7.

Note: You can operate the engine only at decreased load.

For more data, see 0500−1, paragraph 1 to paragraph 3.

The exhaust gas temperature after cylinder must be less than the maximum limit of 515°C.

2. Piston Removed

2.1 Problems

- The piston is cracked or has a leak.
- There is damage to the piston and/or cylinder liner.
- There is damage to the piston rod gland and/or piston rod.

3. Preparation

1) Cut out the injection to the related cylinder (see 0510−1 paragraph 1).
2) Cut out the exhaust valve control unit (VCU) (see 0520−1 paragraph 2).
3) Make sure that the exhaust valve is closed (see 4002−2, paragraph 3.8).
4) If necessary, close the cooling water supply and the return pipe of the related cylinder.

4. Procedure

1) Disconnect the electrical connection from the starting air valve (1, Fig. 1).
2) Remove the elbow (2) from the starting air pipe (4).
3) Install the blank flange (3, tool 9486−01) to the starting air pipe (4).
4) Install the cover and the lifting plate (6) (tool 9433−03) on to the crosshead (7).
5) Install the cover plate (5, tool 9423−01) in the position of the piston rod gland.

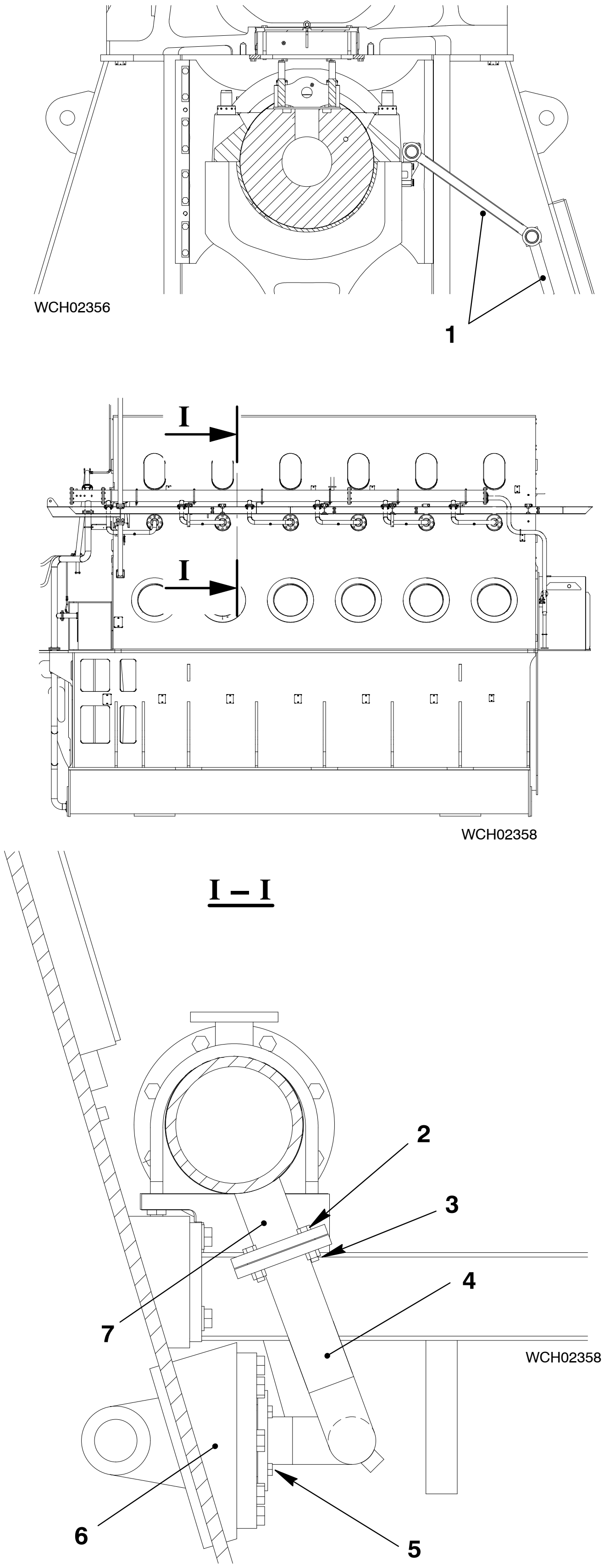


Fig. 2: Tools 9486–01 and 9423–01

5. Piston, Crosshead and Connecting Rod Removed

5.1 Problems

- The crosshead or guide shoes are defective.
- The connecting rod bearing is damaged.
- The crosshead pin or the connecting rod is defective.

6. Preparation

1) Cut out the injection to the related cylinder (see 0510–1 paragraph 1).
2) Cut out the VCU (see 0520–1 paragraph 2).
3) If necessary, close the cooling water supply and the return pipe of the related cylinder.

7. Procedure

1) Do the procedure given in paragraph 4 above.
2) Remove the top and bottom levers (1) (see Fig. 2).
3) Remove the screws (5) from the flange of the pipe (4).
4) Hold the pipe (4) and remove the nuts (3) and the screws (2).
5) Remove the pipe (4).
6) Install blanks to the oil inlet (6) and the oil supply pipe (7).

Note: You can operate the engine only at decreased speed/load. Speak to the engine manufacturer for data.

Operation with Water Leakage into the Combustion Chamber

1. General

If there is water leakage into the combustion chamber (e.g. a crack in the cylinder cover or cylinder liner) the defective part must be replaced immediately.

2. Procedures

If it is not possible to replace the defective parts but the engine must continue to operate, do the procedures on the related cylinder as given in steps 1) to 4):

1) Close the valves to the cooling water inlet and outlet of the related cylinder (isolate the cylinder from the cooling system).
2) Drain the cooling water through the drain pipe.
3) Cut out the injection (see 0510−1, paragraph 1.
4) Lock the exhaust valve in the open position (see 0520−1, paragraph 3).

Note: If the cooling flow of the cylinder is stopped, there is a risk of that the combustion chamber will overheat because of compression heat. Thus, the exhaust valve must be opened to prevent damage to other components.

After the procedures above are completed, the engine cannot operate at full load.

Read the data in 0500−1 General Information. Also, make sure that the exhaust gas temperature is not more than 515°C on each cylinder.

Do not operate the engine for a long period after the emergency procedures are completed.

The defective cylinder cover or cylinder liner must be replaced as soon as possible.

When the engine is serviceable again, see the procedures in 0230−1 Engine Start.

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Defective Scavenge Air Cooler / Defective Auxiliary Blowers

1. Defective Scavenge Air Cooler

When a scavenge air cooler (SAC) is defective, water can go into the scavenge air receiver. The water then goes out through the condensate collector of the SAC drain. The related level switch activates an alarm.

Note: If you see water flow through the sight glass of the SAC drain when the engine has stopped, do a check for defects as soon as possible.

If there is a fault in the SAC, it is recommended that you do the procedure given in step 1) to step 4).

1) Replace the defective SAC with the spare as soon as possible.

Note: Step 2) is only possible with a dual-system of coolers and turbochargers.

2) Shut down and drain the defective SAC.

3) Seal the cooling water supply and return pipes of the defective SAC.

4) Open the vent and drain valves. The vent and drain valves must stay open.

Leakage water that goes into the receiver flows away through the drain pipes of the SAC and water separator into the collection pipe.

During operation in this mode, the scavenge air temperature and exhaust gas temperature will increase.

You can only increase the load on the engine so that the scavenge air temperature (measured downstream of the SAC) is not more than the usual limit at service output. You must continuously and carefully monitor the scavenge air temperature.

If the scavenge air temperature increase is too high, the engine speed must be decreased (for the maximum permitted scavenge air temperature downstream of the cooler, see 0250−2 Alarms and Safeguards).

Note: In these conditions, you can operate the engine only at approximately 25% load.

2. Defective Auxiliary Blowers

If one of the auxiliary blowers becomes defective, you can start and operate the engine. At less than full load, there will be more exhaust smoke.

If the two auxiliary blowers become defective, the engine cannot start.

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Defective Remote Control

1. General

If a fault occurs in the remote control, which prevents engine control from the control room, you can operate the engine from the local control panel.

The data are given in the groups that follow:

- 0230–1 Engine Start
- 0260–1 Maneuvering
- 0310–1 Engine Shutdown
- 0320–1 Procedures after Engine Stop
- 4003–1, paragraph 3 Engine Local Control
- 4002–2 Local Control Panel/ Local Display Unit (LDU–20).

CAUTION

Damage Hazard: You must only operate the engine during unusual conditions when necessary. You must not leave the maneuvering stand. You must monitor the engine speed frequently to make sure that procedures are immediately done if large differences in engine speed occur.

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Defective Speed Control System

1. General

Defects in the speed control system must be repaired as soon as possible. If this is not possible, you can control the engine from the local control panel.

If the fuel command signal from the speed control system is missing during engine operation, the speed control system will continue to operate. The last known fuel command will be used.

The data are given in the groups that follow:

- 0230–1 Starting
- 0260–1 Maneuvering
- 0310–1 Engine Shutdown
- 0320–1 Procedures after Engine Stop
- 4003–1, paragraph 3 Engine local control
- 4002–2 Local Control Panel/ Local Display Unit (LDU–20).

CAUTION

Damage Hazard: You must only operate the engine during unusual conditions when necessary. You must not leave the maneuvering stand. You must monitor the engine speed frequently to make sure that procedures are immediately done if large differences in engine speed occur.

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Defective Turbocharger

1. General

If a turbocharger becomes defective, you must shut down the engine as quickly as possible to prevent damage.

If repair or replacement of a turbocharger is not immediately possible, the engine can operate in Emergency Operation at decreased load after the procedure below is completed.

In Emergency Operation, you must operate the engine only for as long as necessary (see 0500–1, paragraph 2 Decreased Power Output).

The loads (outputs) given are guidance values, which are related to the condition of the engine. It is possible that these values will be decreased.

2. Defective Conditions

2.1 Condition One

One turbocharger is defective.

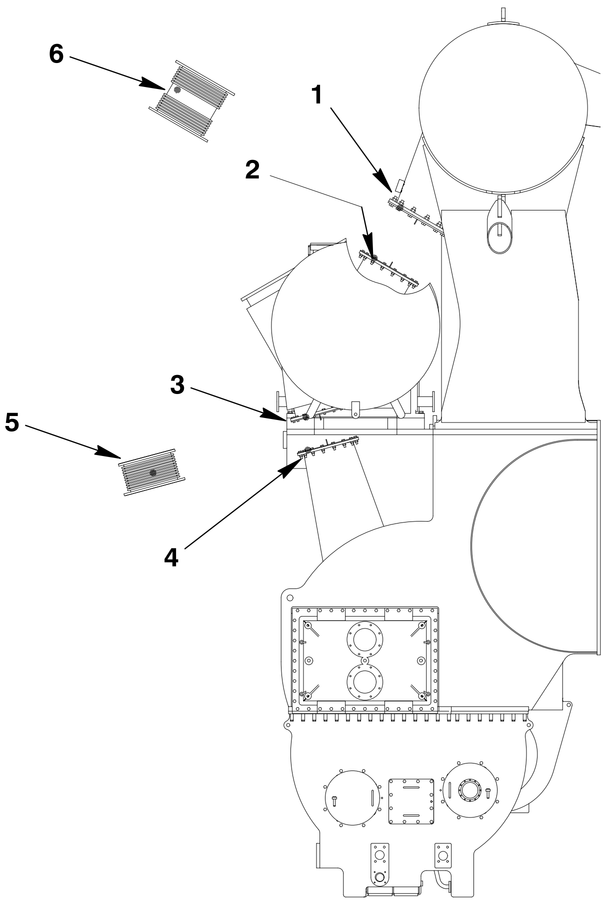


Fig. 1: Defective Condition One

2.1.1 Procedure

The engine load output is approximately 50% of the CMCR. This is related to the output of the auxiliary blowers.

1) Lock the rotor of the turbocharger (see the turbocharger manual).
2) Remove the expansion joint (6, Fig. 1) from the defective turbocharger and the exhaust manifold.
3) Install the blind flanges (1) and (2, tool 94653).
4) Remove the expansion joint (5) from the defective turbocharger air outlet and the diffusor.

Note: Install the blind flange (3) only if air flows in through a suction duct.

5) Install the blind flanges (3, tool 94655) and (4, tool 94653).

The scavenge air pressure, turbocharger speed and firing pressures must not be higher than during usual operation.

Note: Before you start the turbocharger, make sure that you remove the plugs from the oil supply pipes.

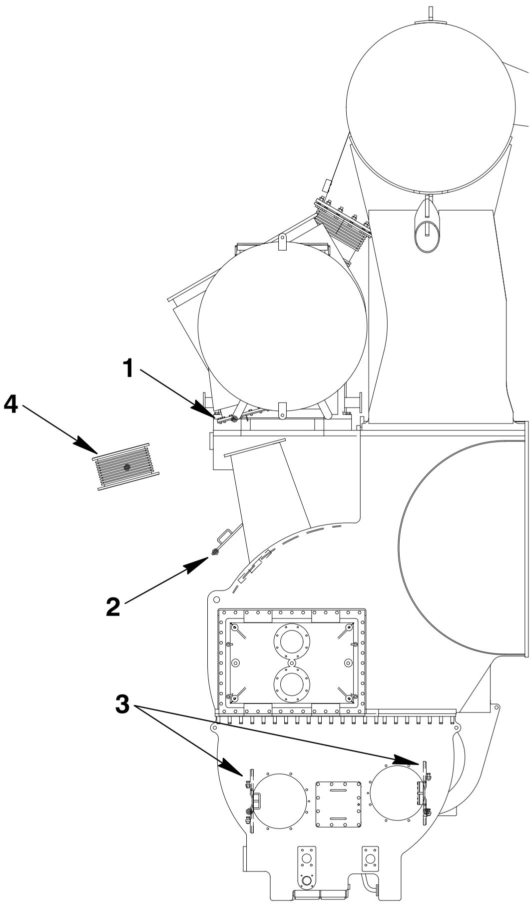


Fig. 2: Defective Condition Two

2.2 Condition Two

All turbochargers are defective.

The engine load output is approximately 10% to 15% of the CMCR. This is related to the output of the auxiliary blowers.

2.2.1 Procedure

1) Lock the rotor of the defective turbocharger (see the turbocharger manual).
2) Remove the expansion joint (4, Fig. 2) from the turbocharger air outlet and the diffuser.
3) Install the blind flange (1, tool 94655).
4) Open the covers (2) and (3) on the scavenge air receiver.

Note: Install the blind flange (1) only if air flows in through a suction duct.

5) Set to on the auxiliary blowers.

The exhaust gas temperature upstream of the turbocharger must not be higher than during usual operation. Thick, black exhaust smoke must be prevented.

Prepare for Engine Start after a Long Shutdown Period or an Overhaul

1. General

For an engine that that was shut down after a long period or an overhaul, do the special procedures in paragraph 2.

Note: If the engine was shut down only for some days, you must do the procedures given in 0110−1 Prepare for Engine Start after a Short Shutdown Period.

2. Special Procedures

1) Do a check of the engine control as given in 4003−1, paragraph 4.
2) If bearings or parts of the running gear were replaced or removed (for checks), do a check of the the lubricating oil supply at the usual oil pressure (see 0250−1 Operating Data Sheet).
3) Do a visual check through the open running gear doors to see if there is sufficient oil flow from all bearing locations.

During the operation period, it is recommended that you monitor the parts for unusual heat. You monitor the parts as follows:

4) Start and stop the engine for short intervals (see 0210−1 Temperature, paragraph 9).
5) Compare the temperatures of the newest parts with those that were installed before.
6) Start and stop the engine for longer intervals.
7) Compare the temperature again as given in steps 4) to 6).

Note: For data about running-in new pistons, piston rings and cylinder liners, see 0410−1 Running-in New Cylinder Liners and Piston Rings.

8) Make sure that the scavenge air and exhaust gas can flow freely.
9) If the cooling water for the scavenge air cooler was drained, fill and bleed the system.
10) Make sure that the drains in the exhaust gas manifold and on the exhaust gas pipe are closed.
11) Make an analysis of the lubricating oil quality after a long shutdown period (some months), see 0750−1 Lubricating Oils.

Intentionally blank

Prepare the Engine for a Long Shutdown Period

1. General

When you prepare the engine for a long shutdown period, make sure that you know the correct precautions to protect the engine from corrosion. There are two conditions as follows:

- Condition One has the procedures for when there is less crew on board for a period of some weeks.
- Condition Two has the procedures when for some months there is no crew on board.

2. Condition One

2.1 Procedure

Note: It is recommended that you operate the engine on diesel oil as an alternative to heavy fuel oil for some time before engine shutdown (see Change–over from Diesel Oil to Heavy Fuel Oil and Back 0270–1).

Note: The numbers (e.g. 30-8605_E0_7) refer to items shown in the control diagrams 4003–2 and 4003–3.

1) Close the stop valves on the starting air bottles.
2) Turn the handwheel on the starting air shut-off valve 30-4325_E0_1 to the position CLOSED.
3) Open the ball valves 30-8605_E0_6 and 30-8605_E0_7.
4) Make sure that the pressure gages show zero pressure.

WARNING
Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel.

5) Engage the turning gear.

Note: The water and oil pumps must operate for a minimum of 20 minutes after the engine has stopped. This is to make sure that when the engine temperature has decreased, the temperature of engine parts become as stable as possible.

6) Open the indicator valves on the cylinder covers.

Post-lubrication starts automatically during the slow-down of the engine.

7) Close the stop valves on the fuel tanks.
8) Open the drain valves of the exhaust gas manifold and on the exhaust gas pipe to drain the condensate.
9) Close the drain valves of the exhaust gas manifold and the exhaust gas pipe.
10) Put a cover (e.g. a tarpaulin) on the exhaust gas manifold and the turbocharger silencer to make an airtight seal. This will prevent a flow of air through the engine and thus condensation.
11) For the scavenge air coolers (SAC), see the recommended procedures in the documentation of the manufacturer. If this is not available, it is recommended that the SAC are fully drained, or the cooling water pump is operated daily for approximately 30 minutes (with the flow quantity control valves in the same position as for usual operation conditions).
12) Keep the cylinder cooling water at approximately room temperature (monitor the temperature for a risk of frost).

13) Repair all the damage and leaks found during the previous operation period and the checks made after shut-down.
14) Do all scheduled overhauls and obey the general guidelines for maintenance (see the Maintenance Manual 0011–1 and 0012–1).
15) When the auxiliary engines and boilers do not operate and there is risk of frost, fully drain all of the cooling systems (in such conditions, protect the drained systems from corrosion).
16) In the power supply box E85, set to off the circuit breaker to disconnect electrical power to the engine control system (ECS).
17) In less than 48 hours after you have completed the steps 1) to 16), do step 18) below.
18) Open the covers on the rail unit and look for signs of condensation and corrosion.

2.2 Procedures and Checks

WARNING

Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel.

Do steps 1) to 13) below each week:

1) Make sure that the indicator valves are open.
2) use the turning gear to turn the engine until the piston is at 60° before or after TDC (look on the flywheel). Cylinder lubricating oil can then flow directly into the piston ring pack.
3) In the LDU–20, get the MAIN page (see 4002–2, paragraph 3.3).
4) Use the rotary button to select Cylinder Lubrication. The display shows the CYL. LUBRICATION page.
5) In the Manual Lub. To Cyl. # field, select the applicable cylinder number.

Note: The lubricating oil pump and must operate (see 0140–1 Prepare the Cylinder Lubricating System and 7218–1 Cylinder Lubrication).

6) Use the turning gear to turn the engine two full turns to apply the cylinder lubricating oil to the cylinder liner wall.

The recommended intervals are:

- Weekly in dry climates
- Daily in damp climates.

7) Stop the engine each time in a different position.
8) Open the covers on the rail unit and look for signs of condensation and corrosion.
9) If there are signs of corrosion, carefully clean the affected parts.
10) Apply an anti-corrosion oil to give protection.
11) Decrease the intervals of post-lubrication.
12) Apply oil as a spray to the dry parts.

Do the step below every two weeks:

1) Start the auxiliary blowers for a short time to protect the bearings from corrosion. If this is not possible, manually turn the impeller several times.

3. Condition Two

If the engine must stop for a long period, it must be thoroughly cleaned and preserved on the inside and the outside (ask for the preserving instructions from Wärtsilä Services Switzerland Ltd or Winterthur Gas & Diesel Ltd).

Diesel Engine Fuels

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 Wärtsilä engines with some limits. Wärtsilä 2-stroke diesel engines are designed to operate on up to 700 mm^2/s (cSt) at 50°viscosity heavy fuel oil (ISO 8217:2010 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 be treated 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 fourth edition dated 15 June 2010.

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 8217:2010 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.

The engine inlet fuel quality uses the latest ISO 8217:2010 specification. Bunkers that comply with ISO 8217:2005 can be used until the latest ISO specification is fully released. In such conditions, the higher values for carbon residue and vanadium can be satisfactory.

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

Table 1: Fuel Specifications

Parameter	Unit	Bunker Limit	Test Method	Necessary Fuel Quality at Engine Inlet
Kinematic viscosity at 50°C	mm^2/s [cSt]	Maximum 700	ISO 3104	13 to 17 [2)]
Density at 15°C	kg/m^3	Maximum 1010 [3)]	ISO 3675/12185	Maximum 1010
CCAI	–	870	Calculated	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 0,150	ISO 6245	Maximum 0,150
Vanadium	mg/kg [ppm]	Maximum 450	ISO 14597/ IP501/470	Maximum 450
Sodium	mg/kg [ppm]	100	IP501/IP470	Maximum 30
Aluminum plus Silicon	mg/kg [ppm]	Maximum 60	ISO 10478/ IP501/470	Maximum 15
Used lubricating oils (ULO) may not be present: Calcium and zinc 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 8217:2012 [1)]				

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

- 1 mm^2/s=1cSt (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 13 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/m3 if the fuel treatment plant cannot remove water from high-density fuel.
- [4)] ISO 8217:2010, RMK700. Note that lower sulphur limits can apply and are related to statutory specifications and sulphur limits not given in ISO 8217:2010.
- [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.

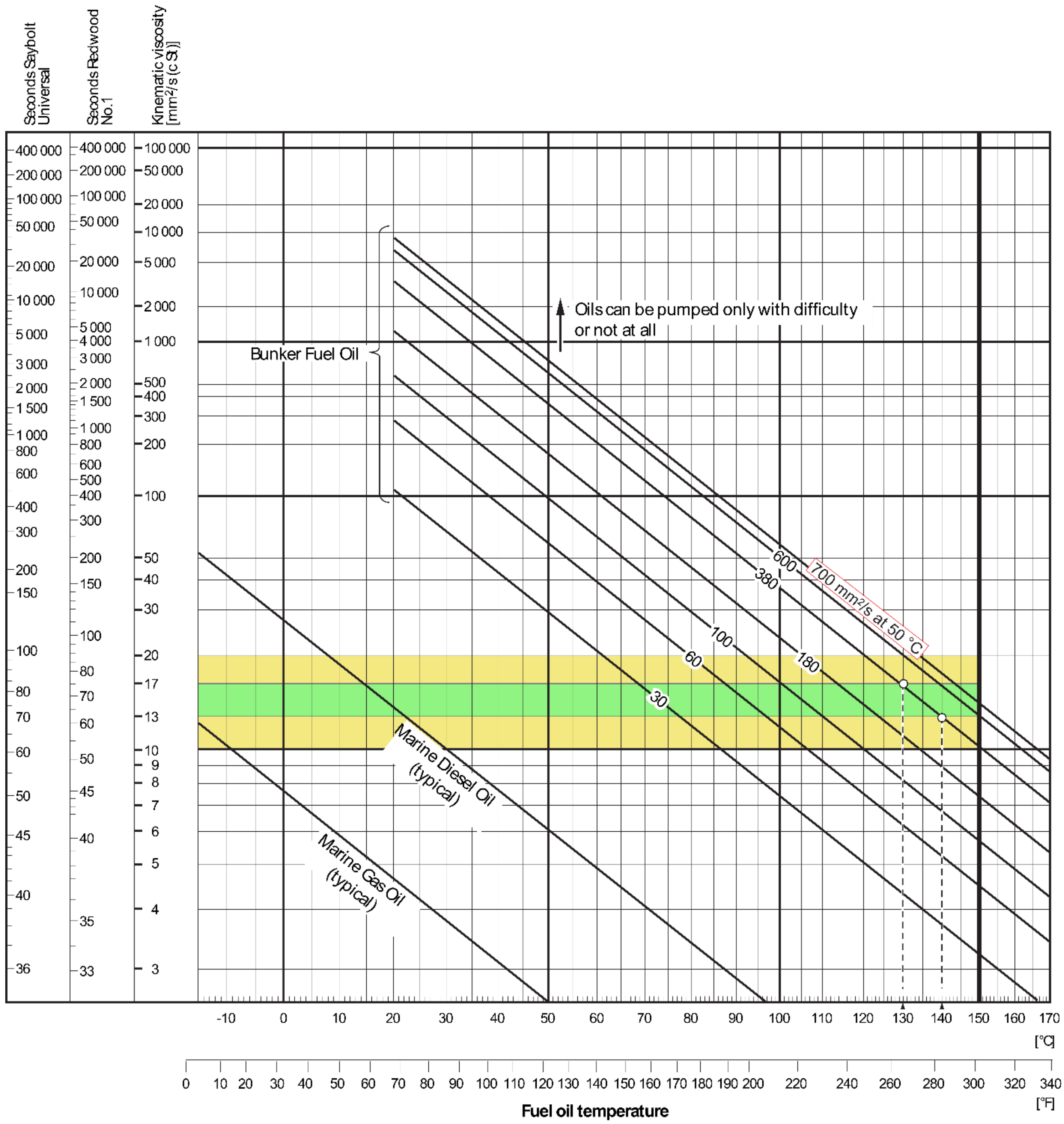
Note: For data about the parameters given in the table above, see paragraph 3.1 to paragraph 3.12.

CAUTION
Damage Hazard: For Wärtsilä 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 0250–1 Operation Data Sheet.

3. Data about Heavy Fuel Oil Specifications

3.1 Viscosity

The recommended viscosity range upstream of the engine is between 13 mm^2/s (cSt) and 17 mm^2/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 mm^2/s [cSt] at 50°C must be heated to between 130°C and 140°C.

WCH03126

Fig. 1: Viscosity / Temperature Diagram

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 8217:2010 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 Calculated Carbon Aromaticity Index (CCAI)

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 8217:2010 because statutory specifications put a limit on this value. The maximum sulphur level that can be used in Wärtsilä 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 cylinder liners and 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 because there can be flammable vapors above the remaining fuel in the tanks. There must be caution on ships when the remaining fuel is heated to above the flash point to help with the filter process and injection.

3.6 Hydrogen Sulphide

WARNING

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 and 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 to 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 damage the turbocharger, exhaust system and boilers. Ash modifiers can correct the effect of high-temperature corrosion and particles.

3.11.2 Aluminum 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 8217:2010 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: 2010 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 to block filters. They can also cause damage to fuel injection systems and cause fuel pump plungers and injectors to stop.

4. Distillate Fuel Specifications

Note: For data about the parameters given in Table 2, see paragraphs 5.1 to 5.12.

Table 2: Fuel Specifications

Parameter	Unit	Bunker Limit	Test Method	Necessary Fuel Quality at the 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 900.0	ISO 3675/12185	Maximum 900.0
Cetane index	–	Minimum 35	ISO 4264	Minimum 35
Sulphur 1)	m/m [%]	2.0	ISO 8754/14596	Maximum 2.0
Flash point	°C	Minimum 60.0	ISO 2719	Minimum 60.0
Hydrogen sulphide 2)	mg/kg	Maximum 2.00	IP 570	Maximum 2.00
Acid number	mg KOH/g	Maximum 0.50	ASTM D 664	Maximum 0.50
Total sediment by hot filtration	m/m [%]	Maximum 0.10	ISO 10307−1	Maximum 0.10
Oxidation stability	g/m^3	Maximum 25	ISO 12205	Maximum 25
Carbon residue: micro method on 10% volume distillation residue (for grades DMX, DMA and DMZ)	m/m %	Maximum 0.30	ISO 10370	–
Carbon residue: micro method (grade DMB)	m/m %	Maximum 0.30	ISO 10370	Maximum 0.30
Pour point (upper) winter 3)	°C	Maximum −6	ISO 3016	Maximum 0
Pour point (upper) summer	°C	Maximum 6	ISO 3016	Maximum 6
Water	v/v [%]	Maximum 0.30	ISO 3733	Maximum 0.20
Ash	m/m [%]	Maximum 0,010	ISO 6245	Maximum 0.010
Lubricity, corrected wear scar diameter (wsd 1.4) at 60°C	μm	Maximum 520	–	–
Winterthur Gas & Diesel Ltd. distillate fuel specifications and quality limits at the engine inlet related to ISO 8217:2012				

The notes that follow relate to data in Table 2:

- $1 mm^2/s = 1 cSt$
- 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: 2010 specifies DMX, DMA, DMZ and DMB categories. The Wärtsilä 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 8217:2010 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

WARNING

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.

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 to 10°C above the pour point to make sure that the fuel is pumped easily. It is possible that in extremely 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 Contamination

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 to 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

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.

Where FAME is used as a fuel, make sure that the on board storage, handling, treatment, service and machinery systems can be used with such a product.

7. Fuel Additives

Usually, fuel additives are not necessary to make sure of the satisfactory operation of fuels that obey the ISO 8217:2010 standard. But some operators can use specified additives to change the effect of some fuel properties. Wärtsilä Services Switzerland Ltd. can make an analysis of such additives and supply a No Objection Letter for specified additives if they are in the limits of internal specifications.

Note: Winterthur Gas & Diesel Ltd. and Wärtsilä Services Switzerland Ltd. do not accept liability or responsibility for the performance or potential damage caused by the use of such additives.

Fuel Treatment and Fuel 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 HFO 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. HFO and Diesel Fuel 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. Configuration of the Fuel 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. 1.

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.

Note: 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 Fig. 1

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

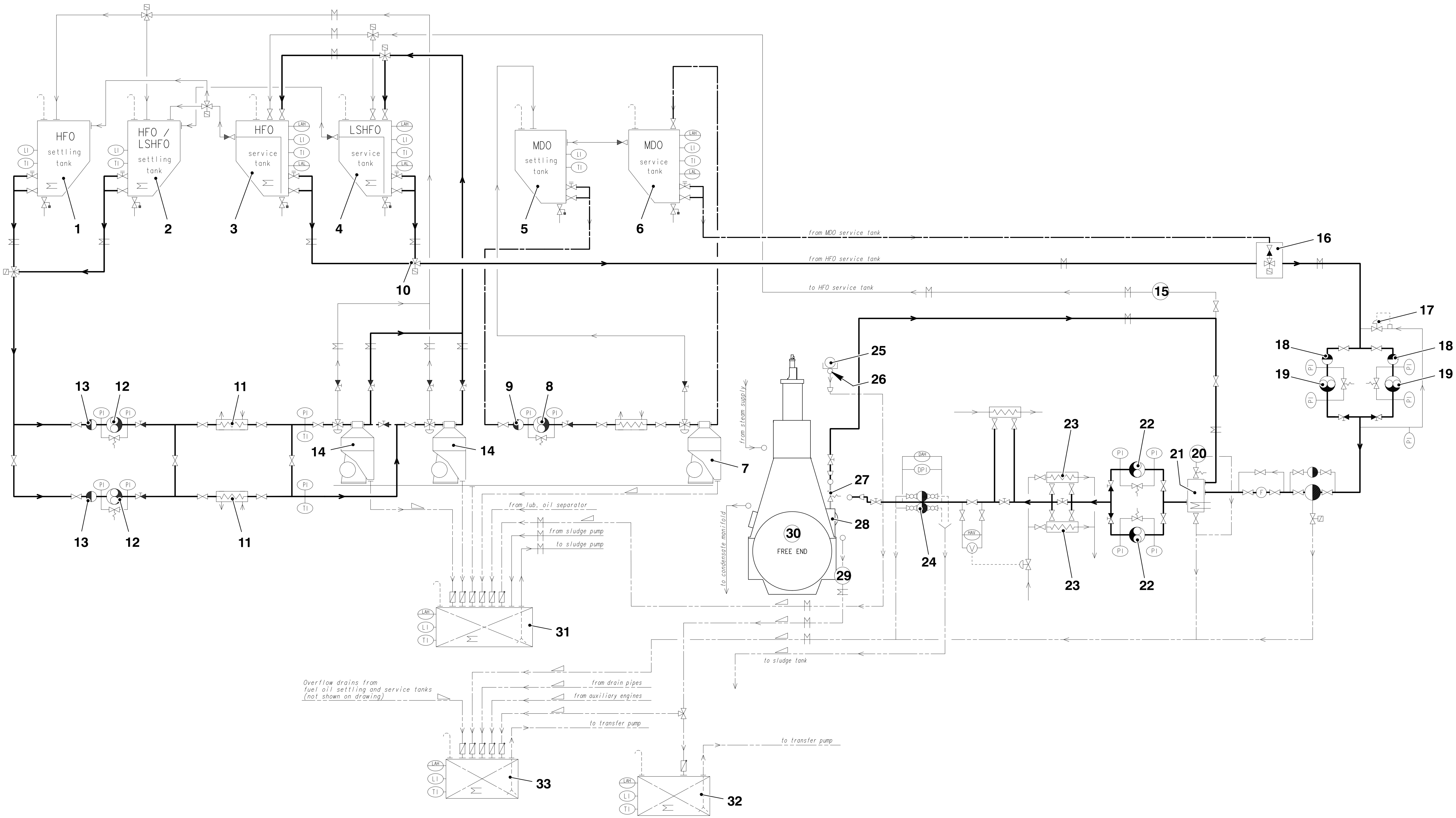


Fig. 1: Schematic Diagram – Fuel System

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Scavenge Air and Starting Air

1. Scavenge Air

The turbocharger compresses the air from the engine room or from outside for the scavenge air and air for the cylinders, (see 6500–1 Turbocharging).

The air must be as clean as possible to keep the wear of cylinder liner, piston rings, turbocharger compressor etc. to a minimum. Silencers are installed to the suction part. The silencers have filter mats in them, which help to keep the air clean.

The filter mats must be serviced and/or cleaned regularly (see the turbocharger manual).

2. Starting Air / Control Air

2.1 Starting Air

Compressors pressurize the air in the starting air bottles to a maximum of 30 bar. The starting air from the starting air bottles flows directly into the cylinder. This air must be clean and dry. The starting air bottles must be drained regularly to remove condensation (see 8018–1 Starting Air Diagram).

2.2 Control Air

The control air and air spring air supplied from the shipboard system must be clean and dry.

If no air comes from the control air board supply, compressed air at decreased pressure is available from the starting air supply (see 4003–2 Control Diagram).

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Lubricating Oils

1. General

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

2. System Oil

System oil lubricates the bearings, the running parts of the engine and the crosshead assembly. System oil is also used as hydraulic fluid in the servo oil system of the engine and used to cool the pistons (see 8016–1 Lubricating oil system).

The system oil must have the properties that follow:

- An additive-type crankcase oil of the SAE 30 viscosity grade must be used as system oil.
- The oil must have a minimum base number (BN) of 5.0 mg KOH/g and detergent properties.
- The oil must have the load carrying performance from the FZG gear machine test method A/8.3/90 in accordance with ISO 14635–1, failure load stage 11 as a minimum.
- The oil must also have good thermal stability, anti-corrosion and anti-foam properties, and good demulsifying performance.

Note: Validated system oils for WinGD 2-stroke engines are shown in paragraph 8.2. For different or new lubricating oils, speak to or send a message to WinGD.

2.1 Oil Care

2.1.1 System Oil

To keep the lubricating oil in good condition for long periods, good oil treatment is necessary. To do this, a self-cleaning centrifugal separator is used.

A self-cleaning centrifugal separator is used as a purifier in bypass. The oil flows from the oil tank through the centrifugal separator. The system oil flow rate through the centrifugal separator is set by the manufacturer of the centrifugal separator. The recommended oil temperature for this treatment is 95°C unless otherwise recommended by the centrifugal separator supplier.

Solid contaminants (dirt) and water must be removed from the oil as completely as possible. There is always a risk that water, specially sea water, can enter the system and cause corrosion on engine parts. Water contamination can also cause bacterial infection of the oil, which causes a decrease in lubrication and heavy corrosion of the system. Good maintenance is the best precaution to keep water out of the oil. The water content of the lubricating oil must not be more than 0.2% by mass during a long period. If higher water contamination is seen, special procedures such as treatment in the centrifugal separator, or in a renovating tank must be done.

2.1.2 Servo Oil

To increase the lifetime of the sliding parts, fine-filtered oil is used in the servo oil system. This fine-filtered oil, which is divided from the system oil, flows through an automatic filter which flushes back to the system oil.

The process and the low differential pressure must be monitored during the operation of the automatic filter (see 0240−1, Usual Operation and documentation of the automatic filter manufacturer).

The bypass filter element can be used temporarily to inspect and clean the standard filter elements, or if these must be removed.

Make sure that the coarse and fine filters of the servo oil system are serviceable. For more data, see the documentation of the fine filter manufacturer and paragraph 2.3.2.

2.2 Limits for Selected System Oil Parameters

You make an analysis of the selected parameters to estimate the condition of the lubricating system oil. Regular checks can find deterioration early and procedures can be done to correct the problems.

Make sure that the limits of the system oil are not more than those given in Table 1 for long periods in service.

Table 1: Alert Limits of System Oil Parameters

Parameter	Limit	Test Method
Viscosity at 40°C	Maximum 140 mm^2/s [cSt]	ASTM D 445
Flash point (PMCC)	Minimum 200°C	ASTM D 92
Total insolubles	Maximum 0.70% m/m [1)]	ASTM D 893b
Base Number (BN)	Maximum 12 mg KOH/g	ASTM D 2896
Water content	Maximum 0.20% m/m	ASTM D 95 or ASTM D 1744
FZG gear machine test	Minimum failure load stage 9	ISO 14635-1 (test method A/8.3/90)

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.

If one of the limits of the system oil is at a value given in the table above, applicable procedures must be done to correct the problem. Such procedures can be purification (decrease of the flow rate, adjustment of temperatures), treatment in a renovating tank (settling tank) or partial exchange of the oil charge. It is recommended that you speak to the oil supplier in such a condition.

The oil condemnation limits are given in Table 2. If the oil condition has so much deterioration that the purifier and filters cannot make the condition better, some of the oil charge must be replaced. The oil charge will then go back to a satisfactory performance level.

Table 2: Condemnation Limits

Parameter	Limit	Test Method
Viscosity at 40°C	Maximum 150 mm^2/s [cSt]	ASTM D 445
Flash point (PMCC)	Minimum 180°C	ASTM D 92
Total insolubles	Maximum 1.0% m/m	ASTM D 893b
Base Number (BN)	Maximum 15 mg KOH/g	ASTM D 2896
Water content	Maximum 0.30% m/m	ASTM D 95
Strong Acid Number (SAN)	nil mg KOH/g	ASTM D 664
Calcium	Maximum 6000 mg/kg [ppm]	ICP
Zinc	Minimum 100 mg/kg [ppm]	ICP
Phosphorous	Minimum 100 mg/kg [ppm]	ICP
FZG gear machine test	Minimum failure load stage 8	ISO 14635-1 (test method A/8.3/90)

These limits are a guide. The condition of the oil in the system cannot be fully calculated by one parameter. Other oil parameters must be used to find the cause of the problem, and the applicable treatment.

If the Base Number (BN) of the system oil increases suddenly, do a check of the piston rod gland box and piston rod condition.

Some consumption and replenishment of the system oil is necessary to keep the oil in good condition.

If there is an important decrease in the flash point below the recommended value shown above, WinGD recommends a replenishment of the oil charge.

By a replenishment, an increase in the system oil BN is prevented. A small increase in BN is often an indication that the system oil consumption is low.

The open cup type of flash point test procedure (e.g. COC) must be used to decide if some of the oil, or a full oil change is necessary. The closed cup type of flash point test procedure (e.g. PMCC) can be used to monitor the system oil condition, but not for oil change.

The FZG gear machine performance test (method A/8.3/90, ISO 14635−1) of the oil is important if a new gear wheel is installed or was polished. This gives protection against scuffing during the running-in of the gears.

If the system oil is in use for more than one year, the FZG performance of the oil must be done to make sure that the performance is sufficient for the new or polished gear(s).

You must do regular on-board checks of the BN and water content to get an early indication of a lower oil quality.

2.3 Particle Size and Count

Particle size analysis can give useful data about the wear in an engine. Abrasive particles in the oil can cause wear, thus the procedures must be carefully followed. The requirements for particle size refers only to the hydraulic oil systems. These systems operate the exhaust valve and the fuel and cylinder lubricating oil injection systems, (i.e. the servo oil downstream of the fine filter, which is usually 10 μm maximum sphere passing size). Some engines have a 25 μm maximum or other fine filter.

The ISO 4406 particle count and size classes are applicable for the system oil downstream of the filter and are given in Table 3.

Table 3: ISO 4406 Particle Count and Size Classes

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
More than 6 μm maximum	500 000	1 000 000	20
	250 000	500 000	19
	130 000	250 000	18
More than 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 operates with three size classes related to a 100 ml oil sample, which are:

- 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 4.

Table 4: NAS 1638 and SAE AS 4059 Cleanliness Classes

	Contamination (particles/100 ml)				
	Particle size (μm or microns)				
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

2.3.1 Recommended Limits for ISO 4406 Particle Count

The specification for a 100 ml oil sample is ISO 4406 −−/20/17 maximum in the system oil downstream of the filter, which means:

- 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)
- A maximum of 130 000 particles of a size equal to or larger than 14 µm (R_{14} count).

ISO 4406 is only for particles up to 21 µm. For particles larger than 21 µm, the NAS and SAE AS particle count must be obeyed.

2.3.2 Recommended Limits for NAS and SAE AS Particle Count

For particles larger than 21 µm, WinGD recommends the NAS and SAE AS specification for a 100 ml oil sample in the system oil as in Table 5.

Table 5: Limits for NAS 1638 and SAE AS 4059 Cleanliness Classes

	Particle size (µm or microns)				
	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

2.3.3 Servo Oil − Particle Counts

If the particle count is more than the limit given, do a check of the coarse and fine filters. This will make sure that all filter elements, gaskets and seals are not damaged. If a high particle count continues and the filters are serviceable, it is possible that an area of wear in the engine causes an unsatisfactory number of particles. Too many particles can also go into the system oil if the piston rod gland boxes do not correctly seal and used cylinder lubricating oil mixes with the system oil.

The purifier removes particles. You must make sure that the purifier is operated at the correct temperature. Refer to the manufacturers recommendations and make sure that the flow rate is adjusted to get the best operation.

2.4 Oil Samples

At regular intervals, (i.e. at approximately each 300 operation hours), it is recommended that you get a sample of the system oil. Send the the sample of the system oil to a laboratory to make an analysis. The analysis must include ISO 4406 particle counts for samples taken from downstream of the coarse filter or fine filter.

Get the sample from downstream of the filter, before the oil flows into the main oil gallery or the servo oil system. Get a sample of system oil as follows:

1) Make sure that the oil pump operates and the engine oil is at the correct temperature for operation.
2) Put an applicable container below a ball valve in the lubricating system.
3) Open the ball valve to flush out possible dirt.
4) Close the ball valve.
5) Use some oil to clean the container.
6) Put the container below a ball valve.
7) Open the ball valve to get a sample.
8) Close the ball valve.
9) Put the sample in a bottle.
10) Write the data that follows on the bottle:
    - Name of the ship or name of plant
    - Engine type
    - Engine serial number
    - Date of sample
    - Operating hours of oil and of engine
    - Location of the sample point
    - Oil brand and quality.

3. Cylinder Lubricating Oil

A high-alkaline cylinder lubricating oil of the SAE 50 viscosity grade that has a minimum kinematic viscosity of 18.5 cSt at 100°C is recommended. But, cylinder lubricating oils of the viscosity grades SAE 40 and SAE 60 can be used in some conditions. The Base Number (BN) measured in mg KOH/g in accordance with method ASTM D 2896 shows the alkalinity of the oil.

To set the correct alkalinity of the cylinder lubricating oil, use an on-board monitoring programme to monitor the piston underside (PU) drain oil. The residual base number (BN) of the piston underside drain oil shows if the setting values for the cylinder lubrication are correct. The BN of the cylinder lubricating oils is not an index for detergency, but a direct measure of alkalinity. The alkalinity of the cylinder lubricating oil must be set in relation to the sulphur content of the fuel, engine operation condition and feed rate of the cylinder lubricating oil. The higher the sulphur content, the higher the BN of the cylinder lubricating oil must be. For a list of validated cylinder lubricating oils, see paragraph 8.2 Cylinder Lubricating Oils.

When the analysis of the piston underside drain oil shows that the engine operates in the safe area shown in Fig. 2, you can adjust the feed rate and alkalinity of the cylinder lubricating oil. The permitted maximum feed rate is 1.2 g/kWh (see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment). If the analysis of the piston underside drain oil shows that an adjustment to a higher feed rate than 1.2 g/kWh is necessary, you must change to a higher BN cylinder lubricating oil.

3.1 Fuel Sulphur Content and Cylinder Lubricating Oil Base Number

Fig. 1 shows recommendations of applicable cylinder lubricating oils related to the sulphur content of the used fuel.

If you do not use an on-board monitoring programme to monitor the piston underside drain oil, use the data given in Fig. 1 to choose an applicable cylinder lubricating oil. For data about the applicable feed rates, see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment.

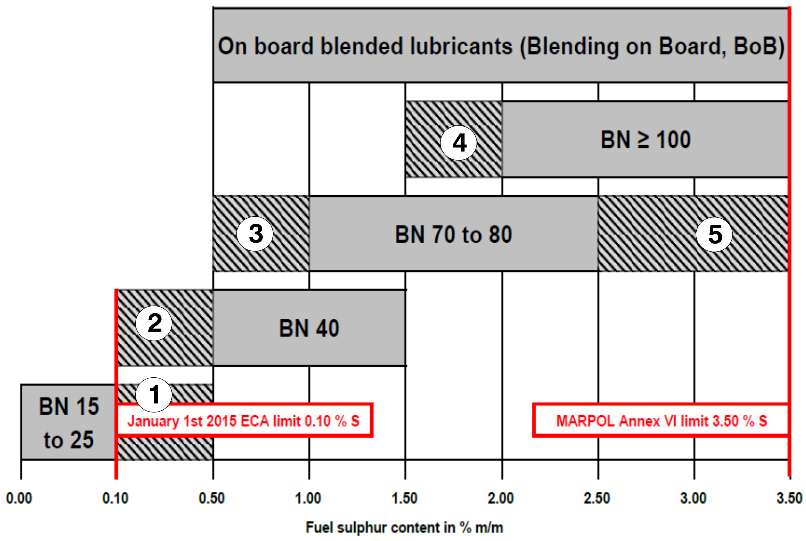

Fig. 1: Relation between Fuel Sulphur Content and Cylinder Lubricating Oil BN

- Range 1 (see Fig. 1): When the fuel sulphur content is more than 0.1% m/m and less than 0.5% m/m during operation with BN 15 to BN 25 cylinder lubricating oil, you must do an analysis of the piston underside drain oil from the on-board monitoring system. You must obey the data that follows:
  - The residual base number must not be less than BN10.
  - The iron (Fe) content must be less than 500 ppm.
  - Do regular checks of the piston and piston ring conditions through scavenge port inspections. If necessary, increase the cylinder lubricating oil feed rate to more than 1.2 g/kWh (refer to 7218-1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment).

  Note: Permitted for engine operation of less than 48 hours only.
- Range 2 (see Fig. 1): When the fuel sulphur content is more than 0.1% m/m and less than 0.5% m/m during operation with BN 40 cylinder lubricating oil, adjust the cylinder lubricating oil feed rate to the guide feed rate (refer to 7218-1 Cylinder Lubrication). This prevents too much piston crown and top land deposits.

  Note: Permitted for engine operation of less than 48 hours only.
- Range 3 (see Fig. 1): When the fuel sulphur content is more than 0.5% m/m and less than 1.0% m/m during operation with BN 70 to BN 80 cylinder lubricating oil, adjust the cylinder lubricating oil feed rate to the guide feed rate (see 7218-1 Cylinder Lubrication). This prevents too much piston crown and top land deposits.

  Note: Permitted for engine operation of less than 48 hours only.
- Range 4 (see Fig. 1): When the fuel sulphur content is more than 1.5% m/m and less than 2.0% m/m during operation with BN 100 cylinder lubricating oil, adjust the cylinder lubricating oil feed rate to the guide feed rate (see 7218-1 Cylinder Lubrication). This prevents excessive piston crown and top land deposits.
- Range 5 (see Fig. 1): When the fuel sulphur content is more than 2.5% m/m and less than 3.5% m/m during operation with BN 70 to BN 80 cylinder lubricating oil, operation is permitted only, when you do an analysis of the piston underside drain oil from the on-board monitoring system. You must obey the data that follows:
  - Do regular checks of the piston and piston ring conditions through scavenge port inspections.
  - Do regular checks of the cylinder liner condition.
  - You must obey the data given in Fig. 2.

Note: From 1st January 2015 only fuel with less than 0.1% m/m sulphur content must be used in Emission Control Areas (ECA). You can use SO_x scrubbers to reduce the effective exhaust sulphur content. For more data, see paragraph 7.

Note: Use a BN 100 cylinder lubricating oil, if the fuel sulphur content is more than 2.5% m/m and no piston underside drain oil monitoring system is installed.

Note: Monitor the piston underside residual BN of the cylinder lubricating oil and examine the piston rings and cylinder liners. This makes sure that you select the applicable BN oil, set the best oil feed rate, prevent corrosion and excessive piston crown deposits and top land deposits. For more data, see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment.

Cylinder lubricating oils that have a BN that is too high for the fuel sulphur content can cause too much deposits on the piston crown. Piston crown deposits must be carefully monitored through scavenge port inspections. The deposits can cause the lubricant film to break down, which gives excessive liner, piston and piston ring wear.

BN 40 cylinder lubricating oils have neutral additives (low BN) to increase the detergency level and thermal stability to the level of a BN 70 cylinder lubricating oil. No significant increase in corrosive cylinder liner and piston ring wear is to be expected when BN 40 cylinder lubricating oils are used (up to 1.5% m/m sulphur) when the cylinder lubricating oil feed rate is kept high. You must make sure that the cylinder lubrication feed rate is applicable (maximum 1.2 g/kWh) and related to the data from the analysis (residual base number) of the piston underside drain oil.

BN 40 lubricating oils cause less and softer deposits on the piston crown land and in exhaust areas (e.g. on the turbocharger nozzle ring) in relation to the BN 70 and other higher BN products at the same feed rate.

The BN 40 products can also be used safely with HFO that has a sulphur content in the range 0.5% m/m to 1.5% m/m. It is possible that the feed rate must be increased in relation to the remaining BN measured in the piston underside drain oil or scrape-down samples.

There are intermediate (between BN 50 and BN 60) and other BN cylinder lubricating oils available. To use these cylinder lubricating oils, make sure that their performance is monitored regularly. Also, make sure that the cylinder lubricating oil feed rate is adjusted to prevent a piston underside BN that is too low. Incorrectly adjusted piston underside BN can cause high corrosive wear and scuffing (see the limits and recommendations in paragraph 3.2).

Note: Use only the cylinder lubricating oils given in paragraph 8.2. The oil company assumes all responsibility for the performance of the cylinder lubricating oils in service of all WinGD 2-stroke engines to the exclusion of any liability of any WinGD company belonging to the WinGD group. The oil company and other possible manufacturers and distributors of the products in question shall indemnify, compensate and hold free from liability, WinGD and companies belonging to the WinGD group from and against any claims, damages and losses caused by the cylinder lubricating oils in question.

To prevent problems with fuel sulphur content, keep sufficient fuel from the bunker supplied before. This can be used until an analysis of the sulphur content of the new bunker is received. The results of the bunker analysis and the values given in the Bunker Delivery Note (BDN) can be different. Always use the higher sulphur content value to set the feed rate to make sure that the engine operates safely.

3.2 Oil Samples – Piston Underside Drain or Scrape-down

WinGD recommends to get piston underside drain oil (scrape-down oil) samples at regular intervals from each cylinder and to make an analysis to monitor the engine condition.

These analyses are used to make an estimate of the cylinder liner and piston ring wear and to set the applicable alkalinity and feed rate of the cylinder lubricating oil. The data given in paragraph 3.1 (this document), 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment are calculated values. The applicable values for each engine can be different, related to the engine and operating conditions.

You can adjust the cylinder lubricating feed rate related to the analysis of the piston underside drain oil. The permitted maximum feed rate is 1.2 g/kWh (see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment). If the analysis of the piston underside drain oil shows that an adjustment to a higher feed rate than 1.2 g/kWh is necessary, you must change to a higher BN cylinder lubricating oil.

The recommended intervals for an analysis of the piston underside drain oil are:

- At each bunker change of the HFO (very important if the sulphur content of the HFO is more than 2.5% m/m).
- At each change of more than 10% CMCR of the average engine (24 hours).
- A minimum of one time each week.

Wear metals, the residual BN, viscosity, fuel components and water are measured. The quantity of system oil additive metals in the sample gives an indication about the piston rod gland box condition. It is important to monitor trends and not full values, and to think about the actual quantity of drained oil relative to the analysis results.

For data about the procedure to get an oil sample from the piston underside, see 8016–1 Lubricating Oil System, paragraph 2.1 Dirty Oil Samples.

The total iron in the scrape down oil is measured to determine the corrosion of the liners and steel parts. A large quantity of system oil can be mixed with the used cylinder lubricating oil in the piston underside space. To get an accurate view of the used cylinder lubricating oil, a correction is necessary to remove the effect of the system oil on the results. The iron and residual BN values are corrected in relation to the phosphorus and/or zinc content of the system oil in the used cylinder lubricating oil. This correction analysis must be done carefully because some cylinder lubricating oils also include phosphorus and/or zinc.

The analyses of many piston underside samples from a wide range of engines that operate with a high sulphur content in the range 0.5% m/m to 3.5% m/m and cylinder lubricating oil from BN 40 to BN 100 has shown:

- The safe corrected piston underside residual BN to prevent piston ring and liner corrosion is more than 25 mg KOH/g but less than 50 mg KOH/g (see Fig. 2).
- The alert corrected limit for piston underside residual BN to prevent excessive corrosion is between10 mg KOH/g and 25 mg KOH/g.
- The danger corrected limit is less than 10 mg KOH/g piston underside remaining BN. It is possible that there will be excessive corrosion and fast piston ring and liner wear if not corrected. Scuffing and the fast failure of piston rings and very fast corrosive liner wear is possible.

It is necessary to find the safe value for continuous operation on fuel oil with a low sulphur content (of between 0.0% m/m and 0.5% m/m) and a low BN cylinder lubricating oil (between BN 15 and BN 25) for each engine. To find this safe value, you monitor the piston underside samples and do regular checks of the pistons, piston rings and cylinder liners for excessive deposits, corrosion and wear.

Fig. 2 shows data for fuel oil with a sulphur content in the range of 0.5% m/m to 3.5% m/m and cylinder lubricating oil with a base number between BN 40 to BN 100.

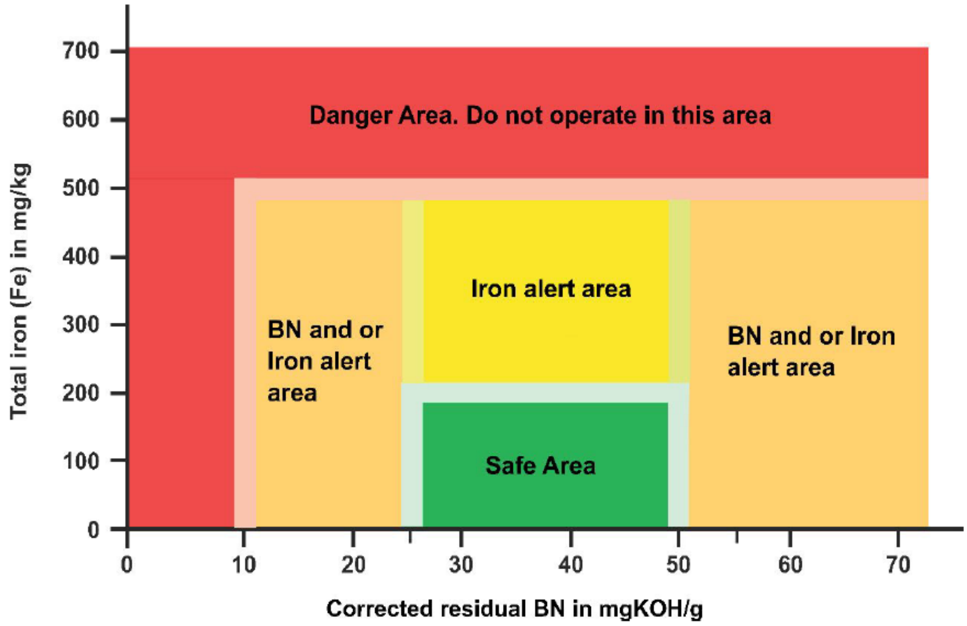

Fig. 2: Piston Underside, Scrape-down or Drip Oil Analysis Interpretation

Note: There are smooth transitions between the different areas shown in Fig. 2.

Fig. 2 shows the operation ranges for engines with chrome ceramic piston rings and fully honed cylinder liners installed. It shows the relation between the piston underside total oil iron content and the residual BN. If necessary, the cylinder lubricating oil BN and/or feed rate must be adjusted to prevent excessive corrosion or magnetic iron in the piston underside oil.

For engines with chrome ceramic piston rings installed, the chromium content of the piston underside oil shows if there is corrosion or wear in the engine.

- A chromium content less than 25 mg/kg shows small corrosion or wear in the engine.
- A chromium value more than 25 mg/kg shows corrosion or wear in the engine. The lifetime of the piston rings and the cylinder liners can decrease.
- The chromium value must not be more than 25 mg/kg for a longer period.

Note: Engines with cast iron or non-chrome ceramic piston rings installed, can have a much larger total iron level than engines with chrome ceramic piston rings under usual operation conditions.

3.3 General Recommendations

Service experience has shown that the corrosion behavior can vary significantly while the engine operates at less than 60% CMCR (low load).

If the engine is to be operated at continuous low load (i.e. more than 24 hours of operation below 60% CMCR) and the sulphur content of the used HFO is more than 2.5% m/m, WinGD strongly recommends the use of a BN 100 cylinder lubricating oil, as the cylinder oil feed rate cannot be adjusted to adequately compensate for the lower alkalinity. If you use a cylinder lubricating oil with a BN less than 100, the permitted maximum feed rate is 1.2 g/kWh (see 7218−1 Cylinder Lubrication and 7218−3 Feed Rate − Adjustment). If the analysis of the piston underside drain oil shows that an adjustment to a higher feed rate than 1.2 g/kWh is necessary, you must change to a BN 100 cylinder lubricating oil.

For data about validated cylinder lubricating oils, see paragraph 8.2.

Note: You can use the WinGD Blending on Board package to adjust the base number of the cylinder lubricating oil. For more data, speak to or send a message to WinGD.

It is necessary to monitor the residual BN at regular intervals (see paragraph 3.1 and paragraph 3.2). WinGD recommends the use of an on-board monitoring programme that, at a minimum, gives you an analysis of the residual BN from the piston underside drain oil. WinGD also recommends the analysis of the total iron and chromium content in the piston underside oil. A sudden increase of the iron or chromium content indicates excessive cold corrosion (see paragraph 3.2).

3.4 Intermediate BN Lubricating Oils

If an intermediate BN cylinder lubricating oil (BN is more than 50 mg KOH/g and less than 60 mg KOH/g) is used, WinGD recommends the procedures that follow:

- Use an on-board monitoring programme that, at a minimum, gives you an analysis of the residual BN from the piston underside drain oil. The recommended intervals for an analysis are:
    a) At each bunker change of the HFO (very important if the sulphur content of the HFO is more than 2.5% m/m).
    b) At each change of more than 10% CMCR of the average engine (24 hours).
    c) A minimum of one time each week.

CAUTION

For engine operation at less than 60% CMCR (low load) for more than 24 hours, you must only use intermediate BN lubricating oils (between BN 50 and BN 60) if the sulphur content of the used HFO is in the range of 0.5% m/m to 2.5% m/m.

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, refer to the specification in the Maintenance Manual 3206-1, and the recommendations from the engine manufacturer.

The lubricant suppliers are given in paragraph 8.4.

7. Environmentally Acceptable Lubricants

Environmentally Acceptable Lubricants (EAL) are necessary for ships that operate in USA waters, and this area could be extended.

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

EAL must not be mixed into system or cylinder oils where they are to be used in engine applications. Even small contamination of EAL (related to the base oil quality) into system and cylinder oil can cause elastomer compatibility, water emulsification and high temperature deposit formation issues.

8. Validated Lubricating Oils

8.1 Lubricating Oil Instruction and Liability

The application and handling of lubricating oils must be in compliance with the WinGD general lubricating oil specifications and recommendations given in the Operation Manual (this manual) and the Maintenance Manual.

The oil supplier company takes all responsibility for the performance of the oil in service to the exclusion of any liability of WinGD.

8.2 Cylinder Lubricating Oils

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

Table 6: List of Validated Lubricating Oils (Last Update: May 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 Taro Special HT 100X	–
CPC	–	–	–	Marilube Oil CO−700 Plus	–	–
ENI	Punica 525 (BN 25)	–	–	Punica 570	–	–
ExxonMobil	Mobilgard 525 (BN 25)	Mobilgard L 540	Mobilgard 560VS (BN 60)	Mobilgard 570	Mobilgard 5100	–
FL Selenia	–	–	–	MECO 5070	–	–
Gaspromneft	Ocean CCL 17 ULSF (BN 17)	Ocean CCL 40 LSF 1)	–	Ocean CCL 70	Ocean CCL 100 HSF 1)	–
Gdanska	–	–	–	Marinol RG 7050	–	–
Gulf Oil Marine	GulfSea Cylcare ECA 50 (BN 17)	–	–	GulfSea Cylcare DCA5070H	GulfSea Cylcare 50100 2)	–
Hin Leong	–	–	–	Universal Cyl EN 7050 2)	–	–
IOC	–	–	–	Servo Marine 7050	–	–
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			–
Mexicana de Lubricantes	–	–	–	Marinelub 7050	–	–
Pars Oil	–	–	–	Pars Oghyanous 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 S6	Alexia 140 (BN 140) 1)
SINOPEC	Cylinder Oil 5025 (BN 25)	Cylinder Oil 5040 1)	–	Cylinder Oil 5070; Cylinder Oil 5070S; Cylinder Oil 5080S (BN 80)	Cylinder Oil 50100 1)	–
SK	Supermar CYL 25 (BN 25)	Supermar CYL 40; Supermar CYL 40L	–	Supermar CYL 70 plus	Supermar CYL 100	–
Total	Talusia LS 25 (BN 25)	Talusia LS 40	Talusia Univer-sal (BN 57)	Talusia HR 70	Talusia Univer-sal 100; Talusia Optima 4)	–
United Oil Company Pte Ltd.	–	–	–	U Star Lube Star Marine 570	–	–

Notes to Table 6:

1) This product is under testing and is not validated at this time.

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

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

Note: Intermediate cylinder lubricating 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 lubricating oil feed rate must be adjusted to prevent a piston underside BN which is too low and can cause excessive corrosive wear and scuffing. See the data given in paragraph 3.4.

Note: If HFO with a sulphur content of between 1.5% m/m to 3.5% m/m is used, see the data given in paragraph 3.2.

8.3 System Oils

Table 7: List of Validated System Oils (Last Update: May 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	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
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

Notes to Table 7:

1) This product is under testing and is not validated at this time.

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

8.4 Lubricants – Flywheel and Pinion Gear Teeth

To correctly apply the lubricants given in Table 8 see the Maintenance Manual 3206-1.

Table 8: List of Lubricants – Flywheel and Pinion Gear Teeth (Last Update: May 2017)

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

Cooling Water / Cooling Water Treatment

1. General

An applicable treatment is used to give the cooling water the correct properties, which will prevent service problems. Cooling water that has not had treatment can soon cause problems in the cooling system from corrosion, sediment and hard particles.

2. Raw Water – Closed Cooling Water Circuits

Do not use seawater as raw water. Sea water has a high salt content and causes damage to the cooling water system.

Before you fill the system, the raw water must be fully desalinated. Condensate water from e.g. the fresh water generators or from auxiliary steam systems can be used, but must have additives. Condensate water is highly corrosive and must have corrosion inhibitors to prevent problems.

Use potable water or process water from the local mains only as a last option. The hardness of this water must not be more than 10°dH (German hardness degrees). If the hardness is more than this limit, desalinate the water to the values given in the Table 1.

Table 1: Water Data

Parameter	Value	Test Method
pH, (see Note)	6.5 to 8.5	ASTM D 1287 or D 1293
Hardness	Maximum 10°dH	ASTM D 1126
Chlorides (Cl^-)	Maximum 80 mg/l	ASTM D 512 or D 4327
Sulphates (SO_4^{2-})	Maximum 150 mg/l	ASTM D 516 or D 4327

Note: For reverse osmosis technologies, the minimum pH value is 6.0.

If you think there is a problem, do an analysis of the water. Send the results of the analysis to Wärtsilä Switzerland Ltd to get advice.

Corrosion protection oils (emulsion oils) are not recommended for the treatment of the cooling water. If instructions about the use of corrosion protection oils are not obeyed and coolant checks are not sufficient, then water / oil emulsion can occur. This can cause the cooling system to become clogged.

3. Cooling Water during Operation

The cooling water must have the correct corrosion inhibitor. Inhibitors that contain the agents Nitrite and Borate, and are related to the Organic Acid Technology (OAT) are known to be satisfactory. You can get a list of recommended products from Wärtsilä Switzerland Ltd.

The instructions of the manufacturer must be obeyed for the correct quantity of the corrosion inhibitor. You must do regular checks during operation to keep the correct concentration.

It is recommended that you choose such suppliers of inhibitors who can also give specified advice for the new cooling water and for during operation.

If there are leaks, you must add the correct quantity of water with the correct concentration of inhibitor. If evaporation causes a decrease of the coolant, add the applicable quantity of raw water (see paragraph 2 above). This will make sure that the concentration of inhibitors is not too much.

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

4. Cleaning the Cooling Water System

For new cooling water, the full system must be clean. The system must not contain grease, oil or unwanted particles.

During operation oil or sediment can go into the system, which can cause a decrease in the heat transfer and cooling effect. Such problems will occur after an unusually short time if the cooling water and system is not monitored correctly. An applicable agent must be used for the treatment of the full system to remove grease and chalk sediment.

Before you fill the cooling water system with new cooling water, the system must be fully flushed. This will remove sediment and oil and make sure that remaining acids are made neutral.

There are many cleaning agents available, which are not in a list here. It is recommended that you speak to specialist companies that can help you.

5. Antifreeze

CAUTION
Damage Hazard: Antifreeze decreases the heat transfer rate of the cooling water. This can cause damage to the engine. If the concentration of the antifreeze is more than 20%, you can operate the engine only at decreased load.

During usual operation, it is not necessary to use antifreeze. We recommend to use antifreeze only if the engine does not operate for a long period in conditions of cold / frost (ambient temperature below the freezing point of water).

Always use the correct water / antifreeze ratio related to the ambient temperature. The instructions of the manufacturer must be obeyed for the correct quantity of antifreeze.

It is possible to use each of the two types of high quality antifreeze that follow:

- Monopropylene glycol (MPG)
- Monoethylene glycol (MEG).

It is recommended that you use MPG, because it is better for the environment.

You must do regular checks during operation to keep the correct concentration.

You must obey the instructions of the manufacturer to prevent problems during operation.

You must make sure that the cooling water system has the correct concentration of corrosion inhibitor (see paragraph 3).

General

1. General

If the operation and maintenance instructions are obeyed, problems during operation can be prevented.

If a fault occurs, do not search randomly for the cause. Use a sequence to find possible causes. This applies specially to problems during engine start and engine stop.

The possible causes of the faults shown in paragraph 1.1 to paragraph 1.4 are given in their related chapters.

1.1 Problems during Engine Start and Stop

See the list below:

- Engine does not turn during the start sequence
- Engine moves back at start or does not get speed
- Engine turns with air during the start but gets no fuel
- Engine does not fire during the start
- A cylinder does not fire, or does not fire correctly during the start
- Engine fires violently during the start
- Engine cannot be stopped.

For more data, see 0810–1.

1.2 Irregular Functions during Operation

At the same load indication compared to results or with data in the shop trial documents:

- Scavenge air pressure decreases
- Scavenge air pressure increases
- Scavenge air pressure is too high
- Exhaust temperature upstream of the turbocharger increases
- Exhaust temperature of one cylinder increases
- Exhaust temperature of one cylinder decreases
- Firing pressure of all cylinders decreases
- Engine speed decreases
- Smoke comes out of the exhaust
- Engine operates irregularly or misfires at times (one cylinder or all cylinders)
- Undemanded engine stop
- Irregular functions in the cylinder cooling water system
- Crosshead bearing oil pressure decreases to main bearing oil pressure
- Cylinder lubrication becomes defective
- Problem with the exhaust valve
- Surging of turbocharger(s)
- Oil mist detector gives an alarm.
- Engine thermally overloaded.

For more data, see 0820–1.

1.3 Problems and Damage to Engine Parts

- Hot running of a piston
- Hot running of the running gear.

For more data, see 0840−1.

1.4 Engine Control System (ECS) Failures

- Major failures
- Minor failures
- Info logs.

Problems during Engine Start and Stop

1. Problems during Engine Start

For the names and part code numbers, see 4003−2 Control Diagram.

Problem	Possible Cause	Procedure
The engine does not turn during the start sequence	The shut-off valves on the starting air bottles are closed	Open the shut-off valves
	The starting air pressure is too low	Fill the air bottles
	The oil pressure, water pressure, or air pressure for the air spring is too low. The pressure switches have activated a SHUTDOWN signal	Reset SHUTDOWN
Engine will not start from the control stand in the control room	The control stand has no effect	Push the related button on the LDU−20 for mode transfer or to get control (see 4002−2)
	The remote control system (RCS) and / or telegraph system has a fault	Do a check of the RCS or speak to the RCS supplier
	The RCS shows a start interlock	Do a check of the indication of starting interlock in RCS (turning gear, shut-down, auxiliary blower), release interlock
	No signal between the RCS and the engine control system (ECS)	Do a check of the plugs, and CAN open lines, for loose or broken wires
Engine will not start from the control stand at the engine	The control stand has no effect	Push the related button on the LDU−20 for mode transfer or to get control (see 4002−2)
	The turning gear is engaged, the 3/2-way valve 35-31HA prevents the flow of control air to valve unit **E**	Disengage the turning gear
	The 2/2-way valve 35-4325_E0_5 to the starting air shut-off valve cannot move, or does not open fully	Clean the 2/2-way valve 35-4325_E0_5
	The solenoid valves CV7013C and CV7014C in valve unit **E** become defective	Clean or replace valves. Do a check of the wiring
	The electrical connection(s) are disconnected from the solenoid valve(s) in valve unit **E**	Connect the electrical con-nection(s)
	The starting air shut-off valve is in the position CLOSED	Move the shut-off valve to the position AUTOMAT
	The starting air shut-off valve does not open, (cannot move), the non-return valve cannot move and does not fully open	Do an overhaul of the starting air shut-off valve.
	The auxiliary blowers do not operate	Start the auxiliary blowers
	The air flaps in the scavenge air receiver are defective (no pressure from the auxiliary blowers)	Do an overhaul on, or replace the air flaps

Problem	Possible Cause	Procedure
	No air spring pressure, or pressure is too low	Open the 3/2-way valve 35-36HA, adjust the pressure to 6 bar in control air supply unit **A**
	The non-return valve on the exhaust valve (air inlet to air spring) is incorrectly installed. You can hear loud noises and the exhaust valve does not fully close	Do a check and install correctly (see the Maintenance Manual 2751–2)
	The starting valves cannot move or the electrical connection is not connected	Do an overhaul of the starting valves or connect the electrical connection
	Different causes	Try to start the engine in the opposite direction
The engine moves back during the start sequence, or does not get to the applicable speed	A cylinder receives no starting air, or the starting air is not sufficient (blockage in starting air pipe). The solenoid valve(s) CV7241 (to CV7248C) cannot move. The cable to the CCM–20 is broken.	Do a check of the starting air pipe, flame arrestor and remove the blockage. Clean or replace the related solenoid valve(s), do a check of the electrical signal.
	The starting air pressure is too low.	Fill the air bottles.
The engine turns on starting air but receives no fuel. The regulation of fuel injection quantity is in the position 0%	The speed control system is defective. Does not release a controlled fuel injection quantity.	Do a check of the electrical signal from the CCM–20 on cylinder #1 and #2 to the flow control valve on the fuel pumps.
The engine turns on starting air but gets no fuel	The fuel rail pressure is too low. The pressure control valve stays open.	Do a check of the pressure control valve 10-5560_E0_1 (see 0515–1, paragraph 5).
	There is heavy leakage in the high pressure circuit (fuel) on the engine	Do a check for leaks, see 8019–1, paragraph 4.
	The fuel booster pressure is not sufficient. The pressure retaining valve is set too low. The booster pump does not supply fuel.	Adjust the fuel booster pressure.
	The shut-off valves upstream of the engine are closed (plant)	Open the shut-off valves.
No ignition during engine start	The injected fuel quantity is too small. The speed setting is too low.	Adjust the speed setting.
	The fuel is not correct or its viscosity is too high.	Prepare the fuel system (see 0120–1).
	The starting air pressure is not sufficient to turn the engine with sufficient speed.	Fill the air bottles.
	The auxiliary blower or non-return valves in the scavenge air receiver is defective.	Do an overhaul or replace the auxiliary blower or non-return valves.
	The compression pressures are too low. The piston rings are in an unsatisfactory condition. The exhaust valves do not close correctly.	Replace the piston rings. Grind the surfaces of the valve head and valve seat (see the Maintenance Manual).

Problem	Possible Cause	Procedure
No ignition during engine start (continued)	The high pressure circuit has leaks (fuel pumps, HP pipes, fuel rail)	Find the cause and repair the leaks.
	The heating of the high pressure pipe to the injection valves does not operate.	Set the heating lines to on.
A cylinder does not fire or does not fire correctly when starting	The ECS isolates the injection valves (function)	Set the injection to on (see 4002−2, paragraph 3.7 Fuel injection)
	Injection is cut out	Cut in the injection, see 0510−1 and 4002−2.
	The connections between the injection valve and the flow limiter valve have a leak	Tighten the connections correctly. Grind the sealing faces
	No electrical signal to the solenoid valve(s) CV7201−08D, CV7201−08E	Do a check of the wiring. If necessary replace the solenoid valve(s)
	The exhaust valve has a malfunction. No electrical signal to the 4/2-way valve CV7201 to CV7208C	Do a check of the wiring and 4/2-way valves CV7201 to CV7208C. If necessary replace the defective 4/2-way valve.
	The injection nozzles have leaks. The needles do not move.	Replace the injection valve.
	The holes in the injection nozzle are blocked	Replace the nozzle tip
	Compression pressure in the cylinder is not sufficient for fuel ignition.	Replace piston rings. Grind the surfaces of valve head and valve seat (see the Maintenance Manual).
	The exhaust valve spindle cannot move	Replace the defective parts.
	The CCM−20 power supply is disconnected, the connector is removed or incorrectly connected, the internal part(s) have become defective.	Set the power supply to on. Connect the connection. Replace the CCM−20.
	The piston in the exhaust valve control unit 20-5612_CX_2 or the pin in the 4/2-way valve CV7201 to CV7208C cannot move.	Replace the 4/2-way valve CV7201 to CV7208C, or the exhaust valve control unit.
	Exhaust valve control unit is cut out.	Cut in the exhaust valve control unit (see 0520−1, paragraph 3.2).
	Starting valves do not open, cannot move, are damaged or receive no signal.	Do an overhaul or replace the starting valves. Do a check of the wiring.

Problem	Possible Cause	Procedure
Violent firing during engine start	Fuel rail pressure is too high, fuel control does not operate correctly.	Do a check of the power supply and wiring.
	Cylinders were lubricated too much before starting. Unwanted quantity of cylinder oil in the combustion spaces.	Decrease the speed setting (fuel injection quantity) until the unwanted oil has burned. Do not lubricate too much.
	Fuel injection quantity (start fuel charge) is set too high.	Decrease the speed setting (fuel injection quantity).
	The fuel injection quantity (start fuel charge) is set too high.	Decrease the speed setting (fuel injection quantity).
	The fuel limiter is set too high.	Adjust the setting to the standard value.

2. Problems during Engine Stop

Problem	Possible Cause	Procedure
Engine cannot be stopped with the rotary switch or the telegraph in the control room	The cable connector is defective.	Push the EMERGENCY STOP button to stop the engine (see 0310–1 Engine Shutdown, paragraph 2.2)
Engine cannot be stopped with the rotary switch on the local control panel	The cable connector is defective	Push the EMERGENCY STOP button to stop the engine (see 0310–1 Engine Shutdown, paragraph 2.2)

Irregular Operation

1. Load Indications

At the same load indication compared to indications recorded before, or with data in the acceptance records.

Problem	Possible Causes	Procedure
The scavenge air pressure decreases	The scavenge air cooler is dirty on the air side The water separator is clogged or damaged	See 6606–1 paragraph 3
	The intake temperature upstream of turbocharger is high.	Make sure that the air intake is clear
	The diffuser, blower and inducer to turbocharger is dirty or damaged The silencer upstream of the turbocharger is dirty The turbine rotor blade is dirty or damaged The nozzle ring of turbocharger is damaged	Clean the turbocharger during operation, see the related Turbocharger Manual.
	The exhaust gas boiler (plant side) is clogged. There is increased resistance or back pressure downstream of turbine	Clean as soon as possible
The scavenge air pressure increases	The nozzle ring of turbocharger is dirty or clogged	Clean the turbocharger during operation, see the related Turbocharger Manual.
The exhaust temperature upstream of turbocharger increases	The air supply is not sufficient because of a defect, or the turbocharger, silencer or scavenge air cooler is very dirty	Clean the turbocharger during operation, see the related Turbocharger Manual. See 6606–1, paragraph 3 Air side cleaning of the SAC in service
	The air flaps in the scavenge air receiver are dirty or defective	Clean, do an overhaul or replace the air flaps
	The injection nozzles are worn	Replace the injection nozzles
	The intake temperature upstream of turbocharger is high	Make sure that the air intake is clear
	The scavenge ports in the cylinder liner are dirty	Clean the scavenge ports

Problem	**Possible Causes**	**Procedure**
The exhaust temperature of a cylinder increases	The air flaps in the scavenge air receiver are dirty or defective	Clean, overhaul or replace the air flaps
	The injection nozzles are worn	Replace with the spare kit
	The scavenge ports in the cylinder liner are dirty	Clean the scavenge ports
	There is a fire in the piston underside space	See 0450–1
	The exhaust valve has a leak	Grind the valve seat and head (see the Maintenance Manual)
	The exhaust thermometer of a related cylinder is defective	Replace the exhaust thermometer
Exhaust temperature of a cylinder decreases	The injection nozzles are in an unsatisfactory condition, the nozzle tip is broken, the flow limiter valve cannot move	Replace nozzle tip or flow limiter valve
	The related cylinder receives less fuel because of a leakage in the high pressure pipes or injection valves	Grind the sealing faces or replace defective parts (see the Maintenance Manual)
	The exhaust valve does not open. The exhaust valve control unit or its hydraulic pipe is defective	Cut out the injection and exhaust valve control unit of the related cylinder (see 0510–1 paragraph 1 and 0520–1 paragraph 2)
	The exhaust thermometer of the related cylinder is defective	Replace the exhaust thermometer
The firing pressure of all cylinders decreases	The flow limiter valve cannot move	Do a check to make sure the flow limiter valve is serviceable, or replace
The engine speed decreases	The speed setting from the speed control system is decreased or not in the limits	Do a check of the speed control system
	The fuel injection quantity from the speed control system decreased to prevent too much load in heavy sea	A procedure is not necessary. Usual operation
	Hull resistance increased because of growth, age of hull, propeller damage	See 0070–1 The Relation between Engine and Propeller
	An injection valve is defective , an injection pipe is defective	Cut out or replace the related part (see 0510–1 paragraph 1 and 0515–1, paragraph 3.3.2)
	The air and exhaust gas pipes are clogged	See Scavenge air pressure decreases

Problem	Possible Causes	Procedure
There is smoke from the exhaust	Air supply is not sufficient. Unwanted material in: the exhaust side or air side of the turbocharger, scavenge air cooler, air flaps in the receiver, scavenge ports in cylinder liners or in the exhaust boiler	See Scavenge air pressure decreases
	The engine has too much load	Decrease the fuel injection quantity
	The engine operates with too much cylinder lubricating oil	See 7218–1, paragraph 6.4 Adjustment – lubricating oil feed rate
	Injection nozzles do not completely change the fuel into a spray, e.g. because there trumpets, worn or blocked spray holes	Clean the parts. Do a check to adjust the parts, or replace the parts
	The fuel is incorrect, or the viscosity is too high (not not sufficiently heated)	See 0270–1 paragraph 2
	The compression pressure too low. The piston rings have leaks, exhaust valve leaks	Replace the piston rings, grind the valve seat and head
	Bores in upper housing of the exhaust valve are clogged. Exhaust valves close too late	Do a check and clean the parts
	The servo oil pressure is too low, the servo oil pump control is defective, oil leakage	Do a check of the oil flow. Find and repair the leaks
	An auxiliary blower operates at part load, or the two auxiliary blowers do no operate.	Set the auxiliary blowers to on
Engine operates irregularly or misfires at times, on one or all cylinders	There is high water quantity in the fuel	See 0720–1, paragraph 2 Treatment of HFO and treatment plant
	The fuel temperature upstream of the fuel pumps is too low or too high	See 0270–1, paragraph 2
	The pressure in the fuel rail is too low. The pressure control valve is defective. One of the fuel pumps does not supply fuel	See 0515–1, paragraph 5. Do a check of the pressure transmitter.
The engine stops without operator input (without a shut-down indication)	The fuel daily tank is empty, or fuel supply is stopped. The fuel filters are blocked. The booster pump is defective. Defective switching. The fuel rail pressure is too low. The fuel system leaks.	Fill the daily tank. Clean the filter. Find other causes and repair the defects. Find and repair leaks.
	There is no electrical power supply to the engine control system (ECS)	Repair the cause and start the ECS
	The speed setting system is defective, e.g. broken cables	Repair the fault
	The engine stops in heavy sea	Set the Heavy Sea Mode to on (see 4002–2, paragraph 3.10 User parameters)

Problem	Possible Causes	Procedure
Irregular operation of the cylinder cooling water system	Air collects in the cooling spaces or in the pipes because pressure release is not sufficient	Release the pressure
Pressure increases and decreases quickly	There is a decrease of static pressure at the inlet to the cooling water pump because of a blockage in the return pipe or the expansion tank has drained	See the plant instructions
	The exhaust gases go into the cooling water because of a crack in the cylinder liner, cylinder cover, valve cage	See 0545–1 Operation with Water Leakage into the Combustion Chamber.
Increased cooling water temperature at the outlet of a cylinder	The shut-off valves in the pipes of the related cylinders were accidentally closed, or defective	Open the shut-off valves or replace them.
	The pressure in the cooling spaces is not sufficiently released	Release the pressure
	The cooling water pipes or water channels are blocked. The water flow is not sufficient.	See Cooling 0760–1 Cooling Water / Cooling Water Treatment
	The piston is too hot	See 0840–1 Problems and Damage with Engine Parts.
	The exhaust gases go into the cooling water because of a crack (cylinder liner, cylinder cover, valve cage)	See 0545–1 Operation with Water Leakage into the Combustion Chamber
Increased cooling water temperature on all cylinders	Plant side is defective (regulating valve, cooling water cooler etc.)	See plant instructions

2. Cylinder Lubrication

If the cylinder lubrication does not operate correctly, the piston rings and cylinder liners will wear quickly. Also, the piston can seize. Only in emergencies, and then at decreased power and only for the minimum possible time, can an engine operate without cylinder lubrication.

If the cylinder lubricating system does not operate correctly, this causes failure indications to show in the ECS, which are then shown in the alarm and monitoring system.

Problem	Possible Causes	Procedure
Cylinder lubrication is defective. No lubricating oil	The daily tank is empty. The filter element in the filter unit is clogged	Fill the daily tank. Clean, or replace the filter element
	There is air in the cylinder lubricating system	Bleed the cylinder lubricating system (the filter, the pump and the pipes to the lubricating quills).
	One or more lubricating quill(s) in the cylinder liner are blocked.	Do a check of the lubricating quill(s). If necessary do an overhaul of the quill(s) or replace the defective parts
Flex lube pump is defective	There is no servo oil pressure, or the servo oil pressure is too low	Do a check of the oil supply pressure. Adjust the pressure on pressure relief valve 25-8475_E0_2 if necessary Make sure that the shut-off valve on the oil supply unit is closed.
	The 4/2-way solenoid valve (CV7131C to CV713XC), pressure transmitter (PT3131C to PT313XC) or pump body is defective	Send the defective parts to the manufacturer for repair, or to get replacements.

3. Exhaust Valve

Problem	Possible Causes	Procedure
Exhaust valve	Piston in exhaust valve is defective	Do an overhaul, or replace
The exhaust valve makes an unwanted noise	The orifice or filter in the exhaust valve control unit is clogged	Clean the orifice or the filter (see Maintenance Manual 5612–1)
	The strainer holes in the orifice to the exhaust valve are much larger (wear)	Replace the orifice
	The hydraulic pipe has a leak	Repair the leak, or replace the hydraulic pipe
Exhaust valve does not open	The restrictor 35-2751_CX_2 on the exhaust valve is defective	Replace the restrictor 35-2751_CX_2, or do an overhaul on the exhaust valve.
	The piston in the exhaust valve control unit cannot move	Replace the piston or do an overhaul.
	The 4/2-way valve CV7201C to CV720XC is defective or the cable connection is loose	Replace the 4/2-way valve CV 7201–08C or connect the cable connection (see 0525–1)
Exhaust valve does not close	The air spring pressure is too low (less than 2 bar)	Find the cause: leakage, pressure reducing valve, pressure in starting air bottles
	The exhaust valve shank or piston cannot move	Replace or do an overhaul,

4. Turbocharger

Short, loud noise and at the same time the pressure changes on the air side.

Surges do not have a direct effect on the engine when this occurs at irregular intervals, but the air flow rate is decreased.

Problem	Possible Causes	Procedure
Turbochargers surge	There is too much load, or the air is not sufficient.	See the Maintenance Manual of the turbocharger manufacturer and 6606−1, paragraph 3 Air side cleaning of the SAC during operation
	The cylinder is defective (injection, exhaust valve control)	Do a check of the injection and exhaust valve control

5. Oil Mist Detector

CAUTION

If an oil mist detector activates an alarm, keep away from engine. Do not go into the areas adjacent to the explosion relief valves (see 0460−1 Instructions about the Prevention of Crankcase Explosions).

Problem	Possible Causes	Procedure
The oil mist detector gives alarm	Part of a running is too hot	Decrease the load (rpm) immediately Stop the engine as soon as possible Find the cause, repair as much as possible (see 0210−1 Safety Precautions and Warnings and 0840−1 Problems and Damage with Engine Parts)

6. Exhaust Waste Gate

The exhaust waste gate is defective, low-load tuning causes too much thermal load on the engine, or a scavenge air pressure that is too high.

Problem	Possible Causes	Procedure
The engine has too much thermal load (a slow-down signal is released)	The butterfly valve stays in the OPEN position at a load range of less than 85%.	Adjust the screw for manual operation on the solenoid valve ZV7076C (see 8135–1, paragraph 3 and Fig. 2) Do an overhaul and replace the butterfly valve As a temporary solution, install a blind flange in exhaust bypass and operate engine only up to 85% load
The scavenge air pressure is too high (a slow-down signal is released)	The butterfly valve stays in the CLOSED position at a load range of more than 85%.	Do an overhaul and replace the butterfly valve Do a check of the function of the solenoid valve ZV7076C. If necessary, do an overhaul or replace the solenoid valve. As a temporary solution, operate the engine only up to 85% load

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Problems and Damage to Engine Parts

1. Piston − Hot Operation

The possible indications of a piston that operates at a temperature that is too hot, but where combustion is correct are as follows:

- A temperature increase at the piston cooling oil outlet
- A temperature increase at the jacket cooling water outlet
- A temperature increase of the piston underside.

Possible Causes	Repair Procedure
Gas flows through defective or worn piston rings There are scratches on the cylinder liner surface because the cylinder lubricating oil has decreased too much	Cut out the injection of related cylinder for a short time (see 0510−1, paragraph 1) On the related cylinder, increase the feed rate of the cylinder lubricating oil (see 4002−2, paragraph 3.9 Cylinder lubrication, page and 7218−1 paragraph 6.4). If the temperature does not decrease, or increases more after injection is cut in, cut out the injection again (see 0510−1). Stop the engine as soon as possible, then let the temperature of the cylinder and piston decrease. Do a check of the running surface of the piston and the cylinder liner. If the damaged areas are small, use an oil stone to repair these areas. If there is much damage, replace the piston, piston skirt and cylinder liner (see the Maintenance Manual. If a replacement of these parts is not possible, remove the piston see the Maintenance Manual 3403−1. When the piston is removed, see 0540−1, paragraph 2.

2. Hot Operation of Running Gear Parts

Possible Causes	Repair Procedure
An oil pipe or pipe connection is defective.	Decrease speed (power) and increase the bearing oil pressure
There is water in the lubricating oil (the journals have corrosion) The lubricating oil is dirty.	If the temperature continues to increase, stop the engine to let it become cool.
There was damage to the bearing or journals during the install procedure.	Make sure that you know the necessary precautions for preventing crankcase explosions (see 0460−1)
The bearing clearance is not sufficient	Disassemble and inspect the bearing that was hot
Bearing has deformation (waisted studs were not tightened in accordance with the instructions). Bearing oil pressure is not sufficient (do a check of the pressure gauge and oil pressure monitoring system) The level in the oil tank is too low. The pump supplies an air and oil mixture.	Do an overhaul, or replace the damaged parts, or remove the defective running gear (see 0540−1)

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Bedplate and Tie Rod

Group 1

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Main Bearing

1. General

The main bearing has a bottom bearing shell (7, Fig. 1) and a top bearing shell (5).

The bottom main bearing shell (7) is is installed in the bearing girder (9) of the bedplate and the top main bearing shell (5) in the bearing cover (4). The screws (6) engage and hold the top bearing shell and bottom bearing shell in position.

The spring dowel pin (10) helps to get the bearing cover (4) in position.

The elastic studs (2) have a non-hardening locking compound applied to the threads. Hydraulic tension is applied to the elastic studs during the install procedure. The round nuts (3) keep the bearing cover (4) against the bearing girder (9).

2. Lubrication

Oil flows from the bedplate through the oil inlet (OI) to the main bearings. The oil flows through the grooves (OG) and bores (OB) to the running surface of the main bearing.

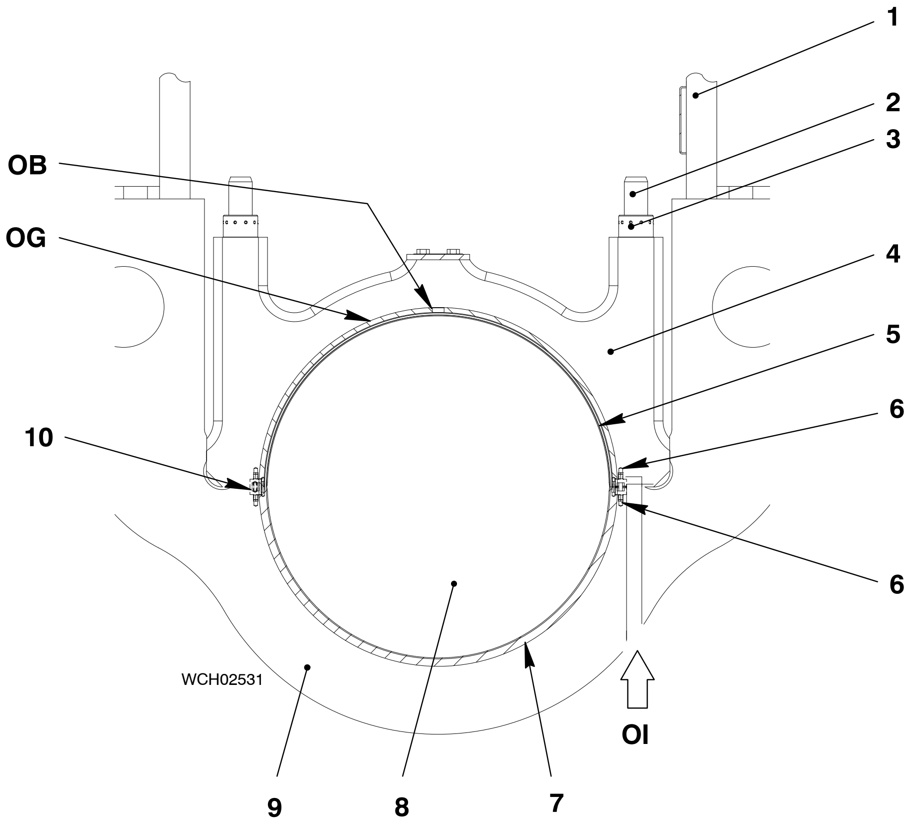

Fig. 1: Main Bearing

1	Column	9	Bearing girder
2	Elastic stud	10	Spring dowel pin
3	Round nut	11	Plug
4	Bearing cover		
5	Top main bearing shell		
6	Screw	OI	Oil inlet
7	Bottom main bearing shell	OG	Oil groove
8	Crankshaft	OB	Oil bore

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Thrust Bearing

1. General

The thrust bearing is installed at the driving end of the engine. The thrust bearing flange transmits the force from the propeller through the thrust pads into the bedplate.

The arbor supports (4, Fig. 1) prevent axial movement of the thrust pads.

There are six thrust pads (5 and 9) on each side of the thrust bearing flange (10, Fig. 2). The thrust pads absorb the axial force from the crankshaft and propeller.

The crankshaft gear wheel moves the intermediate wheel of the supply unit.

1.1 Engines with Fixed Pitch Propellers

For clockwise and counterclockwise rotation, six thrust pads are installed on each side of the thrust bearing flange. The thrust pads adapt to the clockwise or counterclockwise rotation.

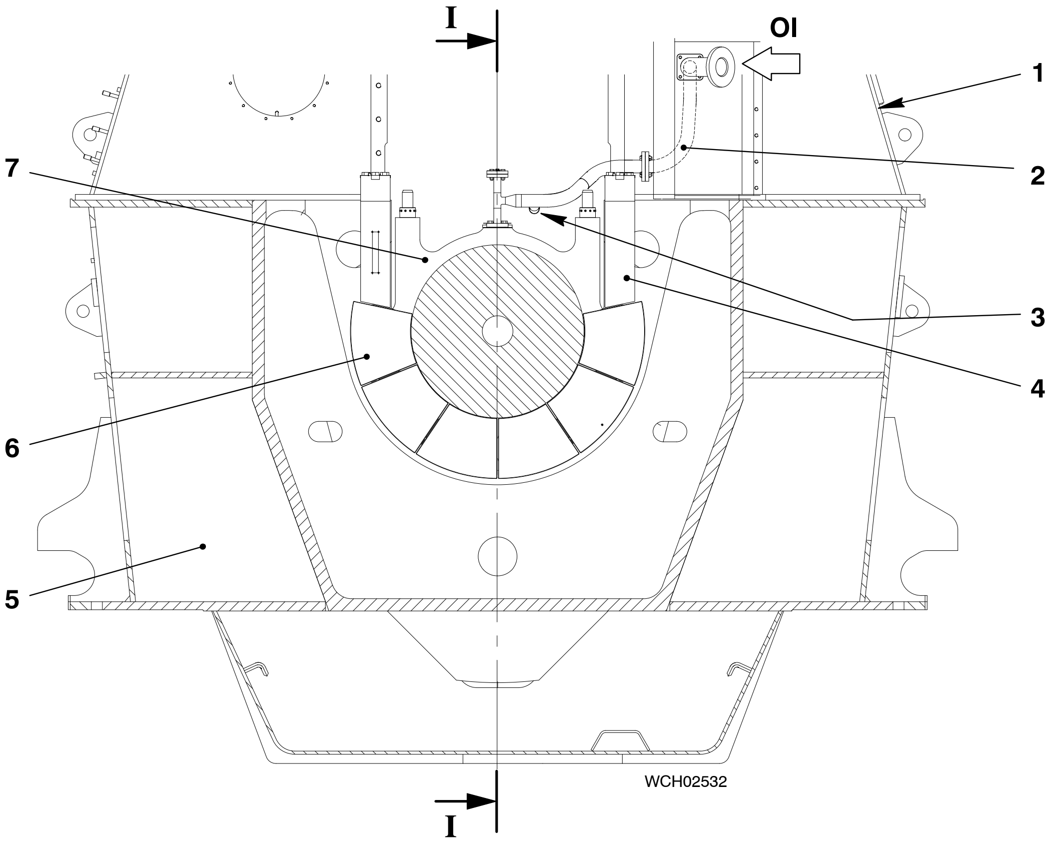


Fig. 1: Cross Section

1	Column	6	Thrust pad
2	Oil pipe	7	Bearing cover
3	Nozzle		
4	Arbor support		
5	Bedplate	OI	Bearing oil inlet

2. Lubrication

During operation, bearing oil flows through the oil pipe (2) to the two nozzles (3, Fig. 1). The oil flows out of the two nozzles as a spray, which becomes an oil layer between the thrust bearing flange (10) and the thrust pads (5 and 9, Fig. 2).

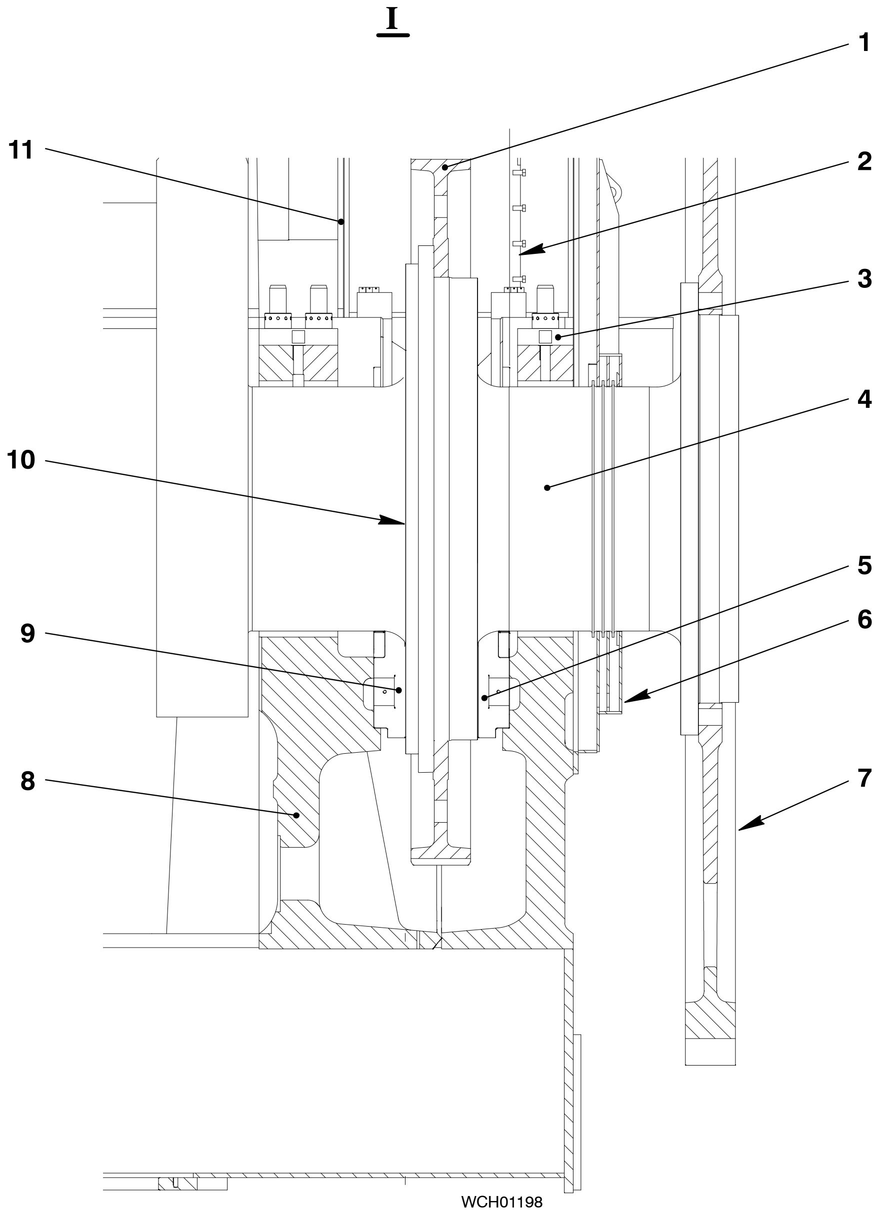


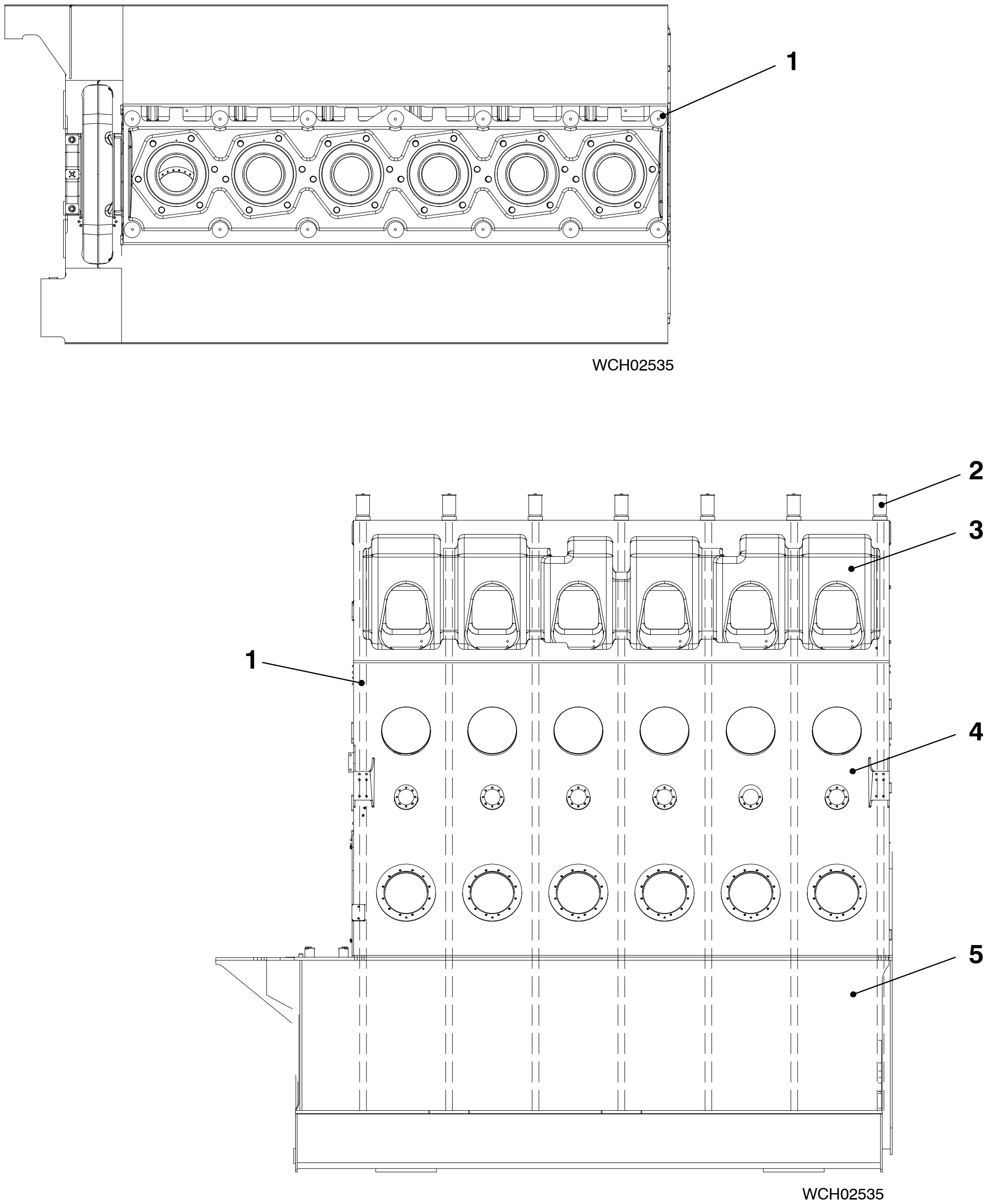
Fig. 2: Longitudinal Section

1 Crankshaft gear wheel
2 Bearing cover
3 Bearing cover
4 Crankshaft
5 Thrust pads (driving end)
6 Two-part oil baffle
7 Flywheel
8 Bedplate
9 Thrust pads (free end)
10 Thrust bearing flange
11 Column

Tie Rod

1. General

The tie rods (1, Fig. 1) keep the cylinder block (3), column (4) and bedplate (5) together at four locations around the cylinders.



FOR 6-CYLINDER ENGINES

Fig. 1: Tie Rod Configuration and Locations

1 Tie rod
2 Protection cover
3 Cylinder block
4 Column
5 Bedplate

A two-part bush (8) is welded on the tie rod (4, Fig. 2). At the bottom of the cylinder block, two set screws (7) keep the two-part bush in position to prevent vibration of the tie rods.

If a tie rod breaks in the bottom area, the holders (11) and screws (12) make sure that the nut (10) does not fall into the crankcase.

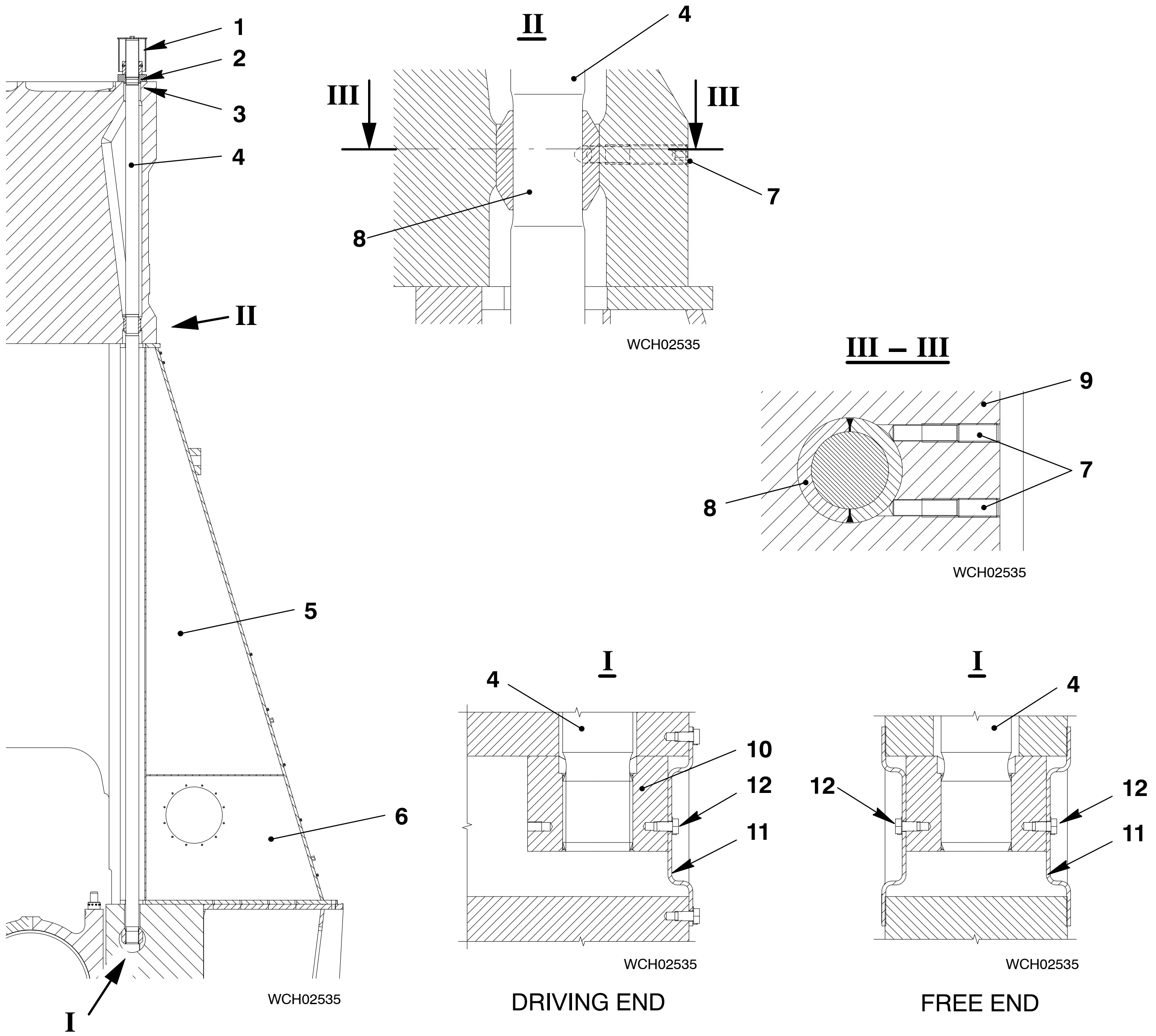


Fig. 2: Tie Rod Assembly

1	Protection cover	7	Set screw
2	Round nut	8	Two-part bush
3	Intermediate ring	9	Cylinder jacket
4	Tie rod	10	Nut
5	Column	11	Holder
6	Bedplate	12	Screw

Cylinder Liner and Cylinder Cover — Group 2

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Cylinder Liner

1. General

The screws (7, Fig. 1) and holders (6) hold the cylinder liner (4) in the cylinder jacket (5). The nuts of the elastic bolts attach the cylinder cover (1), cylinder liner (4) and the top and bottom water guide jacket (2) and (3), to the cylinder jacket (5).

The surfaces of the cylinder liner (4) and the cylinder jacket (5) make the metallic seal MS. A non-hardening compound is applied around the surface of the metallic seal MS to prevent leakage.

An antipolishing ring (10) is installed in the top part of the cylinder liner (4). The antipolishing ring removes coke contamination at the piston crown during operation.

2. Cooling

The cooling water flows through CI into the bottom water guide jacket (2) to the water space WS and around the cylinder liner (4). Cooling water flows also through the tube (11) into the top water guide jacket (3).

From the top water guide jacket (3), the cooling water flows through the cooling bores (9) and the cylinder cover (1) into the exhaust valve cage. Cooling water then flows through the cooling water outlet (1, Fig. 2) and back to the plant.

The O-rings (12, Fig. 1) are used to seal the water space WS. If water leaks you must replace the O-rings as soon as possible.

To prevent unwanted tension in the top part of the cylinder liner, the temperature of the cooling water must be kept in the permitted range. The maximum permitted temperature ranges are:

- $\pm 2°C$ at constant load
- $\pm 4°C$ during load changes.

3. Lubrication

Cylinder lubricating oil flows to the running surface of the cylinder liner (4) through six lubricating quills (8). The lubricating grooves LG are milled around the circumference of the cylinder liner and make sure that the lubricating oil is equally supplied (see 2138−1 Lubricating Quill).

Oil between the piston rings collects in the oil grooves OG and stays on the surface of the cylinder liner. This oil can decrease the lubricating oil feed rate.

For more data about the cylinder lubrication, see 7218−1.

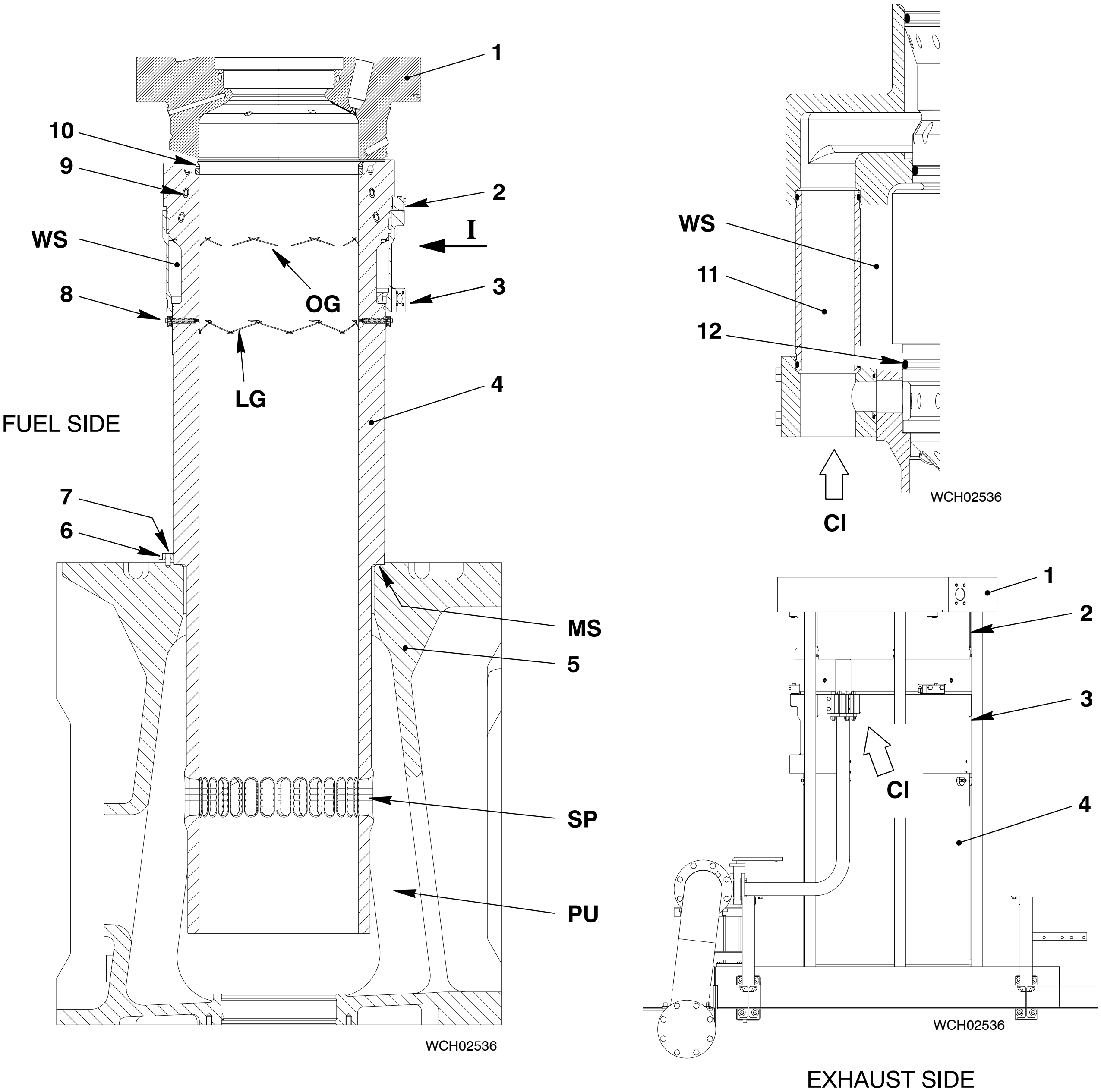

Fig. 1: Cylinder Liner

1 Cylinder cover
2 Top water guide jacket
3 Bottom water guide jacket
4 Cylinder liner
5 Cylinder jacket
6 Holder
7 Screw
8 Lubricating quill
9 Cooling bores
10 Antipolishing ring

11 Tube
12 O-ring

OG Oil grooves
CI Cooling water inlet (water guide jacket)
MS Metallic seal
LG Lubricating grooves
SP Scavenge ports
PU Piston underside
WS Water space

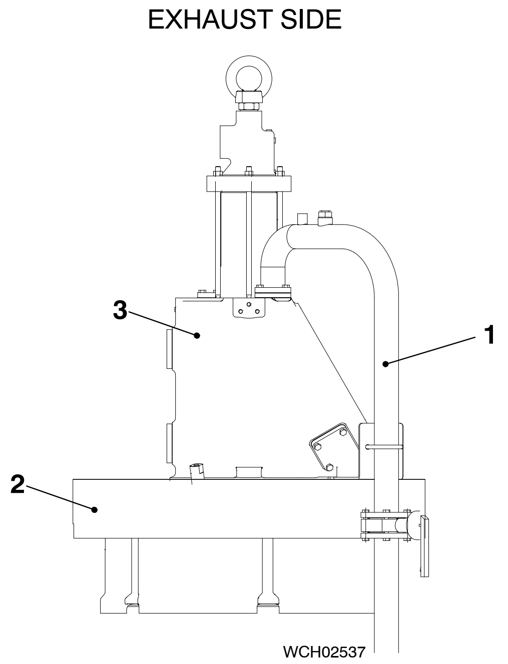

Fig. 2: Cooling Water Outlet

1 Cooling water outlet
2 Cylinder cover
3 Exhaust valve cage

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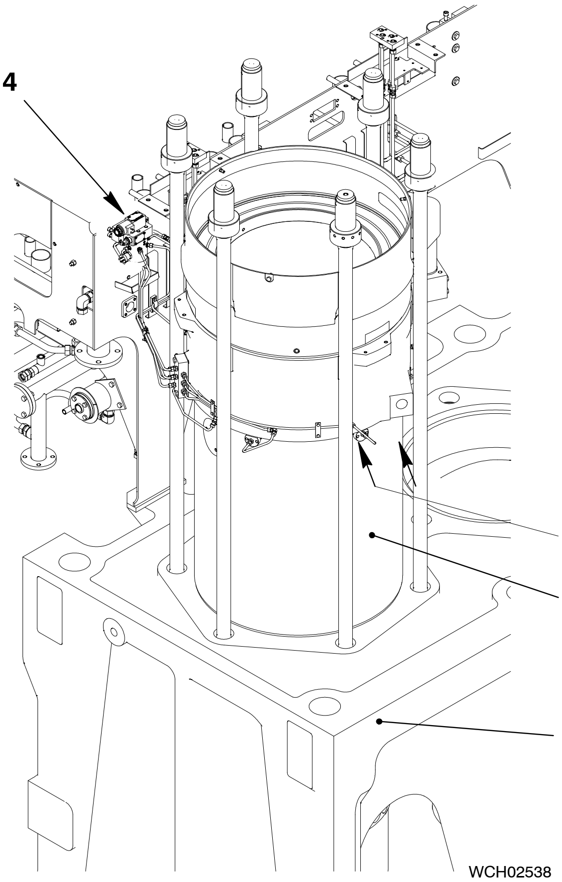
Lubricating Quills on Cylinder Liner

1. General

Six lubricating quills (1, Fig. 1) are are installed around the circumference of the cylinder liner (2). The lubricating pump (4) installed on the rail unit, supplies lubricating oil through pipes to each lubricating quill.



FREE END

Fig. 1: Location of Lubricating Quills

1 Lubricating quill
2 Cylinder liner
3 Cylinder block
4 Lubricating pump 25_7206_C#_1

2. Function

The lubricating pump supplies a set quantity of lubricating oil at high pressure through the connection (OI) into the lubricating quills (see Fig. 2).

The non-return valve (8) opens and the lubricating oil comes out of the the nozzle tip and the lubricating point (LP) as a spray. The lubricating oil flows equally into the grooves on the cylinder liner wall (see also 2124−1 Cylinder Liner and 7218−1 Cylinder Lubrication).

After a lubrication pulse, the oil pressure decreases and the force of the compression spring (3) closes the non-return valve (8).

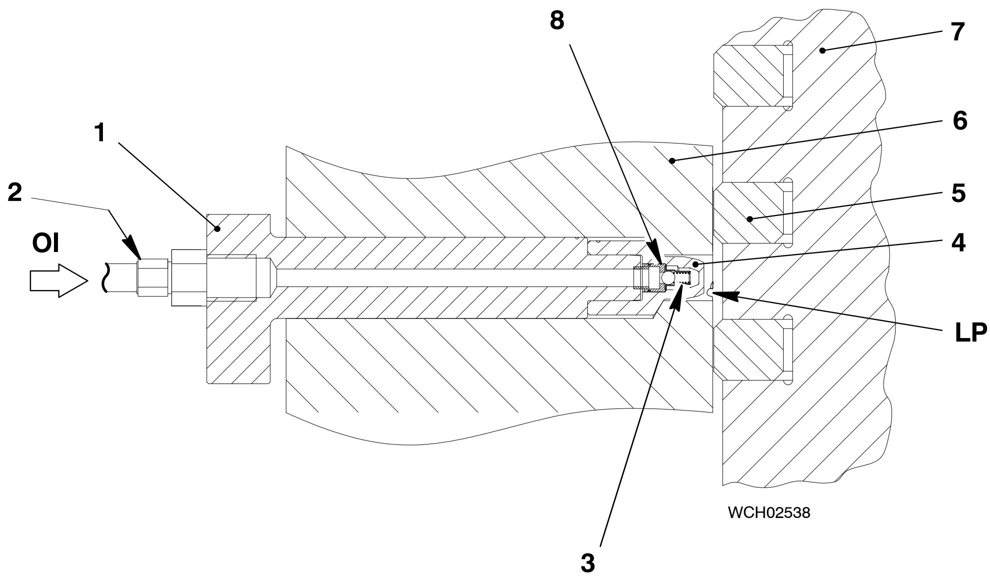


Fig. 2: Lubricating Quill

1	Holder	7	Piston
2	Union nut	8	Non-return valve
3	Compression spring		
4	Nozzle tip		
5	Piston ring	LP	Lubricating point in cylinder liner
6	Cylinder liner	OI	Lubricating oil inlet

Piston Rod Gland

1. General

The piston rod gland (4, Fig. 1) keeps the dirty oil in the scavenge space (SS) and prevents contamination of the bearing oil. Also, the piston rod gland seals the scavenge air from the crankcase (1).

Damaged gaskets cause an increase in the quantity of oil in the leakage oil drain. You use the sample port (3) to get an oil sample. You can measure this sample, and/or send the sample to the laboratory to make an analysis.

WARNING

Danger: The leakage oil drain LD must not become clogged (see 0240–1. There is a dangerous risk of fire if the dirty oil does not flow away from the area (see 0450–1).

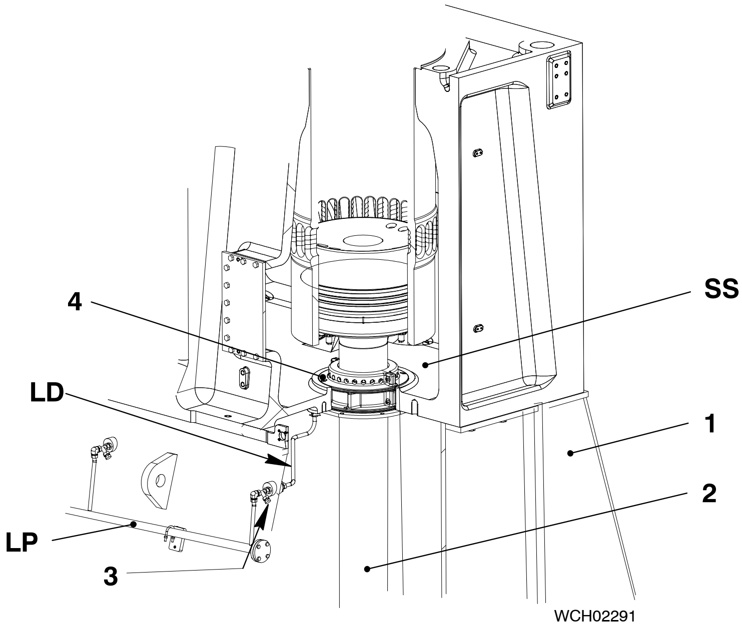


Fig. 1: Location of Piston Rod Gland Box

1	Crankcase	SS	Scavenge space
2	Piston rod	LP	Leakage oil pipe
3	Sample port	LD	Leakage oil drain
4	Piston rod gland		

2. Function

During operation, the two scraper rings (12, Fig. 2) remove dirty oil from the piston rod. The dirty oil flows through the oil bores (1) and collects in the bottom of the scavenge space (SS). The dirty oil flows out through the leakage oil drain on the fuel side.

The two gaskets (9) and (10) prevent the release of scavenge air into the crankcase. The low scavenge air pressure is released through a vent in the plant.

The oil that flows through the relief passages (2) into the neutral space (3) flows into the oil drain.

The four ring supports (4) hold the eight scraper rings (7) in position. The scraper rings (7) remove bearing oil from the piston rod. This bearing oil flows through the bearing oil drain (BD) to the crankcase.

The tension springs, (8) and (11), keep the scraper rings (7) and (12) against the piston rod.

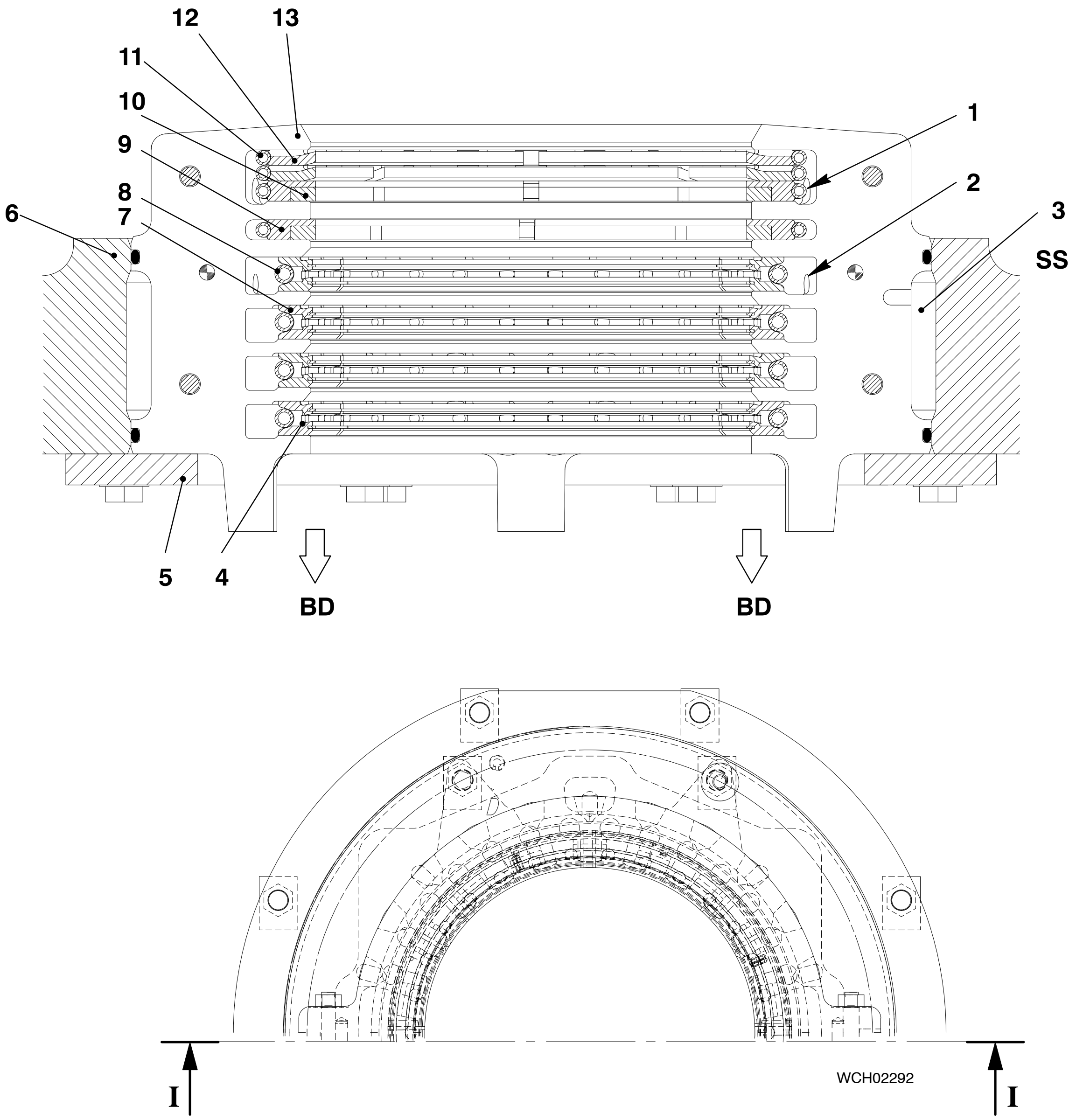


Fig. 2: Piston Rod Gland

1	Oil bore	10	Gasket (4-part)
2	Relief passage	11	Tension spring
3	Neutral space	12	Scraper ring (4-part)
4	Ring support (3-part)	13	Housing (2-part)
5	Support		
6	Cylinder jacket		
7	Scraper ring (3-part)		
8	Tension spring	BD	Bearing oil drain
9	Gasket (four-part)	SS	Scavenge space

Injection Valve (FAST Nozzle)

1. General

Three injection valves (1, Fig. 1) are installed in each cylinder cover.

Fuel is used to operate the injection valves (1). When the injection valve operates and the needle opens, a small quantity of fuel leaks out of the injection valve. This fuel flows back through the control fuel return pipe (2). To prevent contamination of lube oil with fuel, a fuel / lube oil leakage path drains through the fuel / lube oil leakage pipe (3) to the plant (see 8019−1 Fuel System).

To disassemble, assemble and do tests of the injection valves, see the Maintenance Manual, Chapter 2722−1.

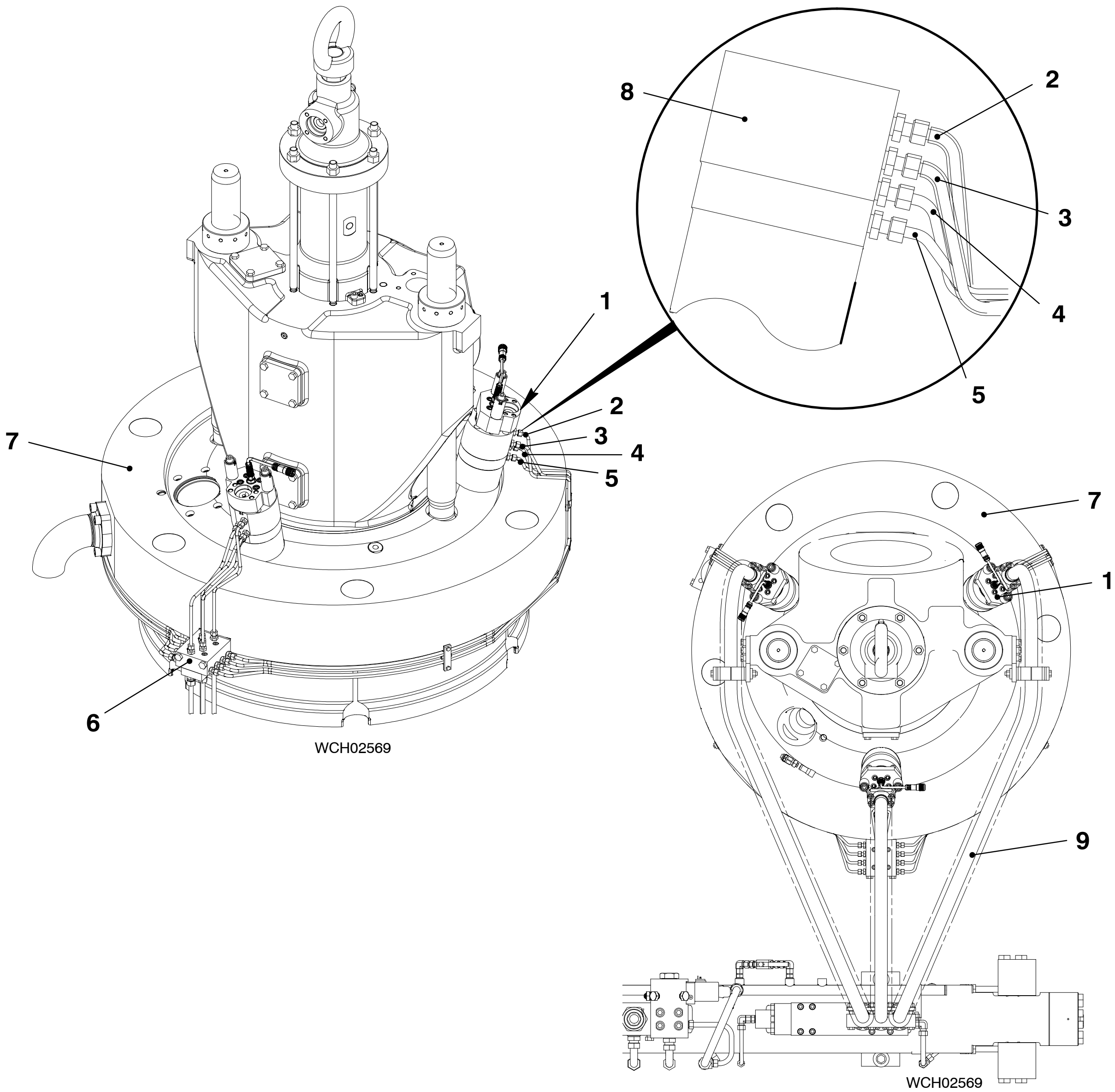


Fig. 1: Location of Injection Valves

1 Injection valve
2 Control fuel return
3 Fuel / lube oil leakage pipe
4 Lube oil return
5 Lube oil inlet
6 Connecting block
7 Cylinder cover
8 Valve bush
9 HP fuel pipe (injection valve)

2. Function

Fuel flows through the high pressure (HP) fuel pipes (9, Fig. 1) to the three injection valves (1).

The control valve for the injection valves is activated, which moves the needle to the open position. Fuel flows through the holes in the nozzle tip (3, Fig. 2) and into the combustion chamber as a spray. A small quantity of fuel flows through the control fuel return.

3. Cooling

Oil from the lubricating oil system lubricates the injection valves and keeps them cool (see 8016−1 Lubricating Oil System). When the engine has stopped, the lubrication also stops. This is because the temperature of the remaining fuel in the injectors would decrease too much.

Oil flows through the lube oil inlet (4) through bores in the injection valve. The oil flows back through the bores in the injection valve through the lube oil return (4, Fig. 1).

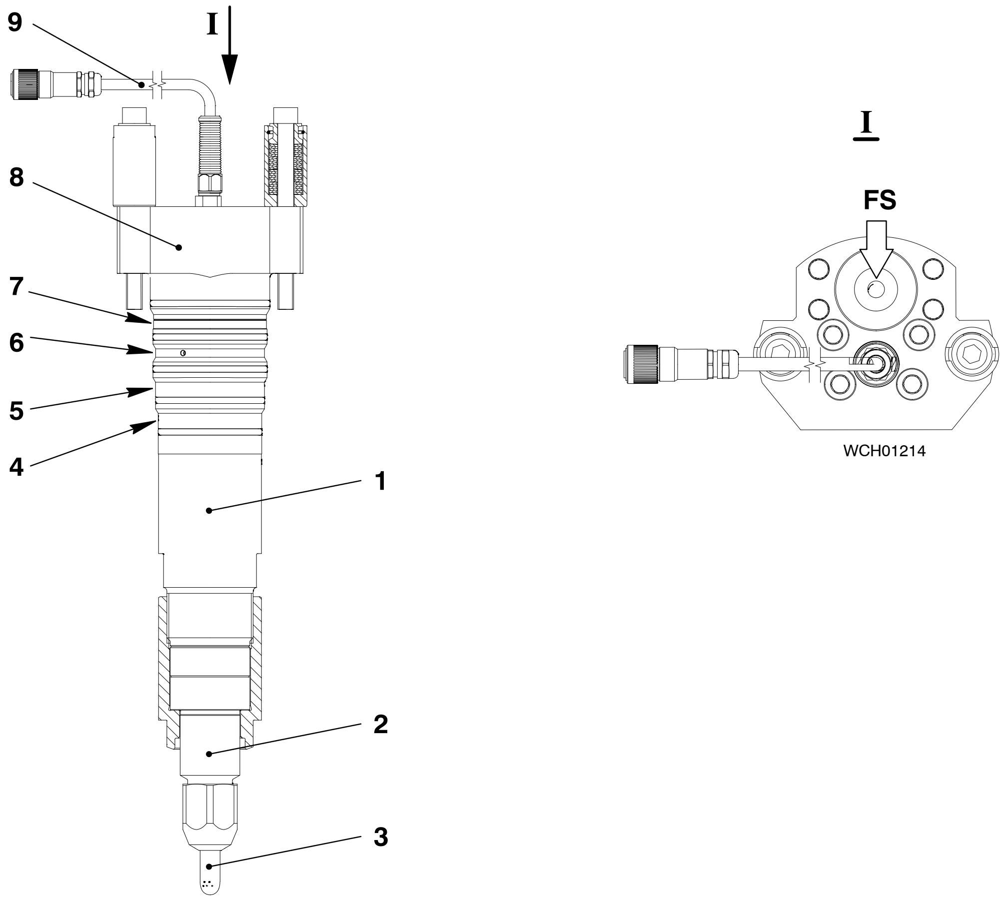


Fig. 2: Injection Valve

1 Injection valve
2 Nozzle body
3 Nozzle tip
4 Annular groove − lube oil inlet
5 Annular groove − lube oil return
6 Annular groove − fuel / lube oil leakage
7 Annular groove −control fuel return
8 Valve bush
9 Electrical cable to control valve
FS Fuel supply

Starting Valve

1. General

A starting valve is installed in each cylinder cover (6, Fig. 1). The starting valves start the engine, or decrease the engine speed for reversing.

The engine control system (ECS) monitors and controls the starting valve operation (see 4002−1, paragraph 3.1). The Cylinder Control Modules (CCM−20) open the starting valves electronically at the correct crank angle to release starting air into the combustion chamber.

The parameter settings of the starting valves are adjustable. The ECS gives access to the parameter settings.

For more data, see the schematic diagrams, 4003−2.and 4003−9.

2. Function

2.1 Initial Conditions

Starting air (SA) pressurizes the air chamber (P_2). The compression spring (4) keeps the valve closed. The pipe (7) in the cover (1) has the starting air pressure.

2.2 Engine Start

The CCM−20 activates the 3/2-way solenoid valve (8). The air chamber (P_1) is pressurized, the valve opens and starting air flows into the combustion chamber. The piston (2) moves down, starting air flows into the combustion chamber and the engine starts to turn.

When combustion starts, the higher pressure (firing pressure) in the combustion chamber keeps the starting air valve closed.

2.3 Engine Slow-down (to Reverse the Engine)

If the combustion and thus the propulsion stops (or a slower speed is selected from the remote control), the movement of the ship continues. The flow of water has an effect on the propeller.

To start the engine in the opposite direction, it is necessary to slow the engine speed to below the set limit. This operation is related to the engine speed and propeller configuration, and can be some minutes.

At the specified engine speed, the ECS opens the starting valve at approximately 100° before TDC. The starting air flows into the combustion chamber. The piston in the cylinder moves up, compresses the air and the engine speed decreases and then stops.

The engine then turns in the opposite direction and starts. For more data about reversing, see 0260−1, paragraph 3.4.

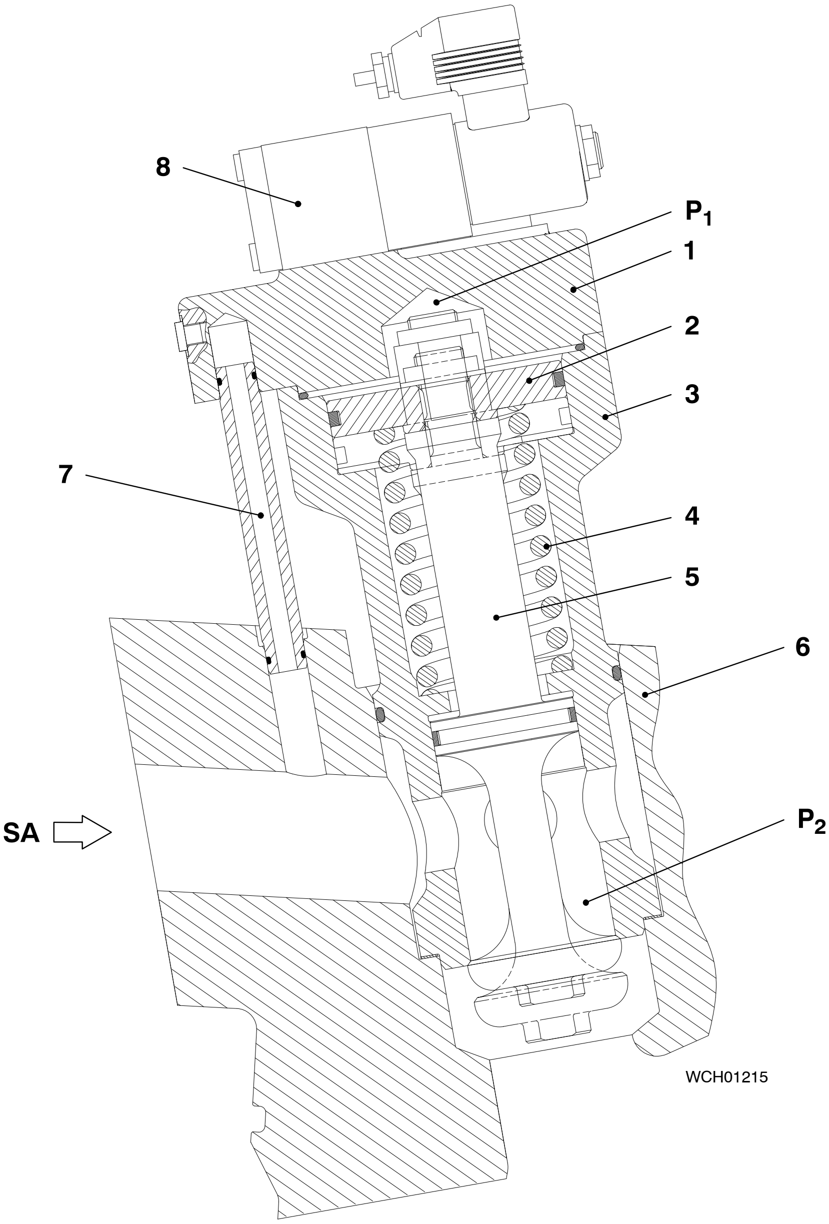


Fig. 1: Starting Valve

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

P_1 Air chamber
P_2 Air chamber

Exhaust Valve

1. General

The exhaust valve (2, Fig. 1) is installed in the centre of cylinder cover (1) and has the parts that follow:

- Top housing
- Housing
- Valve cage
- Valve spindle
- Valve seat.

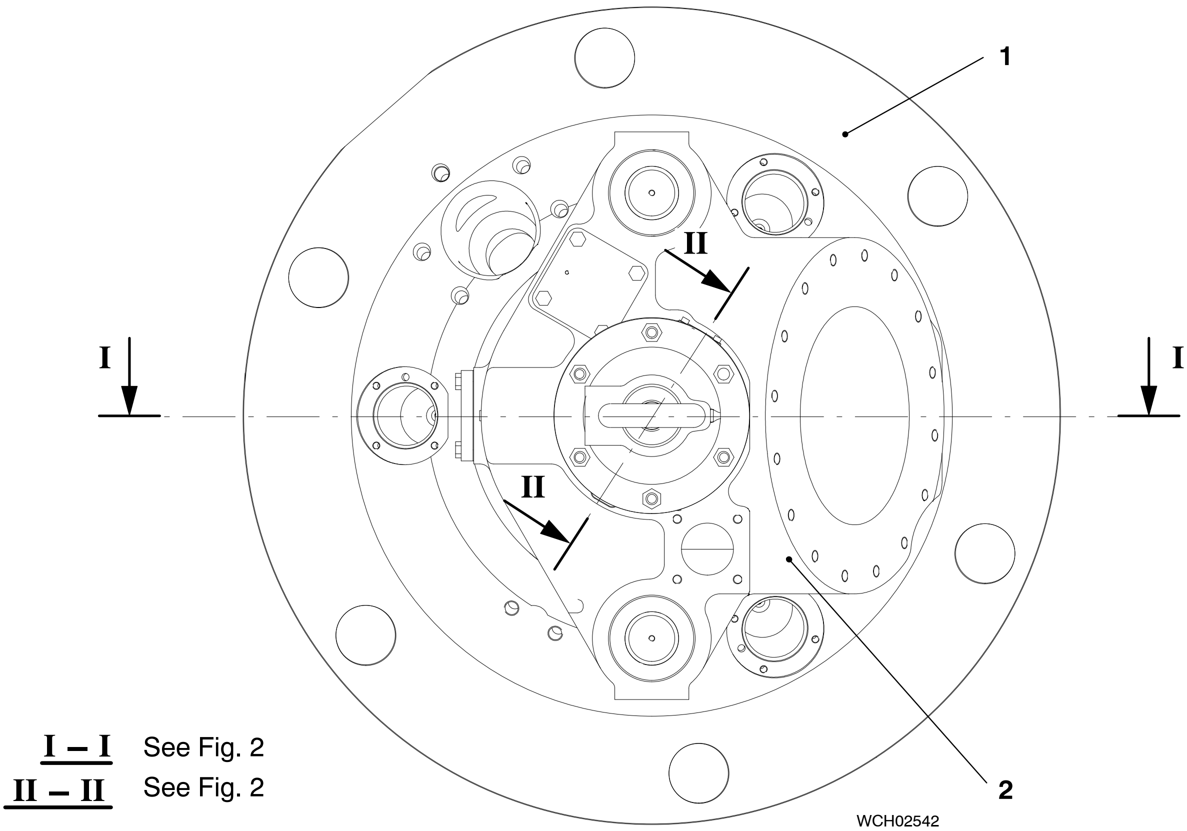


Fig. 1: Location of Parts in Cylinder Cover

1 Cylinder cover

2 Exhaust valve

The air spring (AS) is below the air spring piston (9, Fig. 2).

The valve stroke sensor (19) monitors and transmits the open and closed positions of the valve spindle (16) to the engine control system (ECS).

If there is a large pressure difference between when the exhaust valve opens and the pressure in the air spring (AS), damage can occur to the exhaust valve. Thus, for safety the cup springs (10) are installed to absorb vibration and shock.

The thrust piece (6) prevents damage to the inner piston (5) and the top of the valve spindle (16) when the exhaust valve operates.

Note: Before the lubricating oil pump and servo oil service pump are set to on, the air spring must have pressure and the exhaust valves must be closed. The engine cannot start if the exhaust valves are not fully closed.

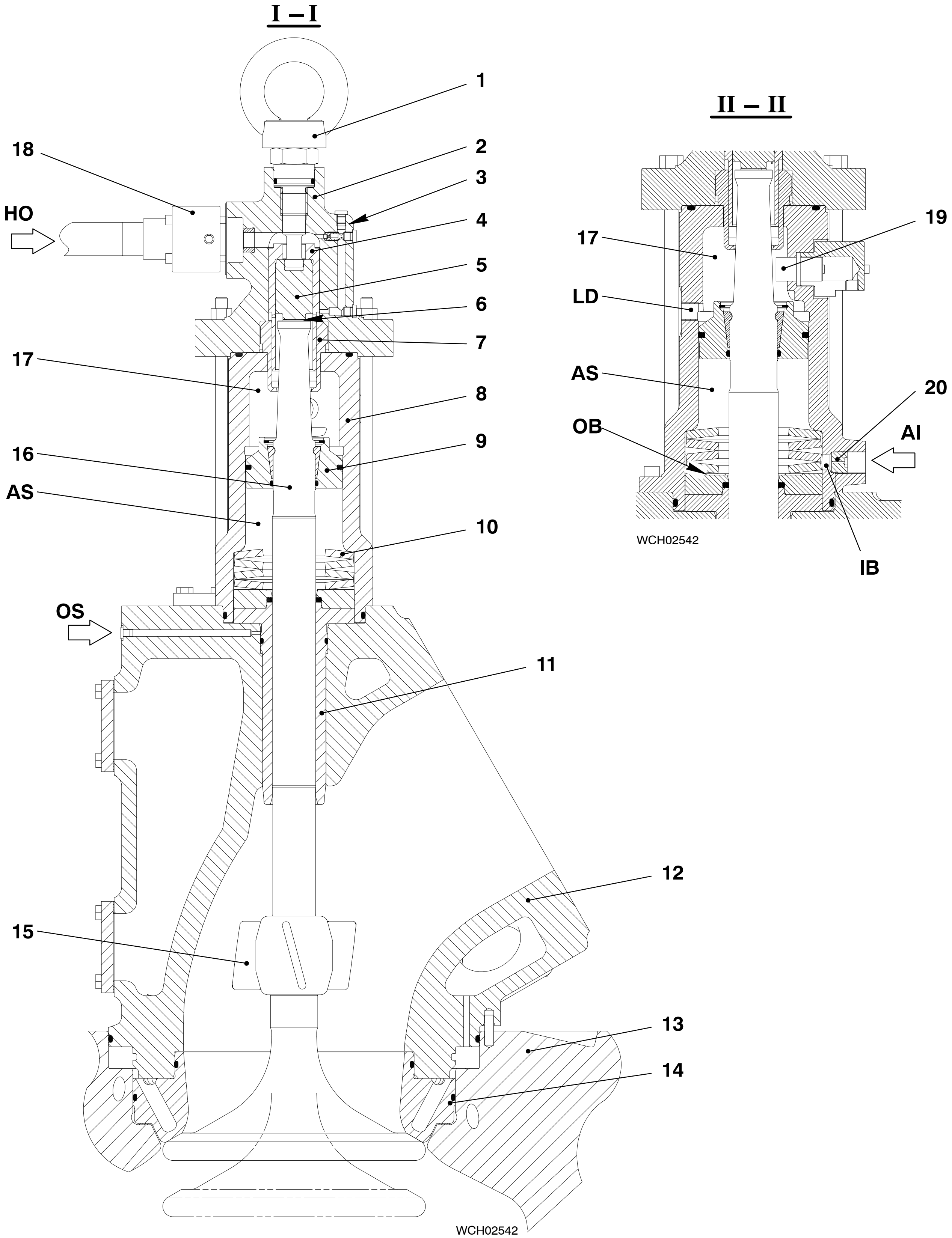


Fig. 2: Exhaust Valve and Leakage Oil Drain

Key to Fig. 2: Exhaust Valve and Leakage Oil Drain

1	Damper	16	Valve spindle
2	Top housing	17	Leakage oil collection space
3	Orifice	18	Hydraulic oil connection
4	Outer piston	19	Valve stroke sensor
5	Inner piston	20	Non-return valve
6	Thrust piece		
7	Piston guide		
8	Housing	AI	Air inlet to air spring
9	Air spring piston	IB	Inlet bore (to air spring)
10	Cup spring	OB	Oil bath
11	Guide bush	AS	Air spring
12	Valve cage	LD	Leakage oil drain
13	Cylinder cover	OS	Oil supply (to valve guide)
14	Valve seat	AS	Air spring
15	Rotation wing	HO	Hydraulic oil inlet

2. Function

2.1 Open

When the piston in the valve control unit (VCU) operates, hydraulic oil (HO) flows through the connection (18, Fig. 2) into the top housing (2). The outer piston (4) and the inner piston (5) move down.

The air spring piston (9), which is attached to the valve spindle (16), moves down against the pressure in the air spring (AS) and the exhaust valve opens. The force of the exhaust gas on the rotation wing (15) turns the valve spindle.

2.2 Close

When the hydraulic oil pressure from the VCU decreases (i.e. when the control rod in the VCU opens the related relief bores) the pressure in the air spring (AS) pushes the air spring piston (9) up.

The valve spindle (16) then pushes the inner piston (5) and the outer piston (4) up and the exhaust valve closes. The hydraulic oil in the top housing (2) flows back to the VCU.

2.3 Hydraulic System

Hydraulic oil and air in the system flow continuously from the top housing (2), outer piston (4) and inner piston (5) into the leakage oil collection space (17). This leakage oil / air then drains though the leakage oil drain (LD).

The hydraulic oil that flows through the internal bores of the VCU continuously keeps the correct oil quantity in the hydraulic system.

2.4 Air Supply to Air Spring

Compressed air flows into the air inlet connection (AI) and through the non-return valve (20) to the inlet bore (IB). The compressed air then flows into the air spring (AS).

When the exhaust valve opens the air spring piston (9) moves down, which compresses the air in the air spring (AS). Some of the compressed air flows back through the inlet bore (IB). After the exhaust valve closes, compressed air flows again into the air spring (AS).

3. Lubrication

Leakage oil from the outer piston (4, Fig. 2) and inner piston (5) lubricates the air spring piston (9). Oil in the leakage oil collection space (17) drains to the leakage oil drain (LD).

While the exhaust valve closes, oil flows through the air spring piston (9) and into the air spring (AS). The air from the air inlet (AI) changes the oil that collects at the bottom of the air spring (AS) (at the inlet bore IB) into a mist. The mist lubricates the top part of the valve spindle (16).

When the exhaust valve opens, unwanted oil flows out of the air spring (AS) through the air spring pipe to an accumulator. The oil in the accumulator automatically drains through the leakage oil pipe at the driving end of the exhaust valves into the crankcase.

Oil from the oil bath (OB) lubricates the bottom part of the valve spindle (16).

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Crankshaft, Connecting Rod and Piston — Group 3

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Axial Damper

1. General

The engine has a built-in axial damper. The function of the axial damper is to decrease the axial vibrations.

The axial damper includes a top cylinder half (3, Fig. 1) and a bottom cylinder half (4) attached with bolts to the last bearing girder.

2. Function

Bearing oil flows from the oil inlet (OI) through the oil pipe (5) into the two inlet pipes (1). The bearing oil then flows through the non-return valves (2) into the groove in the crankshaft (10) (i.e. into the annular spaces (9) on each side of the middle part of the cylinder halves (3) and (4)).

Most of the oil can only flow through the pressure reducing nozzle (7) from one annular space (9) to the other when the crankshaft turns.

The remaining oil drains because of the radial and axial clearances of the sealing rings (11) and (12) and the vent bore in the pressure reducing nozzle (7).

Note: Do not operate the engine when there is no oil supply to the axial damper.

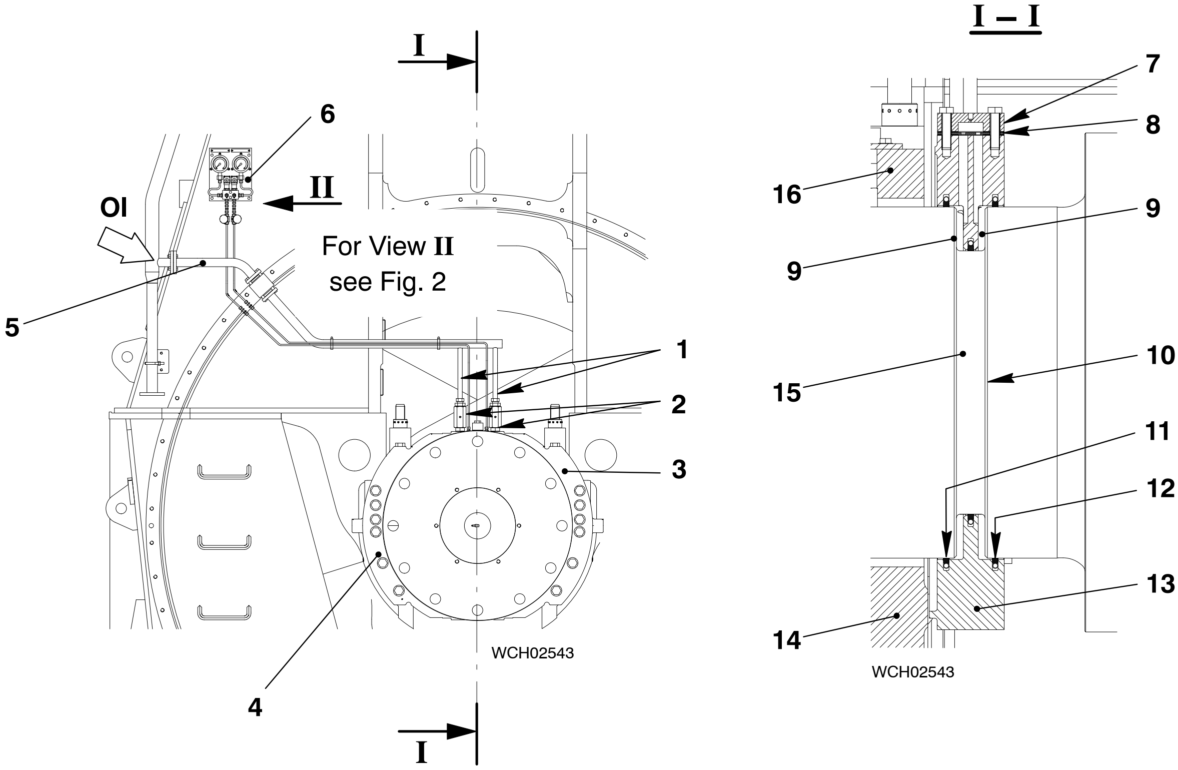

Fig. 1: Axial Damper

1	Inlet pipes	10	Groove in crankshaft
2	Non-return valves	11	Large sealing ring
3	Top cylinder half	12	Small sealing ring
4	Bottom cylinder half	13	Vibration damper
5	Oil pipe	14	Bearing girder (part of bedplate)
6	Axial damper monitor	15	Crankshaft
7	Pressure reducing nozzle	16	Bearing cover
8	Orifice		
9	Annular space	OI	Oil inlet

3. Axial Damper Monitor

The engine has a system that monitors the axial damper, installed at the free end above the end casing (see Fig. 2). This system monitors the oil pressure in the front and rear spaces of the axial damper.

If the oil pressure decreases below a set value, an alarm is activated (for more data about the setting values, see 0250–2 Alarms and Safeguards).

The cause of this alarm must be investigated and and the problem corrected. See the possible causes that follow:

- The orifices in the pressure gauge pipes are clogged.
- The shut-off valves are closed in the pressure gage pipes.
- There is low oil pressure and / or high oil temperature in the bearing oil system.
- The sealing rings have too much wear, e.g. dirt particles (clearance is too large).
- A non-return valve is blocked.

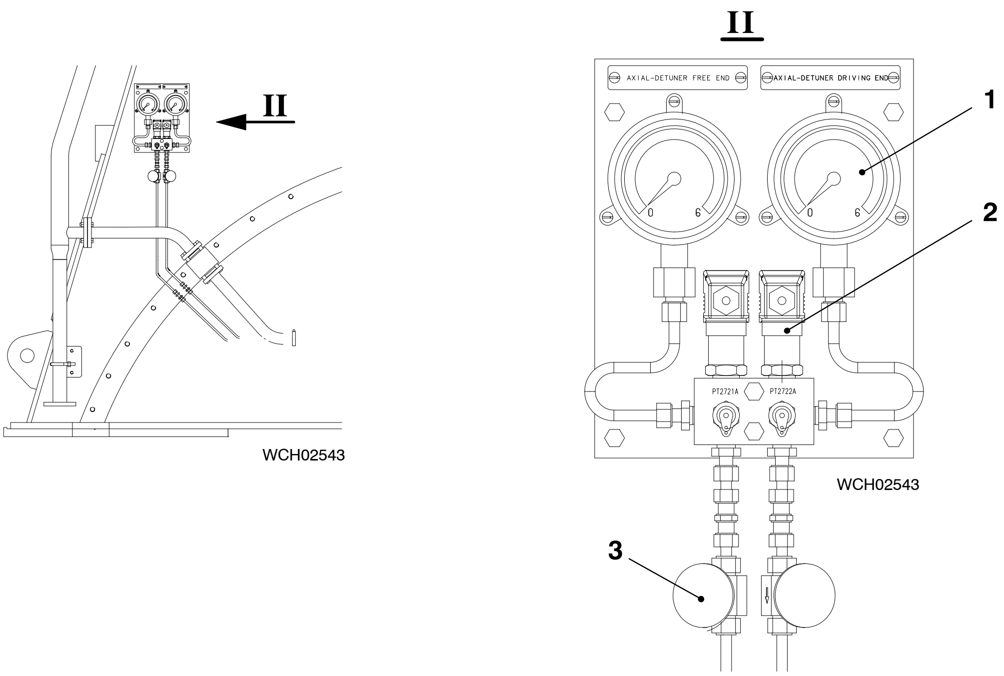

Fig. 2: Axial Damper Monitor

1 Pressure gages
2 Pressure transmitters
3 Needle valves

Connecting Rod and Connecting Rod Bearing

1. General

The connecting rod connects the crosshead with the crankshaft and converts the linear movement of the piston into a circular movement.

The bearing shells (4, 7, and 9, Fig. 1) (that you can replace) are installed on the connecting rod (1) for the bottom end bearing and top end bearing.

The top bearing cover (1) is lined with white metal.

2. Lubrication

Crosshead lubricating oil flows through the connection (CO) to the top end bearing, and holes in the crosshead pin let lubricating oil flow to the guide shoes.

Crosshead lubricating oil flows through the oil bore (OB) in the connecting rod (1) to the bottom end bearing.

Bearing oil flows through the connection (PC) for piston cooling through the related oil bores in the crosshead pin and piston rod.

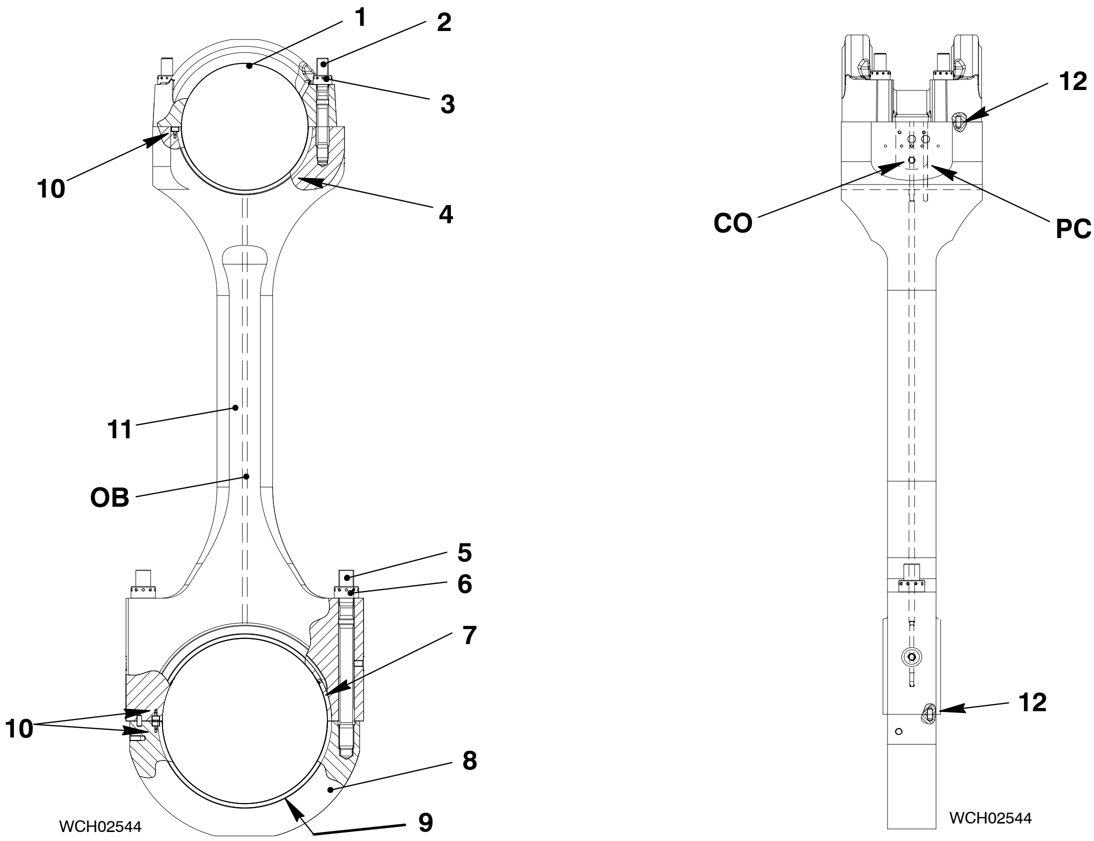

Fig. 3: Connecting Rod and Connecting Rod Bearing

1 Top bearing cover
2 Elastic bolts (top end bearing)
3 Round nut
4 Bearing shell (top end bearing-crosshead)
5 Elastic bolts (bottom end bearing)
6 Round nut
7 Top bearing shell (bottom end bearing)
8 Bottom bearing cover
9 Bottom bearing shell (bottom end bearing)
10 Allen screw
11 Connecting rod
12 Cylindrical pin

PC Piston cooling oil inlet
CO Crosshead lube oil inlet
OB Oil bore

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Crosshead and Guide Shoe

1. General

The crosshead guides the piston rod (8) and absorbs the lateral forces that come from the connecting rod (4) (see Fig. 1 and Fig. 2).

The piston rod (8) is attached to the crosshead pin (6) with screws. The bearing oil necessary to cool the piston flows through the groove (11) and the bore (OB) to the piston. The oil (OR) flows back to the crosshead pin through the oil pipe (1) and returns to the crankcase through the drain (OD).

The guide shoes (3) stay in position on the crosshead pin and move up and down in the guide rails (12), which are in the guide ways of the column (10).

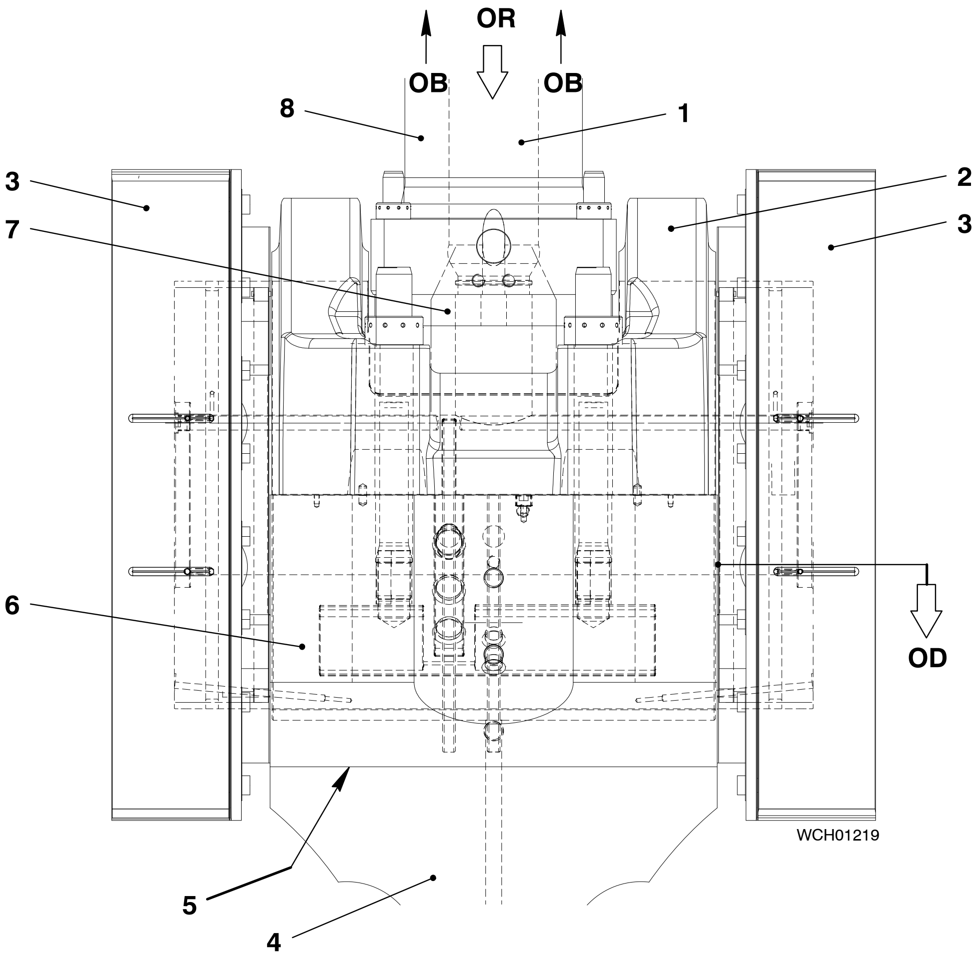

Fig. 1: Crosshead and Guide Shoe (Side View)

1 Oil pipe (to piston)
2 Top bearing half (top end bearing)
3 Guide shoe
4 Connecting rod
5 Bearing shell (top end bearing)
6 Crosshead pin
7 Compression shim
8 Piston rod

OB Oil bore to piston
OR Oil return from piston
OD Oil drain to crankcase

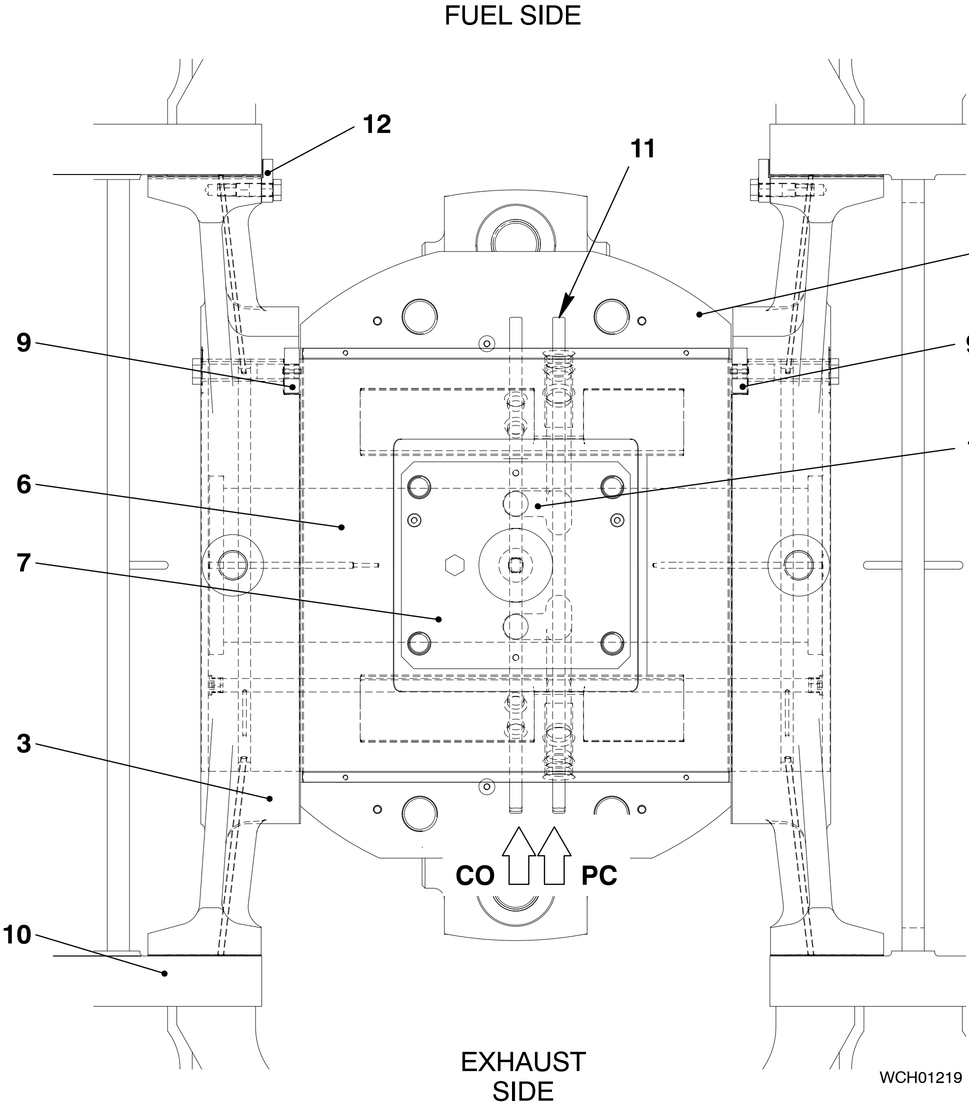

Fig. 2: Crosshead and Guide Shoe (Top View)

3	Guide shoe	11	Groove (in connecting rod)
4	Connecting rod	12	Guide rail
6	Crosshead pin	13	Groove (in crosshead pin)
7	Compression shim		
9	Holding plate	CO	Crosshead lubricating oil inlet
10	Column	PC	Piston cooling oil inlet

Piston

1. General

The piston has the parts that follow:

- Piston crown (1, Fig. 1)
- Piston rings (2)
- Piston skirt (3)
- Piston rod (4)
- Oil pipe (5)
- Compression shim (6).

Nine elastic bolts (8) and round nuts (9) attach the piston crown (1) and the piston rod (4) together. The piston skirt (3) is attached to the piston rod with screws.

The piston rod (4) is attached to the crosshead pin (7) in a specified position. The compression shim (6) is installed between the piston rod and crosshead pin. The thickness of the compression shim is related to the compression ratio.

Note: The mark TOP on all piston rings must point up. For more data about the piston rings, see the Maintenance Manual 3425–1.

2. Piston cooling

Lubricating oil is used to keep the piston crown (1) cool. This cooling oil flows from the crosshead pin (7) into the two oil inlets (OI). The cooling oil then flows through the oil pipe (5) (inside the piston rod (4)) to the spray plate (10).

The cooling oil comes out as a spray (OS) from the nozzles in the spray plate (10) into the cooling bores of the piston crown (1). The oil then flows through the oil return (OR) into the crosshead pin (7) and out through the oil bores to the crankcase.

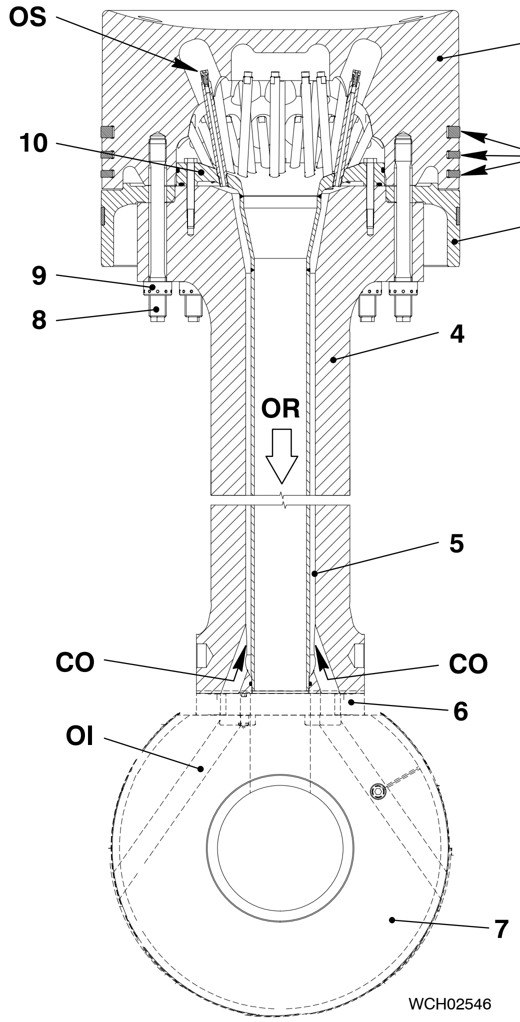

Fig. 1: Piston

1	Piston crown	9	Round nut
2	Piston rings	10	Spray plate
3	Piston skirt		
4	Piston rod		
5	Oil pipe (to spray plate)	OI	Oil inlet
6	Compression shim	OR	Oil return (from piston crown)
7	Crosshead pin	CO	Piston cooling oil
8	Elastic bolt	OS	Oil spray

Crosshead Lubrication and Piston Cooling

1. General

Lubricating oil keeps the pistons cool. Bearing oil lubricates the crosshead. Each oil system operates independently. The oil from each system flows through a double articulated lever to the crosshead.

2. Crosshead Lubrication

The crosshead lubricating oil flows from the oil inlet (OI, Fig. 1) through the support (2), the bottom lever (4) and the top lever (5) to the connection piece (6). The connection piece is attached to the connecting rod (10). The oil enters the ring space (RS) through the bore (7). The crosshead pin (8) is lubricated through bores in the top end bearing shell (9). The oil flows through the bore (OB) through the connecting rod (10) to the bottom end bearing.

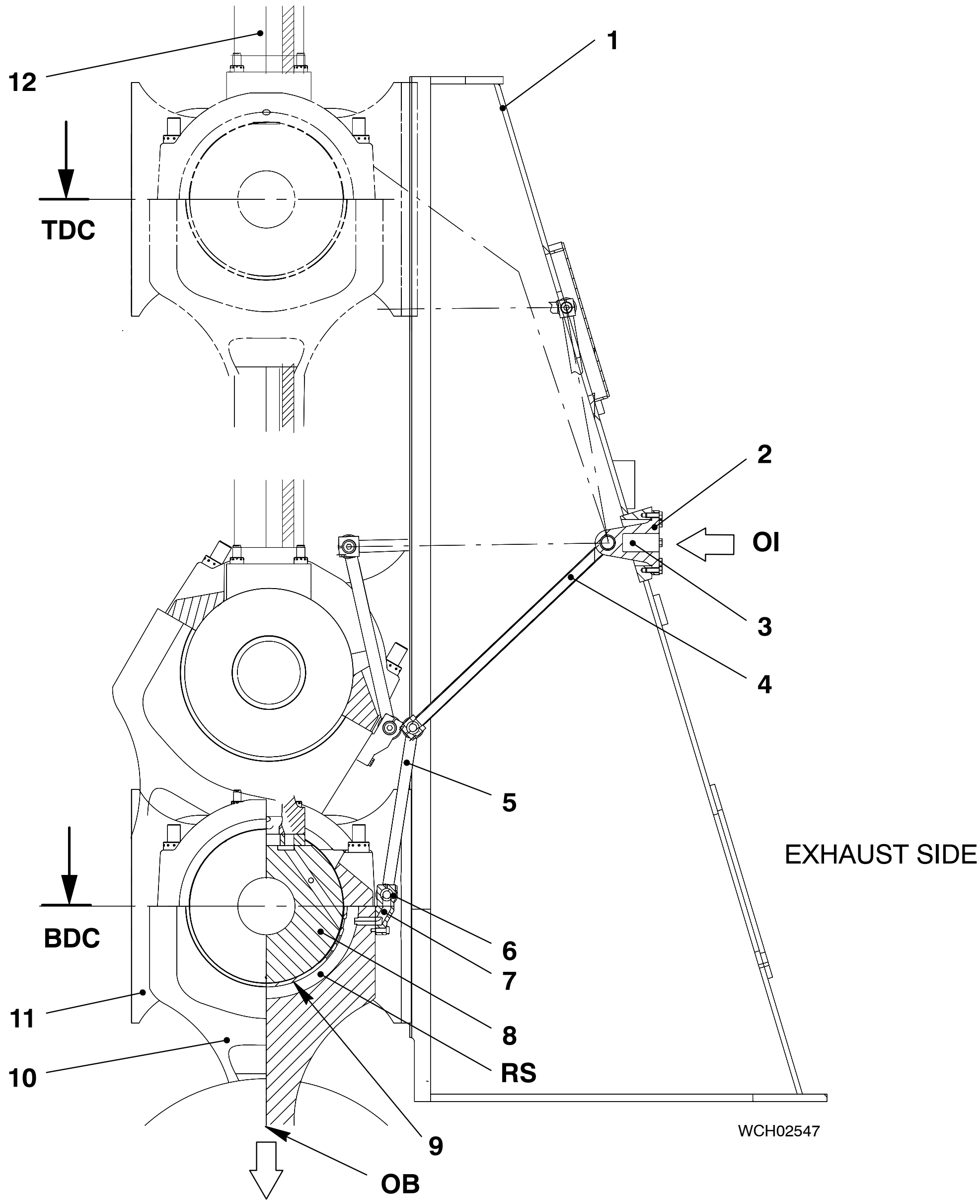

Fig. 1: Articulated Lever – Location

Key to Fig. 1 Articulated Lever – Location

1	Column	9	Top end bearing shell
2	Support	10	Connecting rod
3	Oil inlet (crosshead lubrication)	11	Guide shoe
4	Bottom lever	12	Piston rod
5	Top lever	OB	Oil bore (crosshead lubricating oil to bottom end bearing)
6	Connection piece	OI	Oil inlet
7	Bore (crosshead lubricating oil)	RS	Ring space (crosshead lubricating oil)
8	Crosshead pin		

3. Piston Cooling

Bearing oil flows from the oil inlet (OI, see Fig. 1 and Fig. 2) through the support (2), the bottom lever (4) and the top lever (5) to the connection piece (6). The oil flows through the bore (7) into the ring space in the crosshead pin (8), through bores in the top end bearing shell (9). The oil flows through the outer part of the oil pipe (13) through the piston rod (12) to the piston.

The oil then flows down through the inner part of the oil pipe (13) through the oil return (OR) to the center bore in the crosshead pin (8). Some of the piston cooling oil is used to lubricate the guide shoes (11) and the guide shoe pins. The remaining oil flows into the crankcase.

For more data, see 3326−1 Crosshead and Guide Shoe.

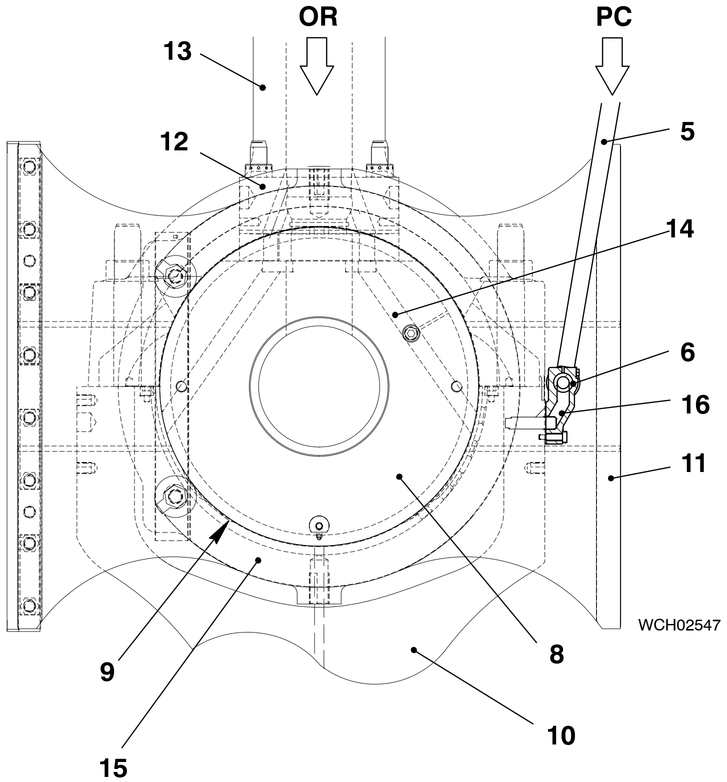

Fig. 2: Cross-section through Crosshead

5	Top lever	13	Oil pipe
6	Connection piece	14	Bore (in the crosshead pin)
8	Crosshead pin	15	Ring space (piston cooling oil)
9	Top end bearing shell	16	Bore (piston cooling oil)
10	Connecting rod		
11	Guide shoe	PC	Piston cooling (oil inlet)
12	Piston rod	OR	Oil return

Engine Control and Control Elements — Group 4

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Engine Control System

1. General

The engine control system (ECS) is an embedded system that has a modular design. Some parts and functions in the ECS configuration are optional and are related to the application.

Note: The name of the Wärtsilä engine control system is Unified Controls Flex (UNIC–flex)

The system uses modern bus technologies for the transmission of signals.

Data buses transmit signals between the external systems:

- Propulsion Control System (PCS) (see paragraph 4.2)
- Alarm and Monitoring System (AMS) (see paragraph 4.3).

These data buses are the interface between the operator and engine control.

CAUTION
Damage Hazard: Software updates must be done only with the supervision of a Wärtsilä service engineer and in accordance with regulations that Wärtsilä Services Switzerland Ltd. has set. Damage to the control system and the engine can occur.

2. System Description

The engine control system on the W-X engine is a modular system that has the items that follow:

- Two local display units (LDU-20) (1, Fig. 1). One LDU-20 is installed at the local maneuvering stand at the free end. The other LDU-20 is installed in the engine control room (ECR). External control systems transmit data to the LDU-20. The LDU-20 gives the operator a graphical user interface for access to data and system adjustments. For more data, see 4002–2 Local Control Panel/Local Display Unit LDU-20, paragraph 3 LDU-20.
- One input/output module (IOM-10) (2), installed at the rail unit in the terminal box E90. The IOM-10 has the engine control functions, e.g. exhaust waste gate control and redundant sensor and actuator signals of the MCM-11.
- One cylinder control module (CCM-20) (3) for each cylinder, installed on the rail unit in the terminal box E95. The CCM-20 has cylinder-related control functions. The CCM-20 also has redundant global functions for engine control.
- One main control module (MCM-11) (4), installed at the rail unit in the terminal box E25. External control systems transmit data to the MCM-11. The MCM-11 has functions for speed control and common engine functions (e.g. start valve control).

Redundant CAN system busses connect all the modules (see paragraph 2.3).

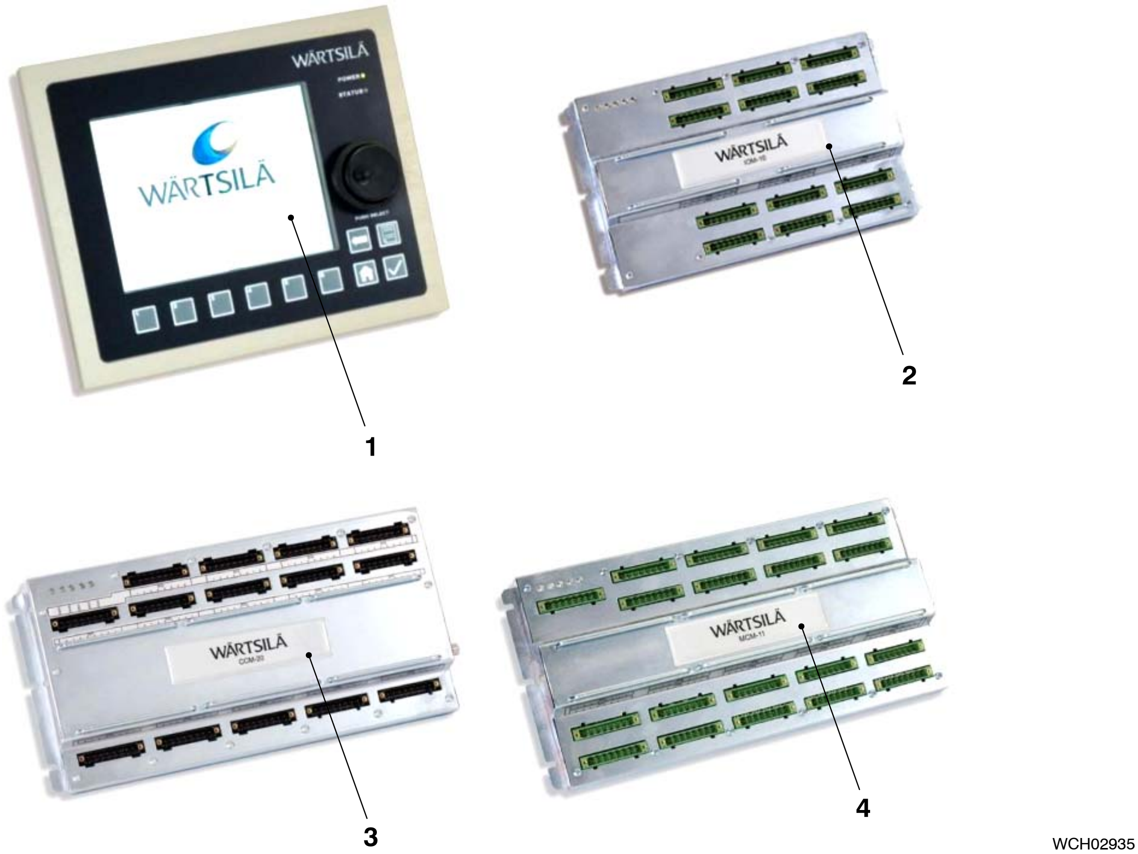

Fig. 1: ECS Modules

1 Local display unit (LDU-20)
2 Input output module (IOM-10)
3 Cylinder control module (CCM-20)
4 Main control module (MCM-11)

Engine Control System UNIC

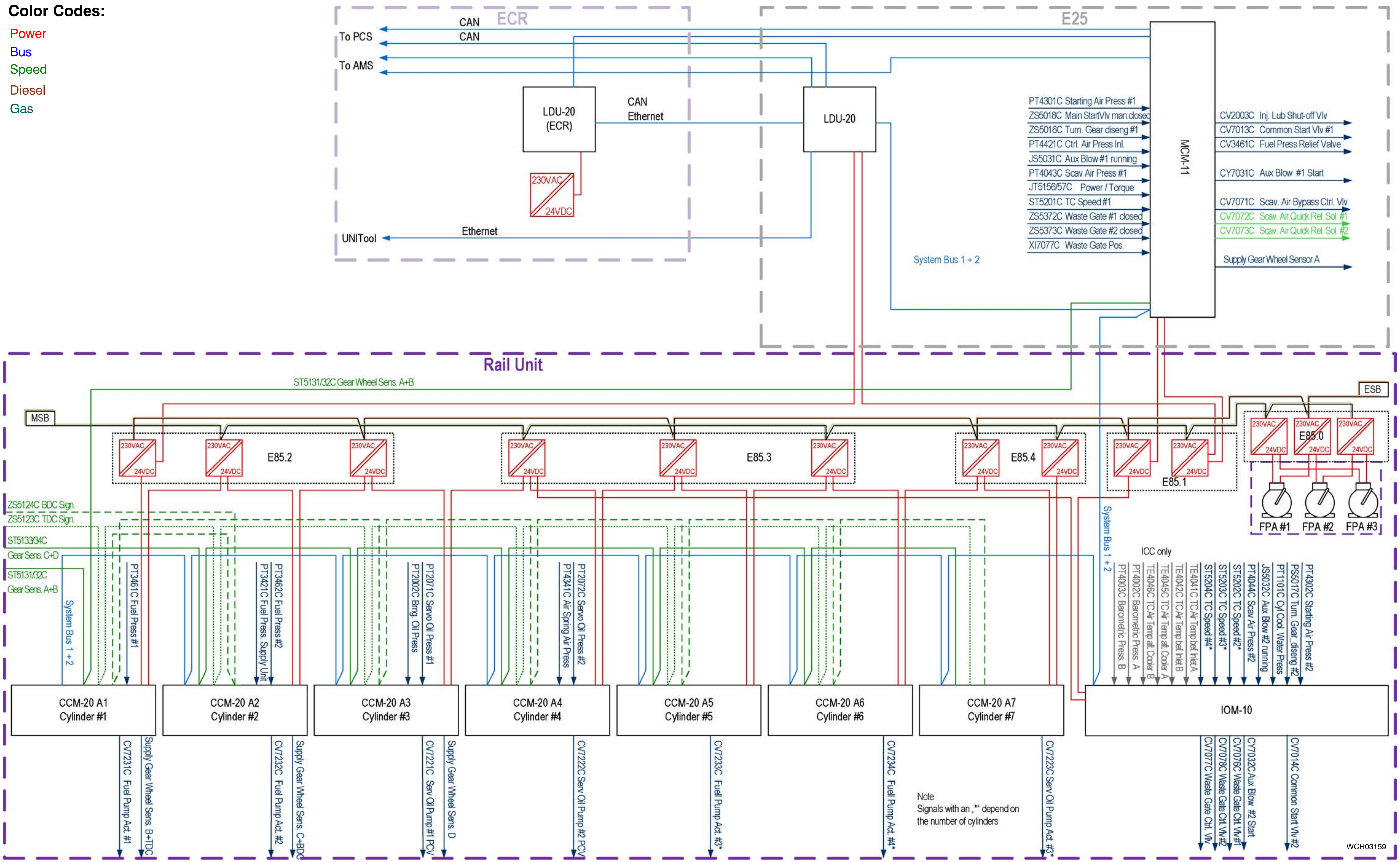

Fig. 2: Schematic Diagram – Bus Routing Connections (without cylinder-related signals)

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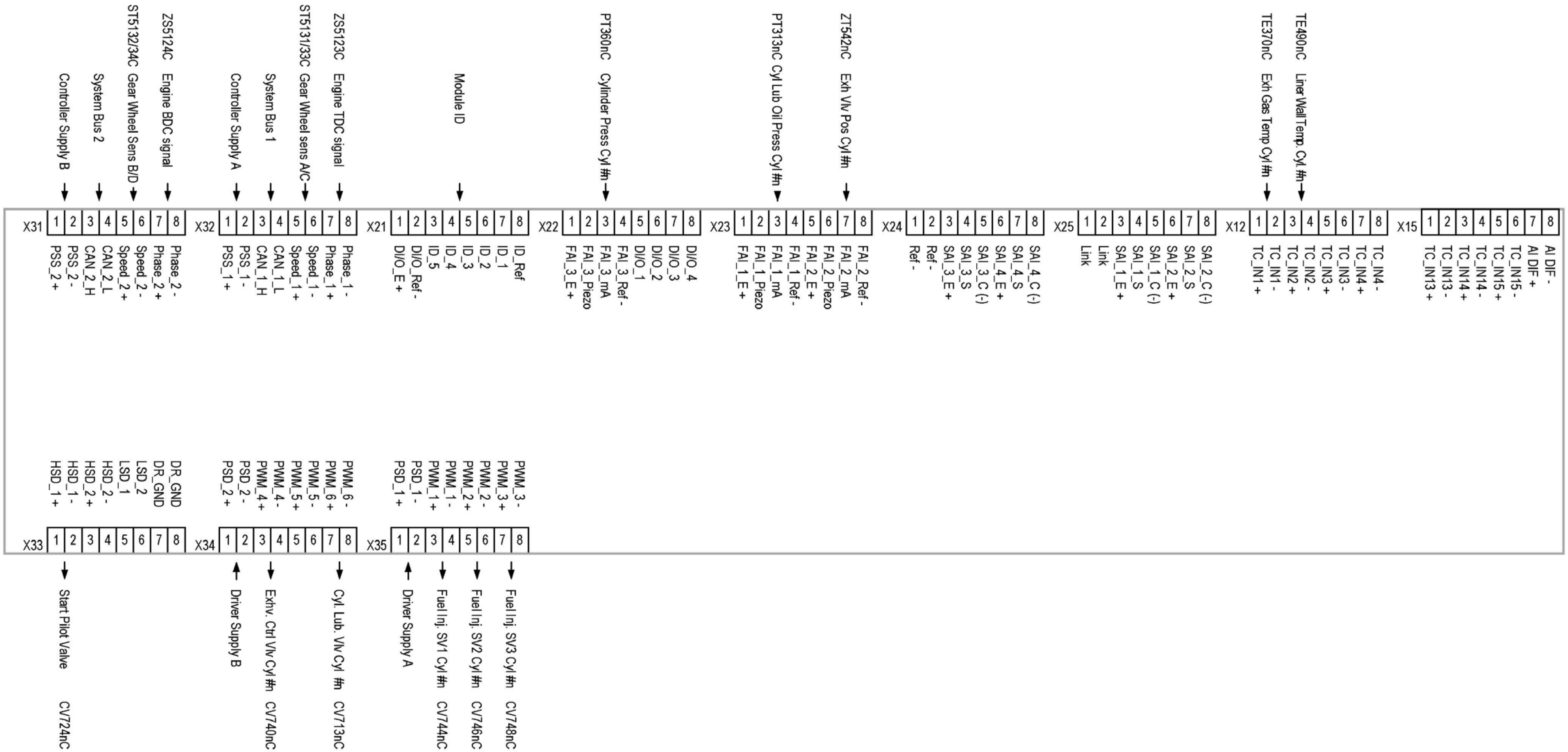

Fig. 3 CCM-20 – Overview Connections Diesel

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2.1 Power Supplies

Two 230 VAC supplies from the ship installation supply electrical power to E85.1 to E85.n. The two 230 VAC supplies are isolated (see Fig. 2).

WARNING
Injury Hazard: The power supplies have redundancy. If it is necessary to isolate the ECS, make sure that each of the two 230 VAC power supplies are set to off. This will prevent injury to personnel.

Note: Each module and the LDU-20 at the local maneuvering stand have two power 24V supplies. This makes sure of redundancy. An AC/DC converter from the ship installation supplies the LDU-20 in the engine control room (ECR). If one power supply becomes defective, the failure causes an alarm in the Alarm and Monitoring System (AMS).

2.2 Installation on the Engine

The engine control system is an embedded system and has no central computer. The ECS modules are installed on the engine near the sensors and different actuators.

The CCM-20 are installed in the terminal box E95.

The IOM-10 is installed in the terminal box E90 (shipyard interface box). The terminal box E90 is attached to the rail unit at the free end of the engine.

The MCM-11 and LDU-20 are installed in the local control box E25. The local control box E25 is installed at the free end of the engine.

For more data, see 9362–1 Location of ECS Electronic Components.

2.3 Redundancy

Each control function that is important for engine operation has redundancy in the engine control system (ECS).

If a CCM-20 becomes defective, the related cylinder will be shut off and a decrease in engine load will follow (slowdown). Each CCM-20 receives reference data for the injection period (fuel quantity) from the speed controller through the double CAN communication busses (see paragraph 3.5).

If a sensor is defective (e.g. fuel rail pressure sensor), the failure causes an alarm in the AMS. The failure is shown on the LDU-20.

Redundant sensors are used for all important parameters (e.g. if one speed sensor is defective, engine operation will continue).

If the speed controller or the complete MCM-11 become defective, you can operate the engine from the LDU-20 at the local maneuvering stand or from the LDU-20 in the ECR (only in fuel command mode).

3. Engine Control System – Functions

The functions of the engine control system (ECS) are as follows:

- Starting valve control (see paragraph 3.1)
- Servo oil pressure control (see paragraph 3.2)
- Exhaust valve control (see paragraph 3.3)
- Cylinder lubricating control (see paragraph 3.4)
- Engine speed and crank angle sensor (see paragraph 3.5)
- Diesel fuel pressure control (see paragraph 3.6)
- Diesel fuel injection control (see paragraph 3.7)

3.1 Starting Valve Control

The CCM-20 of each cylinder opens and closes the starting valve CV7241–48C during the engine starting sequence at a specified crank angle until the conditions for engine operation on fuel oil are established. For more data, see 2728–1 Starting Valve.

The MCM-11 controls the common start valve CV7013C. The IOM-10 controls the common start valve CV7014C. This makes sure of redundancy.

3.2 Servo Oil Pressure Control

3.2.1 Pressure Setpoint

The internal controller of the servo oil pumps keeps the basic servo oil pressure.

The load dependent changes in servo oil pressure is controlled by the CCM-20 Cyl. 3 (with the signal CV7221C to servo oil pump #1) and CCM-20 Cyl. 4 (with the signal CV7222C to servo oil pump #2).

To close the control loop the feedback signal from the servo oil rail pressure transmitter PT2071C is send to CCM-20 Cyl. 3 and from PT2072C to CCM-20 Cyl. 4.

3.2.2 Emergency Mode

If one servo oil pump becomes defective, the system will continue to operate. The other servo oil pump will continue to supply the necessary pressure to the servo oil rail. If both servo oil pumps have an electrical failure, the engine can still operate at low load.

3.2.3 Monitored Items

The servo oil pressure is monitored. If the servo oil pressure is out of the tolerance, a failure indication is shown on the LDU-20.

The sensors are monitored. If the sensors are out of range, an alarm is triggered in the AMS and a failure indication is shown on the LDU-20. If both servo oil pressure sensors have a failure, the engine can still operate at low load.

The leakage of the servo oil pumps is monitored. If there is too much servo oil leakage, the AMS triggers an alarm.

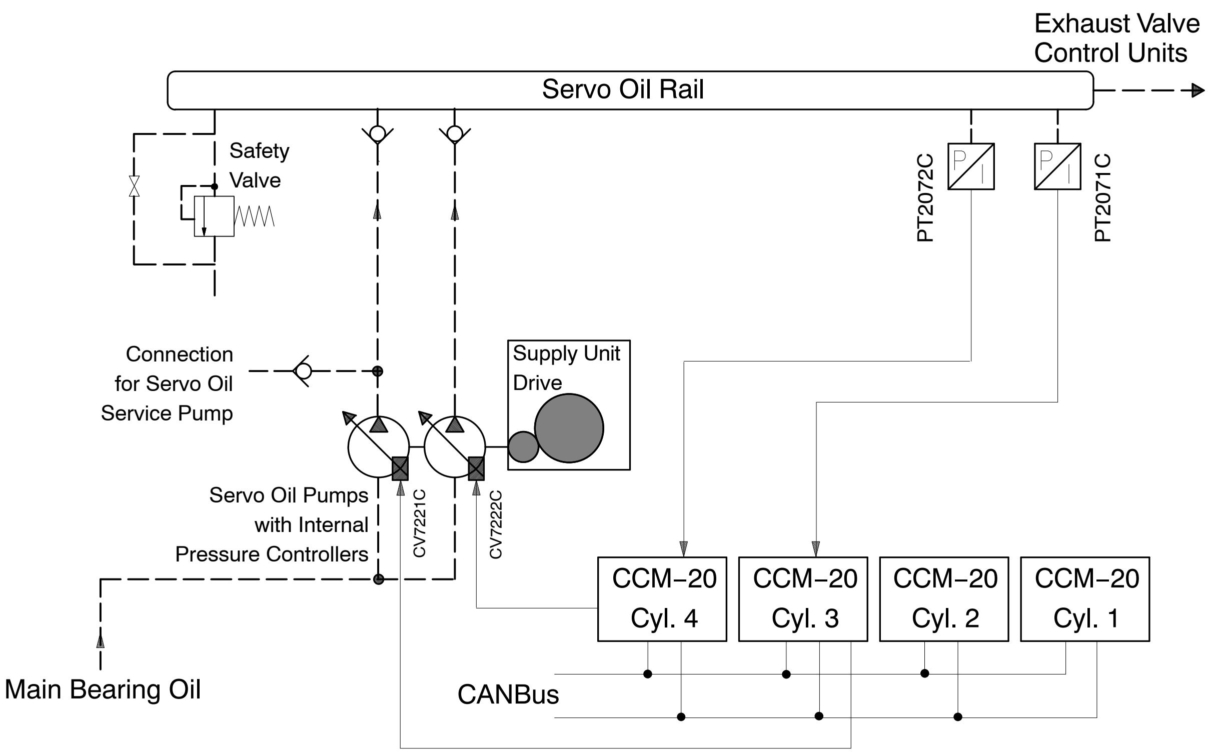

Fig. 4: Servo Oil Pressure Setpoint

3.3 Exhaust Valve Control

3.3.1 Exhaust Valve – Function

When the engine operates, the exhaust valve opens and closes once during each full turn of the crankshaft related to the defined crank angle position (see Fig. 5).

The control valves CV7401–08C are installed on the exhaust valve control unit. The control valves are connected to the CCM-20 on each cylinder (see Fig. 2 and Fig. 3).

The engine control system activates the control valve CV7401–08C to open/close the exhaust valve.

The valve stroke sensor ZT5421–28C monitors the movement of the exhaust valve. On each cylinder, the CCM-20 individually adjusts the stroke and timing to the correct values.

3.3.2 Exhaust Valve – Control

The exhaust valve movement is controlled as follows:

- The crank angle and the variable exhaust opening (VEO) are used to calculate the open command of the exhaust valve.
- The open deadtime, the time between the open command and 15% of the valve stroke, is measured.
- The crank angle and the variable close command (VEC) are used to calculate the close command of the exhaust valve.
- The close deadtime, from the close command to 15% of the valve stroke, is measured.
- After one full turn of the crankshaft, the timing for the next cycle is adjusted in accordance with the deadtime of the cycle before.

3.3.3 Emergency Mode

If a valve stroke sensor becomes defective and there are no valid deadtime values from the other cylinder control units available, the system default time settings are used for the open and close deadtimes of the related exhaust valve. If the system default values are used, the related cylinder operates at reduced power.

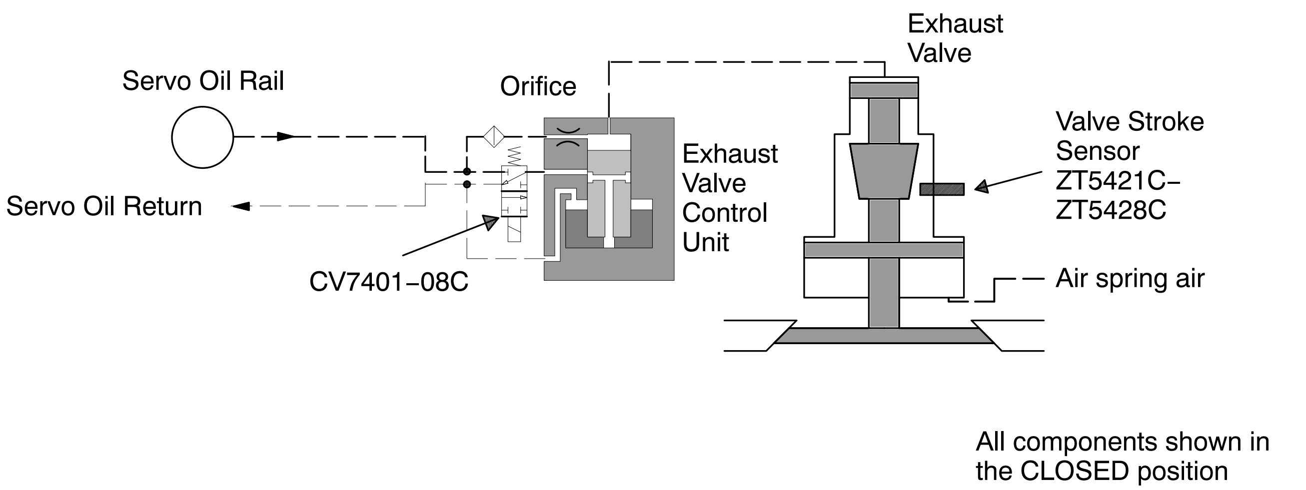

Fig. 5: Exhaust Valve Control

3.4 Cylinder Lubricating Control

3.4.1 General

The cylinder lubricating system (see Fig. 6) is a time-based system, that supplies lubricating oil on to the cylinder liner wall.

Each CCM-20 controls the solenoid valves CV7131−38C that activate an oil pulse on the related cylinder. The pressure sensors PT3131−38C, attached to the lubricating pump, give measurements about the injection pressure of the cylinder lubricating oil. The engine control system uses these measured values to adjust the injection timing to compensate hydraulic and mechanical delays in the system.

The timing and vertical oil supply can be set to the applicable values related to the engine type and engine design. A controlled quantity of lubricating oil then injects as jet above, into and below the piston and piston ring pack (see 7218−1 Cylinder Lubrication, paragraph 8.3).

The specific quantity (g/kWh) of cylinder lubricating oil is related to the engine speed/engine load in a defined time period. The basic input to control functionality are the base feed rate settings (see 7218−3 Feed Rate − Adjustment and 4002−2 Local Control Panel/Local Display Unit LDU-20, paragraph 3.9).

3.4.2 Emergency Mode

If a CCM-20, solenoid valve or pressure sensor becomes defective, an indication shows on the LDU-20. The indication is also sent to the AMS. If a CCM-20 or 4/2-way solenoid valve becomes defective, the engine power output will be limited to engine slowdown level. If an CCM-20 becomes defective, see the data given in 0530−1 Operation during Unusual Conditions, CCM-20 Failure.

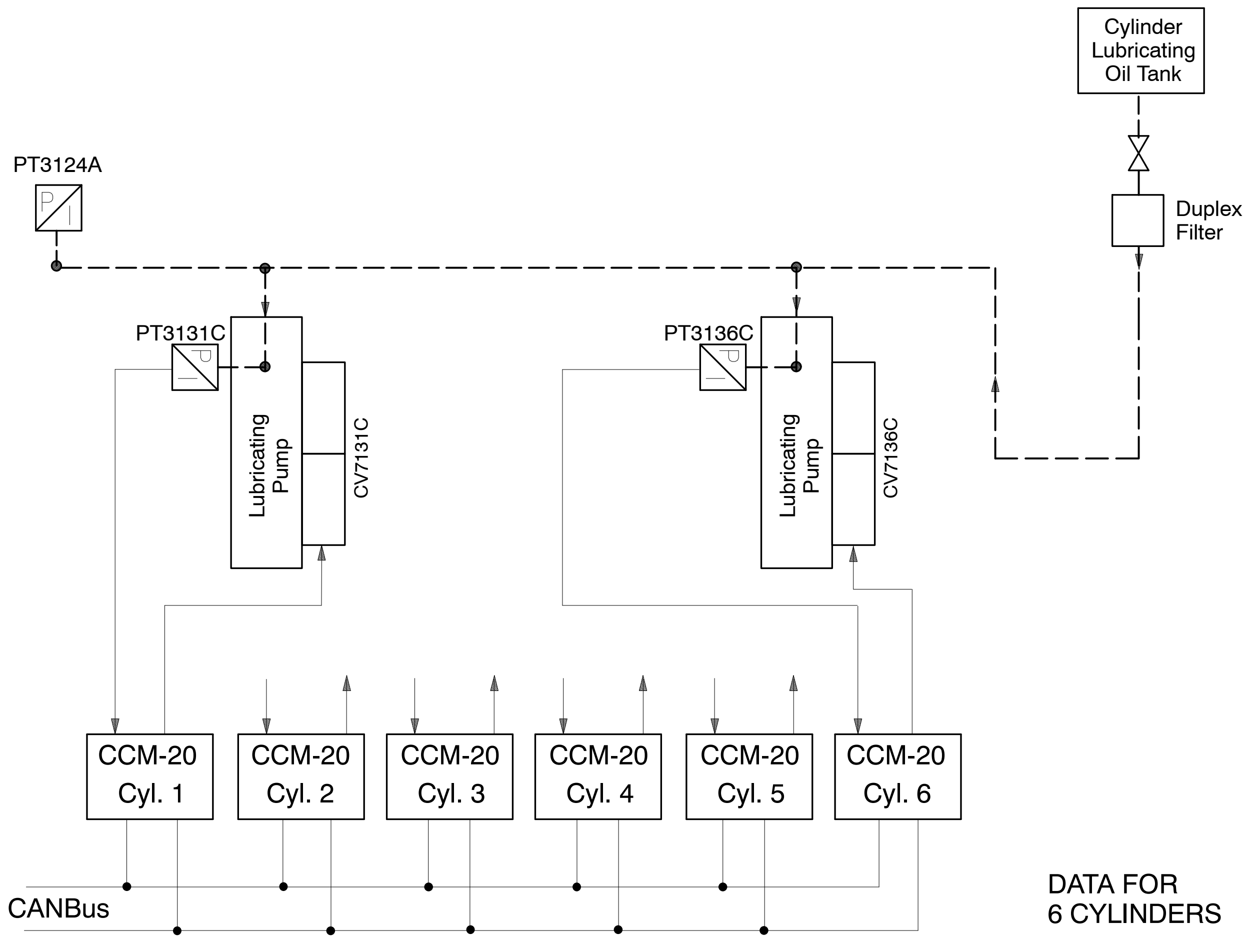

Fig. 6: Cylinder Lubricating System

3.5 Engine Speed and Crank Angle Sensor

Four proximity sensors (A and B, C and D) are installed near the crankshaft gear wheel (see Fig. 7). As the crankshaft gear wheel turns, the proximity sensors sense the movement of the teeth and calculate the crankshaft position (see also 9223–1 Crank Angle Sensor Unit).

The inductive proximity sensors (speed pickups) A and B are connected to CCM-20 Cyl. 1 and then looped to the MCM-11 (see Fig. 2).

The inductive proximity sensors (speed pickups) C and D are connected to CCM-20 Cyl. 2 and then looped through to CCM-20 Cyl. n (see Fig. 2).

Additionally, one proximity sensor for TDC and one proximity sensor for BDC is installed near the flywheel. These proximity sensors detect the reference marks attached to the flywheel (see also 9223–1 Crank Angle Sensor Unit).

The crank angle is calculated incrementally by counting pulses (gearwheel teeth) from the reference position to the current position in each CCM-20 individually.
The reference positions (TDC and BDC) are detected with separate sensors. The reference points are the centers of the TDC and BDC marks.
To detect the sense of rotation there is always a pair of gear wheel sensors (A and B, C and D). If one of the sensors fails the data (sense of rotation) is available on the CANBus.
The reference sensor signals are used to synchronize the relative position signal to the absolute crankshaft angle.

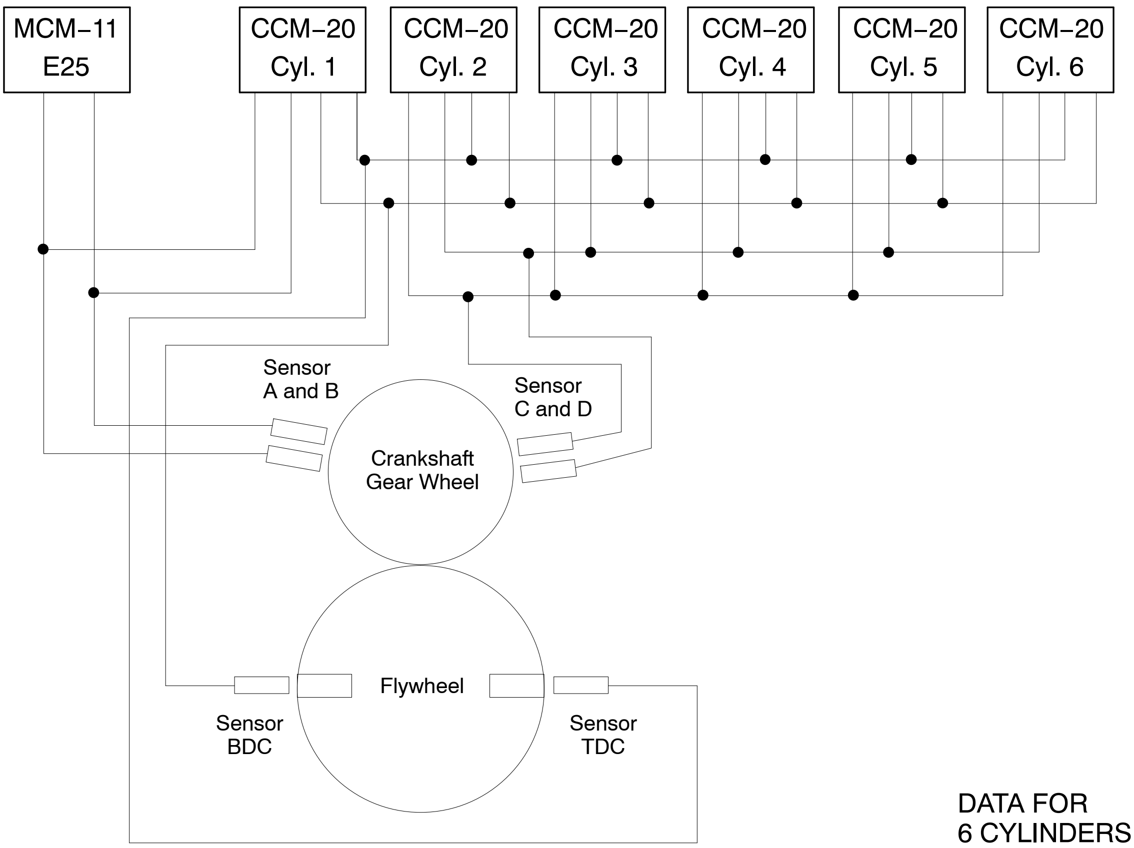

Fig. 7: Crank Angle Sensors

3.6 Crank Angle Determination Algorithm (ADA)

WARNING

Injury Hazard: After an air run, the crankshaft can turn suddenly when the pressurized air in the cylinder releases. There is a risk of death, serious injury or damage to components.

Note: Before you do maintenance on the engine, engage the turning gear, or start the Crank Angle Determination Algorithm (ADA) a second time:

1) **Make sure that there is no pressurized air in the cylinder and the starting air pipes.**
2) **Make sure that you open the relief valves on all cylinder covers to release the pressure.**

3.6.1 Crank Angle Position

The absolute crank angle position is calculated in the CCM-20. The CCM-20 use incrementally measured values. After the CCM-20 start, the crank angle data is not available. The engine must turn and one of the reference marks (TDC or BDC) on the flywheel must activate one of the proximity sensors (TDC or BDC) For more data, refer to paragraph 3.5 and 9223–1 Crank Angle Sensor Unit.

It is possible to start the engine if the crank angle data is not available. The engine control system (ECS) uses the crank angle determination algorithm (ADA). For more data, refer to paragraph 3.6.2.

3.6.2 Crank Angle Determination Algorithm – Operation

The ECS always uses the ADA when the crank angle position is not available or not applicable (e.g. after a blackout or after the start of the ECS). The ECS also uses the ADA in the procedures that follow:

- Air run
- Slow turning
- Engine start from a control location
- Engine start with starting air (general).

3.6.3 ADA Sequence

1) The ECS gets an engine start signal.
2) The ECS cannot find applicable data about the crank angle position.
3) The ECS starts the ADA.
   a) The ECS calculates an applicable sequence and compressed air goes into the cylinders.

      Note: The engine can turn clockwise, counterclockwise or stay in the initial position.

   b) The crankshaft turns.
   c) The ECS uses the feedback from the cylinder movement to continuously calculate the applicable cylinder sequence. Compressed air goes into the related cylinders.
   d) One of the reference marks (TDC or BDC) on the flywheel activates one of the proximity sensors (TDC or BDC).
   e) The ECS synchronizes all ECS modules with the crank angle position.
4) The usual engine start sequence starts.

3.6.4 ADA Start from the LDU-20 Local Control Panel or LDU-20 ECR

If you manually start the ADA from the LDU-20 Local Control Panel or the LDU-20 ECR, do step 1) and step 2):

Note: It is possible to do the ADA procedure with open or closed indicator valves.

1) On the LDU-20, select the USER PARAMETER page.
2) Push the AIR RUN button until the engine status changes from ADA to AIR RUN.

   Note: If the ADA procedure has activated each cylinder but the engine stays in its initial position, release the AIR RUN button. Do step 3 to step 6.

If the ADA procedure is not successful, i.e. the absolute crank angle position could not be found, do step 3) and step 6):

3) Open the indicator valves on all cylinders to release the compressed air.
4) Make sure that the starting air pressure is sufficient.
5) If necessary, use the turning gear to turn the engine to another initial position.
6) Do step 1) and step 2) above again.

3.6.5 ADA Start from the Remote Control – Engine Start Command

Note: Winterthur Gas & Diesel Ltd. recommends to always do the ADA procedure given in paragraph 4.6.4.

The ADA process must be completed if the ADA was activated with the ENGINE START command from the control in the engine room. The engine status changes from ADA to STARTING on the LDU-20 display in the ECR.

If the ADA procedure is not successful, i.e. the absolute crank angle position could not be found, do step 1) and step 2):

1) Open the indicator valves on all cylinders to release the compressed air.
2) Do the procedure given in paragraph 4.6.4.

3.6.6 ADA Start from the Remote Control – Air Run Command

Note: Winterthur Gas & Diesel Ltd. recommends to always do the ADA procedure given in paragraph 4.6.4.

1) On the LDU-20, select the USER PARAMETER page.
2) Push the AIR RUN button until the engine status changes from ADA to AIR RUN.

   Note: If the ADA procedure has activated each cylinder but the engine stays in its initial position, release the AIR RUN button. Do step 3) and step 4).

If the ADA procedure is not successful, i.e. the absolute crank angle position could not be found, do step 3) and step 4):

3) Open the indicator valves on all cylinders to release the compressed air.
4) Do the procedure given in paragraph 4.6.4.

3.7 Diesel Fuel Pressure Control

3.7.1 Engine Start

At engine start, the fuel pump actuators are set to the start position (see Fig. 8).

3.7.2 Engine Operation

The fuel pressure is related to the engine load. The control loop for the fuel rail pressure is given as follows:

- The engine control system (ECS) activates a control signal, which is related to the engine speed or estimated power.
- The signals from the CCM-20 control the fuel pump actuators. Each actuator controls the related fuel pump through the toothed rack.
  - CCM-20 Cyl. 1 controls the fuel quantity of fuel pump No.1. The ECS sends a signal to the control valve CV7231C.
  - CCM-20 Cyl. 2 controls the fuel quantity of fuel pump No.2. The ECS sends a signal to the control valve CV7232C.
  - CCM-20 Cyl. 3 controls the fuel quantity of fuel pump No.3. The ECS sends a signal to the control valve CV7233C.
- Two pressure transmitters PT3461C and PT 3462C measure the fuel pressure. This fuel pressure data is transmitted back to the CCM-20 Cyl. 1 and CCM-20 Cyl. 2.

3.7.3 Engine Shut-down

If the fuel rail pressure must be quickly released, the fuel pump actuators are set to the position zero. The engine will open the pressure control valve (PCV) to release the pressure in the fuel rail (see Fig. 8).

The PCV also operates as a safety valve. For more data, see 5562–1 Pressure Control Valve.

3.7.4 Emergency Mode

If the controlling CCM-20 or fuel pump becomes defective, the remaining fuel pumps keep the fuel rail pressurized and the engine can continue to operate.

3.7.5 Monitored Items

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

The sensors are monitored. If the sensors are out of range, a failure indication shows.

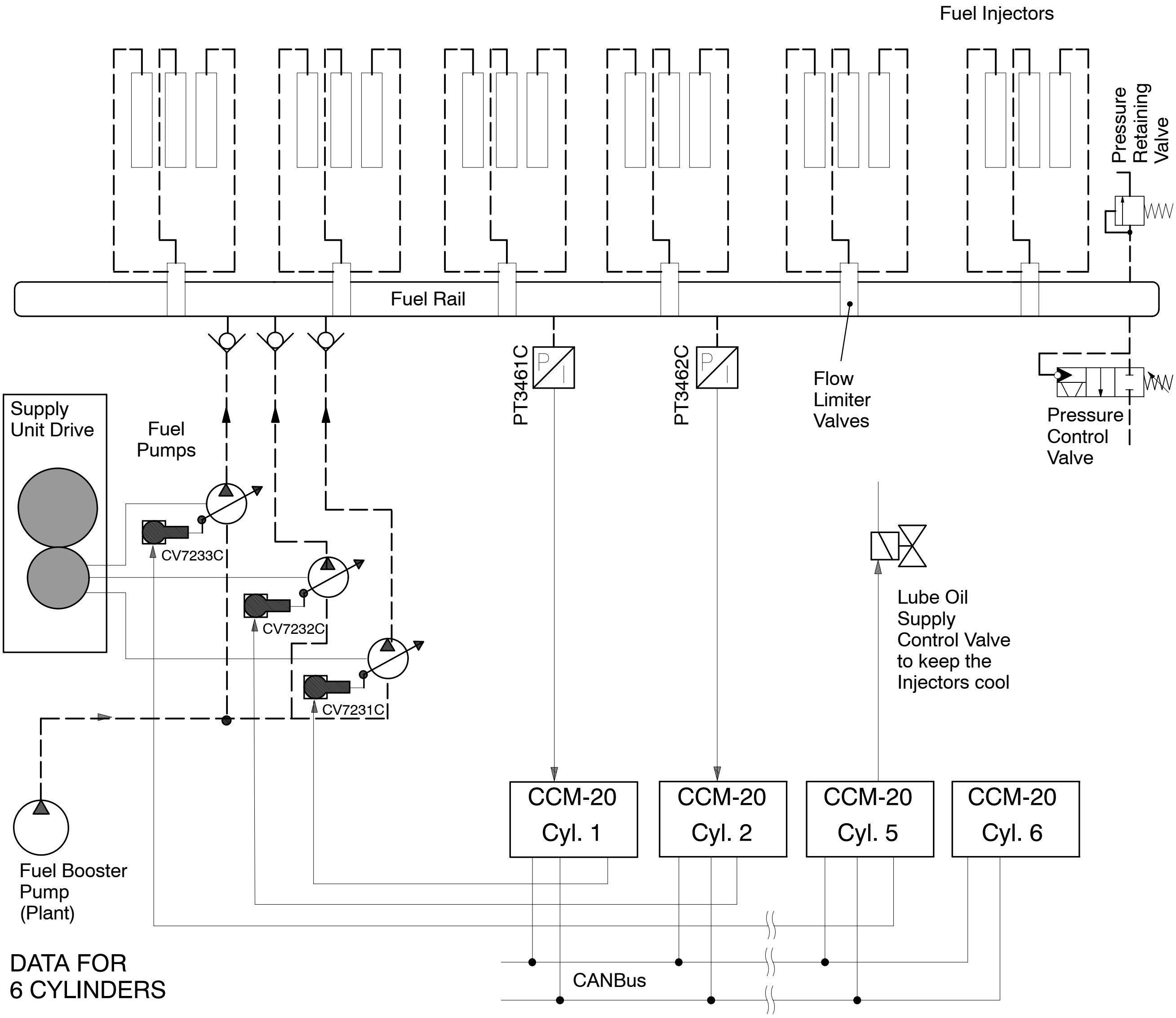

Fig. 8: Fuel Pressure Control System

3.8 Diesel Fuel Injection Control

3.8.1 Injection Valve Control

Each injection valve, related to the solenoid valve in each cylinder, is controlled independently (see Fig. 9).

Usually, the three injection valves on each cylinder operate at the same time. Special operation modes enable fuel injection with one, or the two injection valves, or with multi-shot spray patterns.

To improve the spray at low load, one or two injection valves are cut out automatically (see also 0280−1 Operation at Low Load).

The CCM-20 increases the control outputs up to the applicable signal level for the injection control valves.

3.8.2 Injection Control

A higher current level (pull-in current) at the start of the injection is used to make sure that the injector opens quickly (cycle-to-cycle). The lower current (hold-in current) is set to on when the injector has opened. This lower current (and energy) level will decrease the temperature in the CCM-20 driver circuit and the solenoid valve.

The fuel injection (see Fig. 9) is controlled as follows:

- The CCM-20 calculates the fuel injection quantity (injection period). The input (specified as a Fuel Command), is related to the output from the speed controller.
- The related signal from the speed controller is changed into injection values. These values give the duration of the fuel injection, i.e. the quantity of fuel injected into each cylinder. This quantity is related to the engine load.
- If necessary, adjustments can be made for differences in the fuel supply to each injector.
- The common rail pressure has an effect on the last injection timing values that the engine control system uses. For the last injection timing process, each CCM-20 receives accurate data about the angular position from the speed sensors and crank angle sensors.
- The firing order and angular displacements of the cylinder are programmed in the CCM-20. The engine control system uses different injection timing for each cylinder to get the best operation results for all engine load ranges.

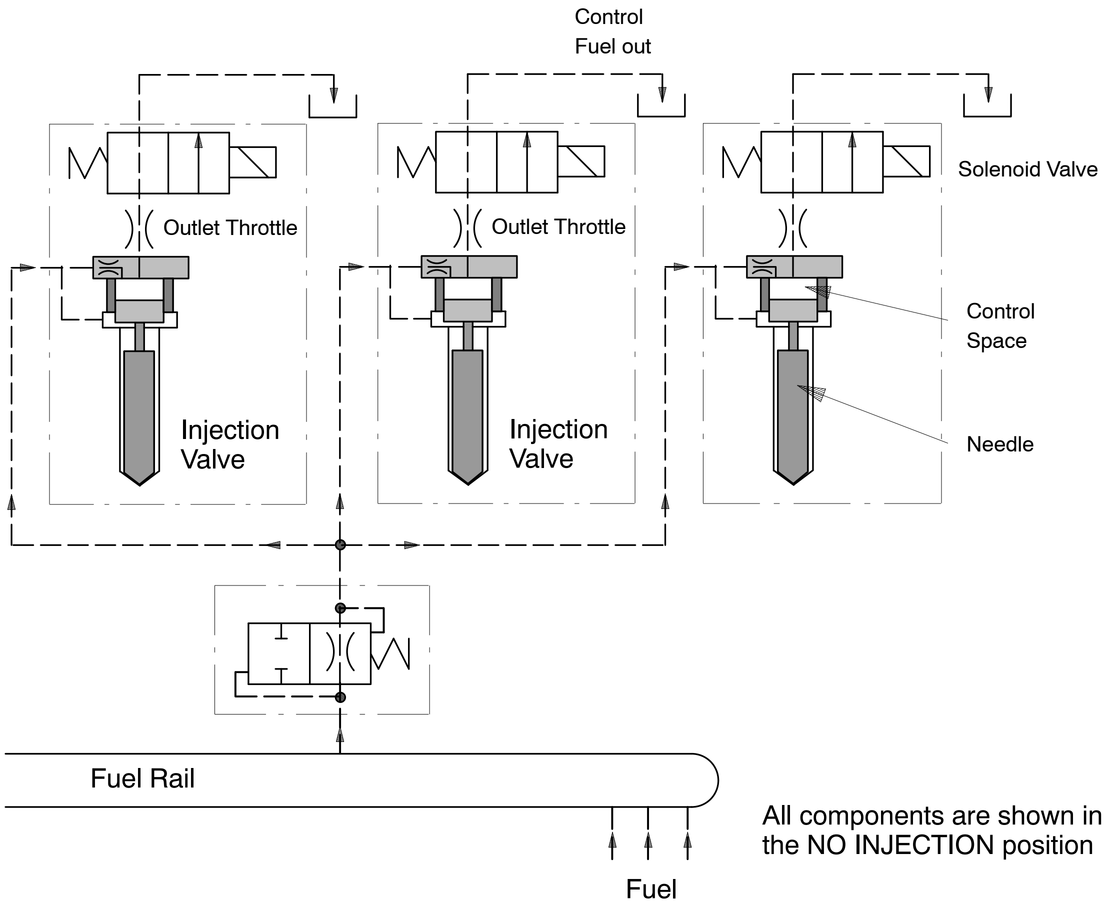

Fig. 9: Fuel Injection Control

4. External Control Systems

4.1 Communication between ECS and External Systems

The Diesel Engine CoNtrol and OptImizing Specification (DENIS) and the engine control system (ECS) are designed so that different remote controls can be used. All nodes are fully specified. The terminal boxes are installed on the engine, to which the cable ends from the control room or from the bridge can be connected.

The engine control has all the parts necessary to operate and monitor the engine, and for the safety of the engine.

The ECS supplies the data communications to:

- The propulsion control system (PCS)
- The alarm and monitoring system (AMS).

The standard version of ECS includes the external communications that follow:

- Two redundant CANBus lines to the PCS (one CANBus connection to MCM-11 and one connection to the LDU-20 in the terminal box E25, see Fig. 2).
- Two redundant Modbus lines to the AMS (one Modbus connection to MCM–11 and one connection to the LDU–20 in the terminal box E25, see Fig. 2).

For the schematic diagrams, see Fig. 2 and Fig. 10.

Note: The communications between the systems can be different. See the related documentation from the approved propulsion control system manufacturer.

4.2 Propulsion Control System

The propulsion control system (PCS) has the subsystems that follow (see Fig. 10):

- Remote control system (RCS)
- Engine safety system (ESS)
- Telegraph system.

Note: The ESS and telegraph systems operate independently and are fully serviceable if the RCS is defective.

4.2.1 Remote Control System

The remote control system (RCS) has the primary functions that follow:

- Start, stop and reverse
- Automatic slow turning.

Data about the engine control system (ECS) status is available in the RCS. This includes measured values of sensors, defects and other indications (see the documentation of the remote control manufacturer).

All commands to operate the engine (e.g. AHEAD or ASTERN), come from the RCS.

If the ECS finds a defect, it sends a signal to the AMS, or a slowdown/shutdown signal to the ESS.

4.2.2 LDU-20 – Engine Control Room

The LDU-20 in the engine control room (ECR) is part of the engine control system (ECS) and installed in the ECR console. The same control functions of the LDU-20 in the ECR are available at the local control panel (see also 4002−2 Local Control Panel/Local Display Unit LDU-20, paragraph 2).

4.2.3 Engine Safety System

The engine safety system (ESS) has the primary functions that follow:

- Emergency stop
- Overspeed protection
- Automatic shutdown
- Automatic slowdown.

If there is a defect, the engine control system (ECS) sends a signal to the ESS.

4.2.4 Telegraph System

The telegraph system transmits maneuvering signals from the bridge to the ECR and local control panel.

4.3 Alarm and Monitoring System

The alarm and monitoring system (AMS) is an external system and monitors the engine. The AMS gives the operator alarms and status data of the engine, to make sure of a safe and efficient engine operation.

The functions of the AMS are specified in the DENIS. The AMS sends signals to the engine safety system to slow down or shut down the engine (see Fig. 10)

For more data, see the documentation of the AMS manufacturer.

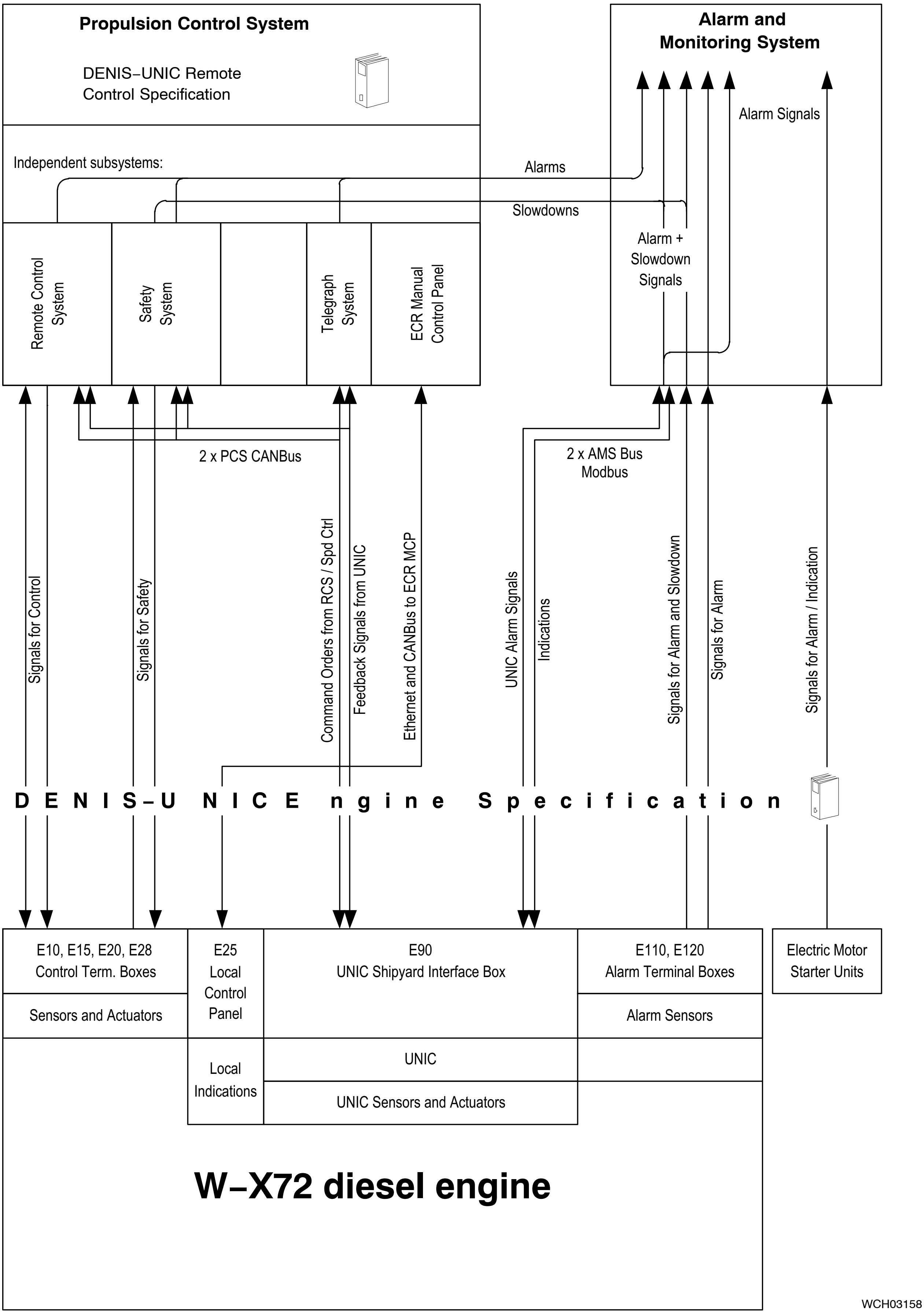

Fig. 10: Signal Flow Diagram

Local Control Panel / Local Display Unit (LDU–20)

1. General

The local control panel is attached to the engine at the free end and has the components necessary for engine operation (see Fig. 1). Because the remote control manufacturer supplies the local control panel, some components can look different.

For data about maneuvering instructions, see 4003–1, paragraph 3 and 0260–1 Maneuvering).

2. Installed Components

2.1 Electronic Components

The local control panel has the electronic components that follow:

- LDU−20
- ME tachometer
- Emergency stop button
- Telegraph system.

2.2 LDU−20

There are two LDU-20 (2, Fig. 1). One LDU-20 is installed in the local control panel. The other LDU-20 is installed in the engine control room. The LDU-20 operate independently from the remote control system. For more data about the LDU-20, see 4002−1 Engine Control System paragraph 2 and this document, paragraph 3.

For data about the control transfer between the control panels, see 4003−1 Engine Control, paragraph 3.5.

2.3 ME Tachometer

The ME tachometer (3, Fig. 1) shows the engine speed in the ahead or astern directions.

2.4 Emergency Stop Button

When you operate the emergency stop button (4), the engine stops immediately.

The fuel pressure control valve 10.5562_E0_5 releases the pressure in the fuel rail (see 5562−1 Pressure Control Valve). At the same time, the fuel pump supply decreases to 0 (zero). For more data, see 0310−1 Engine Shutdown, paragraph 2 Engine Stop.

2.5 Telegraph

The telegraph system is part of the propulsion control system.

2.6 Components

The local control panel (1) has the components that follow:

- LDU-20
- Emergency stop button
- Telegraph receiver
- ME tachometer.

2.7 Remote Control

The remote control has the components that follow:

- RPM indication
- Emergency stop
- Telegraph receiver (auxiliary).

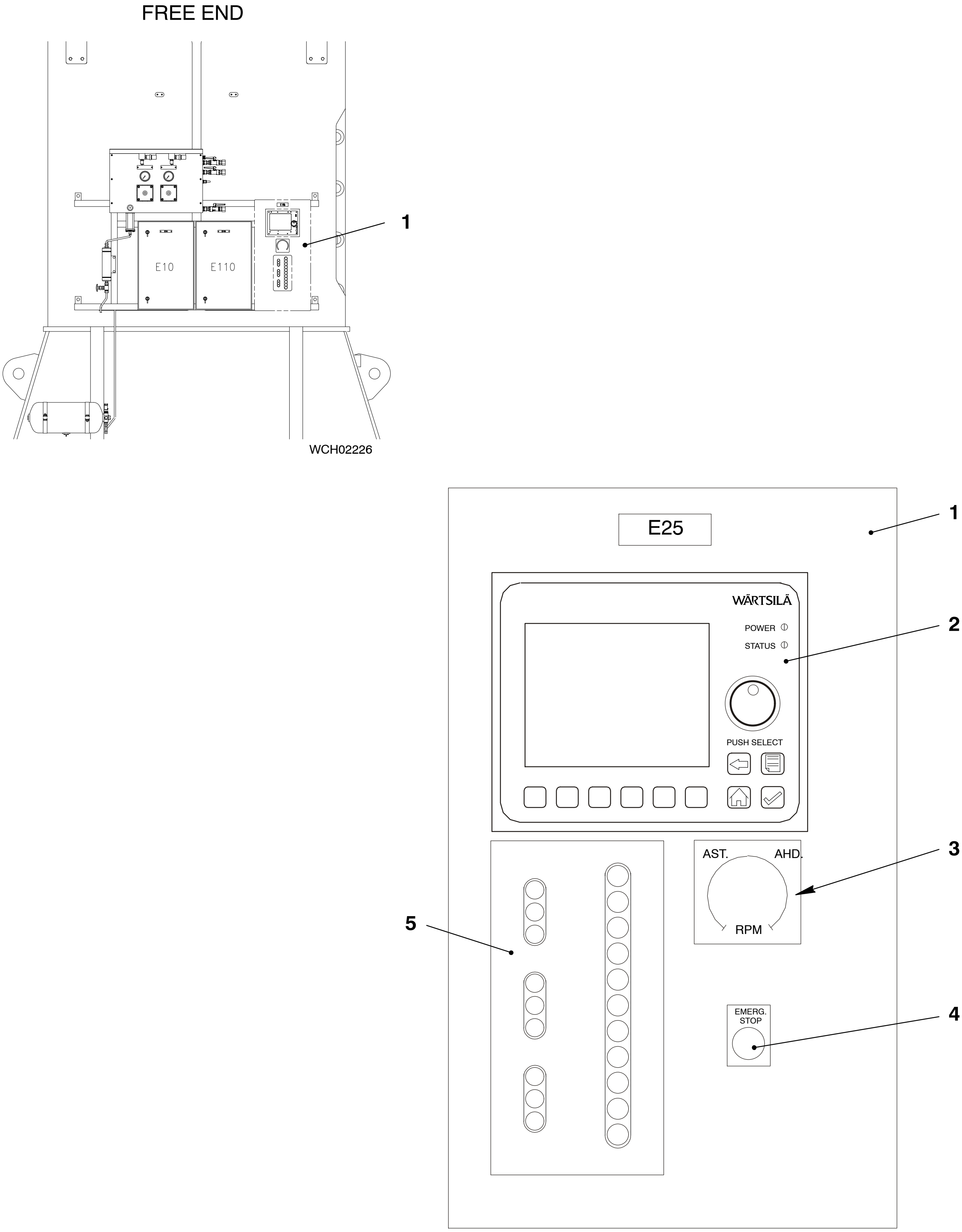

Fig. 1: Local Control Panel − Location

1 Local control panel
2 LDU−20
3 ME tachometer
4 Emergency stop button
5 Telegraph receiver

3. LDU–20

3.1 General

The LDU-20 is a multi-purpose module that has an LCD color display (1, Fig. 2), ten multi-function buttons (3) and a rotary button (2). You can also push the rotary button to select a function.

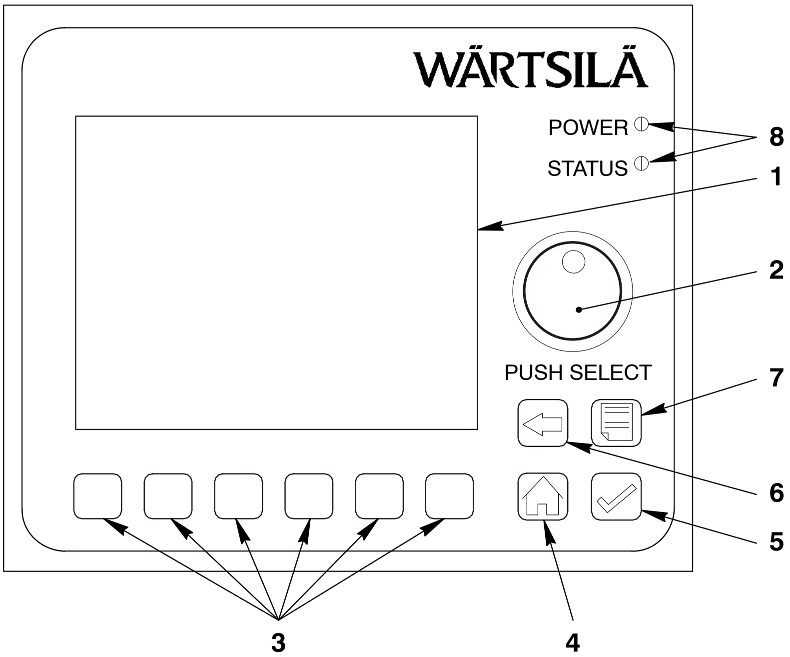

Fig. 2: LDU–20

1 Color display
2 Rotary button (16 steps in one turn. Push to select)
3 Multi-function buttons (function is shown on the display)
4 HOME button (shows the main page)
5 CHECK button (used to accept the action or enter data)
6 BACK button (used to cancel the action or delete data)
7 ALARM LIST button (no function)
8 Power/Status LED

3.2 User Guide

The LDU-20 shows different pages for each application. After boot-up, or when you push the HOME button, the MAIN page is shown.

1) To show other pages, push and hold the rotary button for 3 seconds.

The navigation menu shows on the display. You use the rotary button to select a page.

When you push the rotary button, the navigation menu closes and the selected page is shown.

2) If no more pages are necessary, push the BACK button to close the navigation menu.

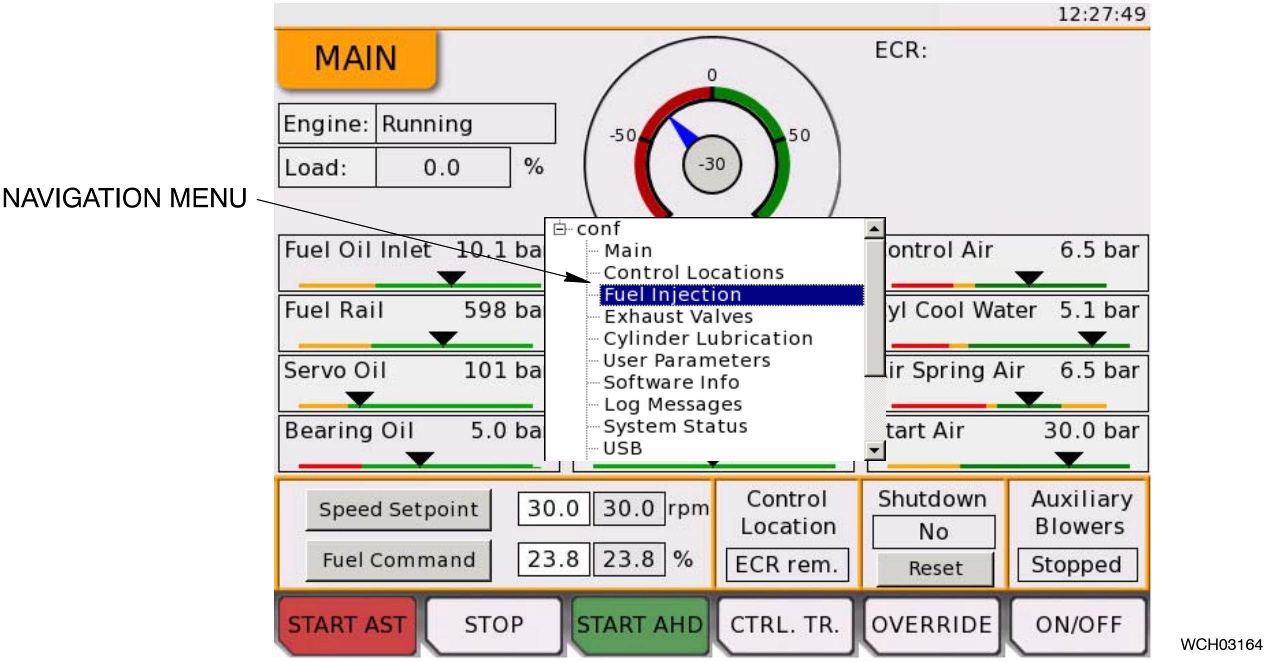

Fig. 3: User Guide

On all pages, you use the rotary button to navigate through the on-screen items. A black cursor frame around the item (Fig. 4) shows that the item is active. You turn the rotary button one step clockwise to highlight / access the next item. You turn the rotary button counterclockwise to highlight / access the item before.

Fig. 4: Cursor Frame

Some elements are shown on all pages:

- In the top, right-hand corner, the system time is shown above the title bar.
- Below the system time, the identifier for the LDU is shown (Local or ECR). If the LDU is the active control location, the words 'In Control' are shown after the identifier.
- The bottom of the screen has some reserved space to show the function of the multi-function buttons.

3.3 MAIN Page

The MAIN page (Fig. 5) shows:

- After you start the LDU-20, or
- When the HOME button is pushed during LDU-20 operation.

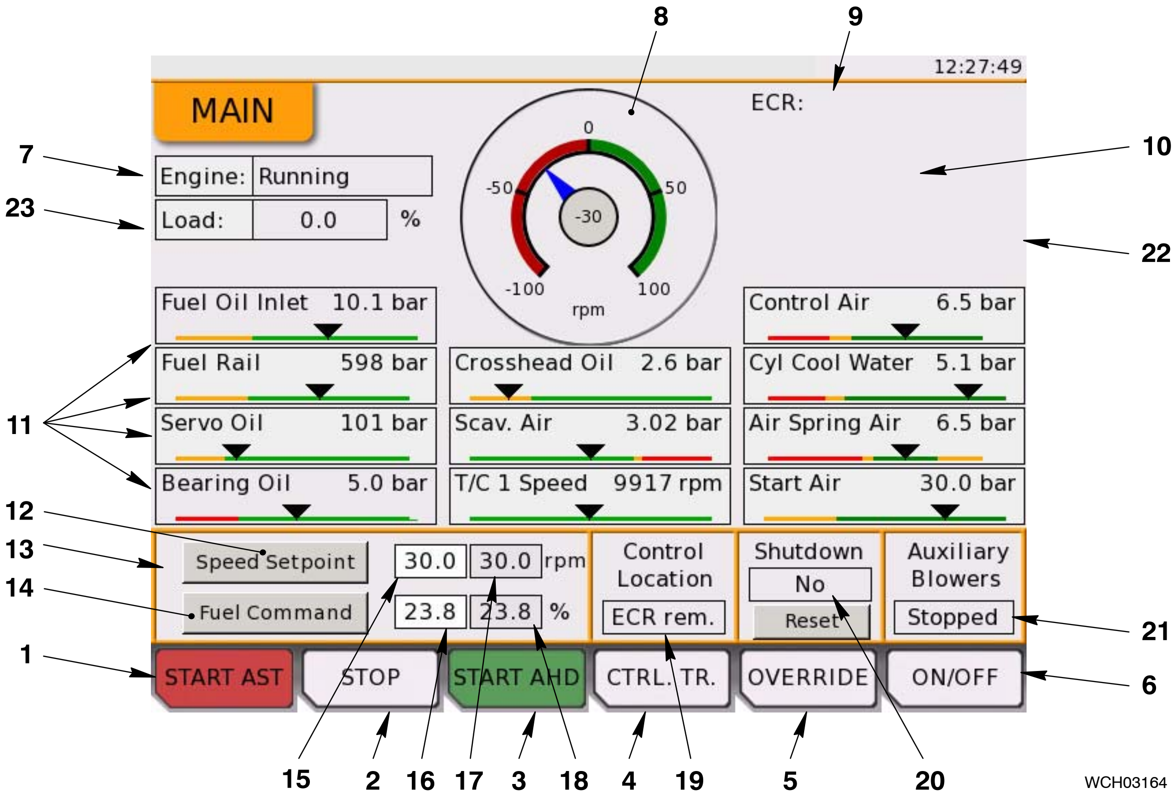

Fig. 5: MAIN Page

Item	Function	Effect / Procedure
1	START AST tab	Start the engine in astern direction
2	STOP tab	Stop the engine
3	START AHD tab	Start the engine in ahead direction
4	CTRL. TR. tab	Request a control transfer to this LDU
5	OVERRIDE tab	Cancels shutdown from the safety system
6	ON/OFF button	Sets the auxiliary blowers off or on. Can also be used to stop them
7	Engine status	Shows the engine status Shows: Start interlock, Stopped, Slow turning, Air Run, Starting, Heavy Start, Running or Shut-down
8	Engine speed gauge	Shows engine rpm in ahead (AHD) or astern (AST) direction
9	Indication of this LDU	Shows if Local has control, or does not have control
10	Control transfer request indication	Text flashes to show a transfer request if one control location requests a control transfer

Item	Function	Effect / Procedure
11	Different sensor indications	Necessary to operate the engine locally
12	Speed Setpoint button	Arrow shows the selected mode: Speed control mode or Fuel control mode
13	Indication of active manual control mode	Use the rotary button to change to manual speed control mode. The indicator (orange triangle, see Fig. 4) shows the control mode (speed mode or fuel command mode)
14	Fuel Command button	Use the rotary button to change to manual fuel command mode
15	Manual speed setpoint	Use the rotary button to adjust between 0 rpm to maximum rpm. The maximum value is related the installation specifications (rating etc)
16	Manual fuel command setpoint	Use the rotary button to adjust between 0% to 150%
17	External speed setpoint	Shows the setpoint sent to the engine control system ECS from the remote control system
18	Used fuel command	Shows the actual fuel command used for injection
19	Control location	Can be Local, ECR manual, ECR remote or Bridge
20	Indication of shutdown	Shows either YES or NO
21	Auxiliary Blower status	Shows either STOPPED or RUNNING
22	Turning gear status/Main starting air shut-off valve status	Shows the conditions that follow: Turning gear ENGAGED, Main starting air shut-off valve CLOSED or no data available.
23	Estimated power	Shows the value of the estimated engine power or the engine load in percent (%)

3.3.1 Procedure – Operate the Engine from the Main Page

1) To operate the engine from the main page, first make sure that the LDU-20 is the active control location (see 9 and 19, Fig. 5). If necessary, select the CTRL.TR button to transfer control.

2) To change modes, move the cursor on the related button (see 13 or 14) then push the rotary button.

Note: The indicator (orange triangle) shows the control mode of the LDU-20 (speed mode or fuel command mode).

Note: If the MCM-11 becomes defective, a fuel command mode is selected automatically.

3) To adjust the speed or fuel command setpoint, move the cursor to the related field (see 15 or 16) then push the rotary button to enter the edit mode.

   - While in edit mode, the text field has an orange frame. Turn the rotary button to adjust the set point (turn clockwise to increase, counterclockwise to decrease).

   Note: The changes have an immediate effect on the engine.

4) To go out of the editing mode, push the rotary button again.

3.4 Control Locations

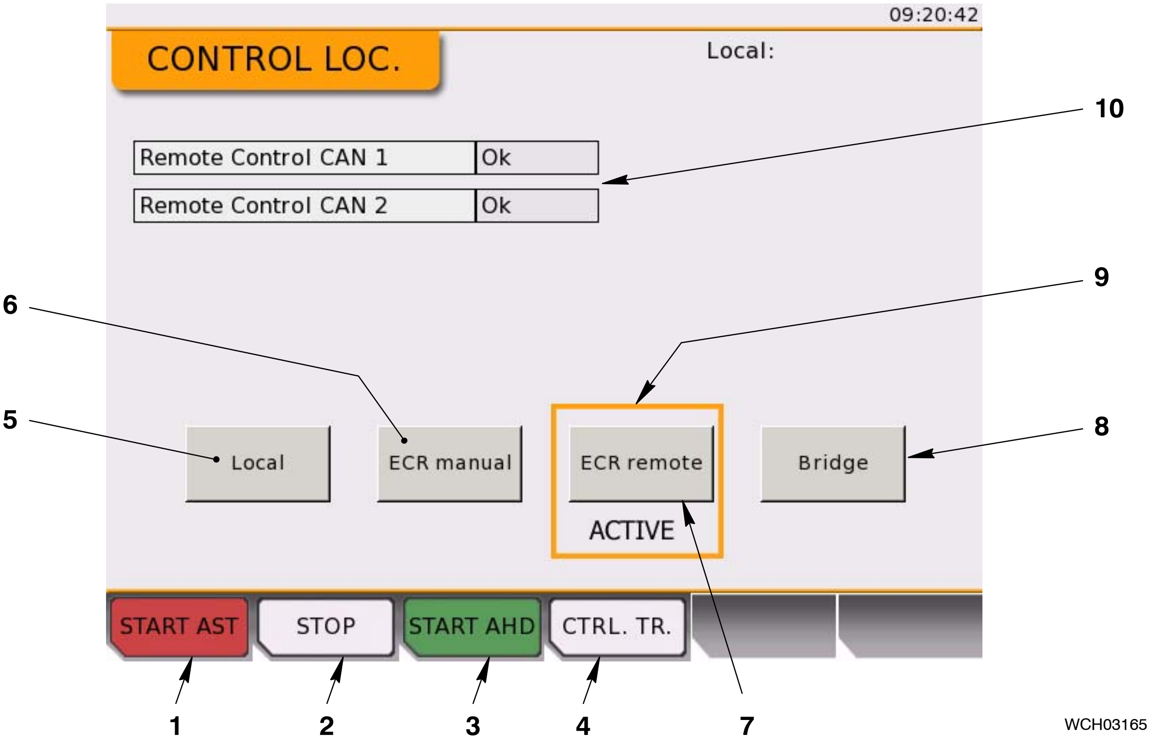

Fig. 6: Control Locations Page

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request control to this LDU
5	Local on-screen button	Request/Accept a control transfer to/from the LDU on the engine
6	ECR manual button	Request/Accept a control transfer to/from the LDU in the ECR
7	ECR remote button	Request/Accept a control transfer to/from the remote control system in the ECR
8	Bridge button	Request/Accept a control transfer to/from the remote control system on the bridge
9	ACTIVE frame	Indicates which of the four possible locations is in control of the engine
10	CAN 1/2 status	Shows the status of the two redundant CANBus lines between the ECS and the remote control system. Shows OK, or ERROR

3.4.1 Procedure – Change the LDU-20 Control Location

1) Push the CTRL. TR. button (4, Fig. 6) to accept control to the LDU-20 at your location.
2) To get/accept control to/from a different location, select the related on-screen button, then push the CHECK ✓ button (see Fig. 2).

3.5 Fuel System

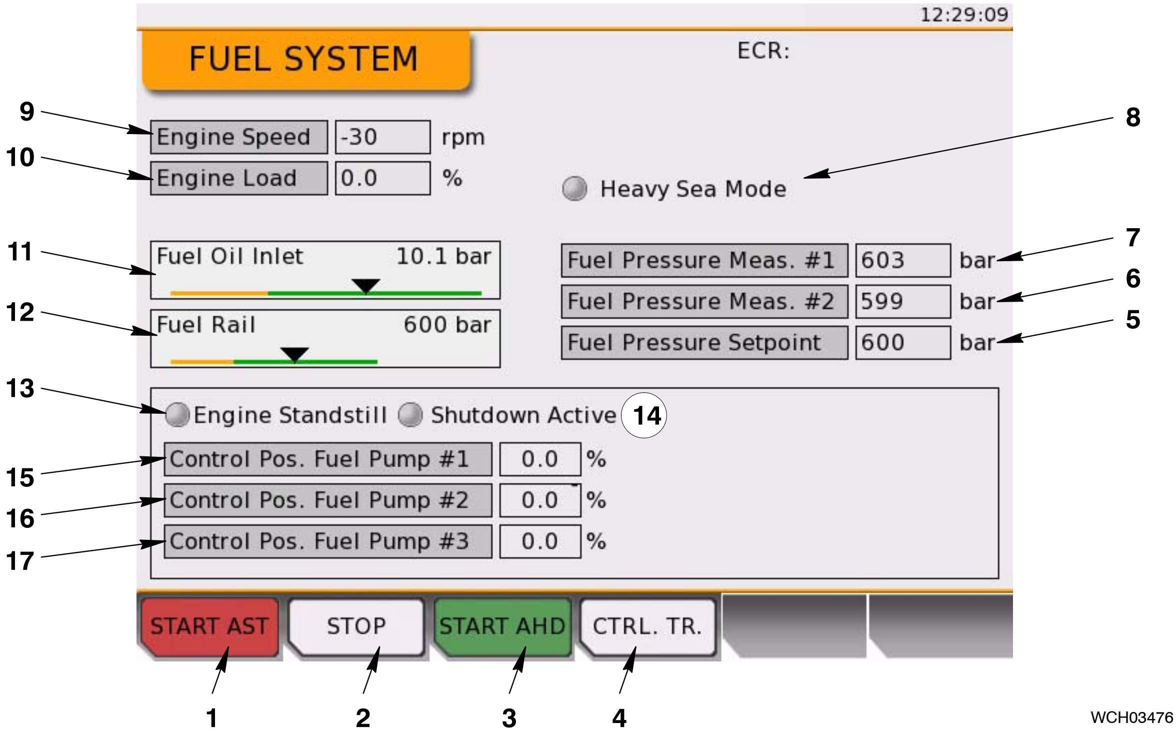

Fig. 7: Fuel System Page

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP tab	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Fuel pressure setpoint	Show the set fuel pressure setpoint in bar
6	Fuel pressure measurement #2	Shows the fuel pressure measured in the fuel rail in bar
7	Fuel pressure measurement #1	Shows the fuel pressure measured in the fuel rail in bar
8	Heavy sea mode indicator	Shows the heavy sea mode status. When the heavy sea mode is active, the green indicator is on.
9	Engine speed	Shows the engine speed in revolutions per minute (rpm)
10	Engine load	Shows the engine load in percent (%)
11	Fuel oil inlet	Shows the fuel oil inlet pressure in bar
12	Fuel rail	Shows the fuel pressure in the fuel rail in bar
13	Engine standstill indicator	Shows the engine standstill mode status. When the engine standstill mode is active, the green indicator is on.

Item	Function	Effect / Procedure
14	Shutdown active indicator	Shows the shutdown mode status. When the shutdown mode is active, the green indicator is on.
15	Control position fuel pump #1	Shows the setpoint of fuel pump #1 in percent (%)
16	Control position fuel pump #2	Shows the setpoint of fuel pump #2 in percent (%)
17	Control position fuel pump #3	Shows the setpoint of fuel pump #3 in percent (%)

3.6 Cylinder Balancing

The cylinder balancing page shows data about the combustion process for each cylinder and related sensor indications (see Fig. 7). For more data about the cylinder balancing, see 9308–1 Intelligent Combustion Control.

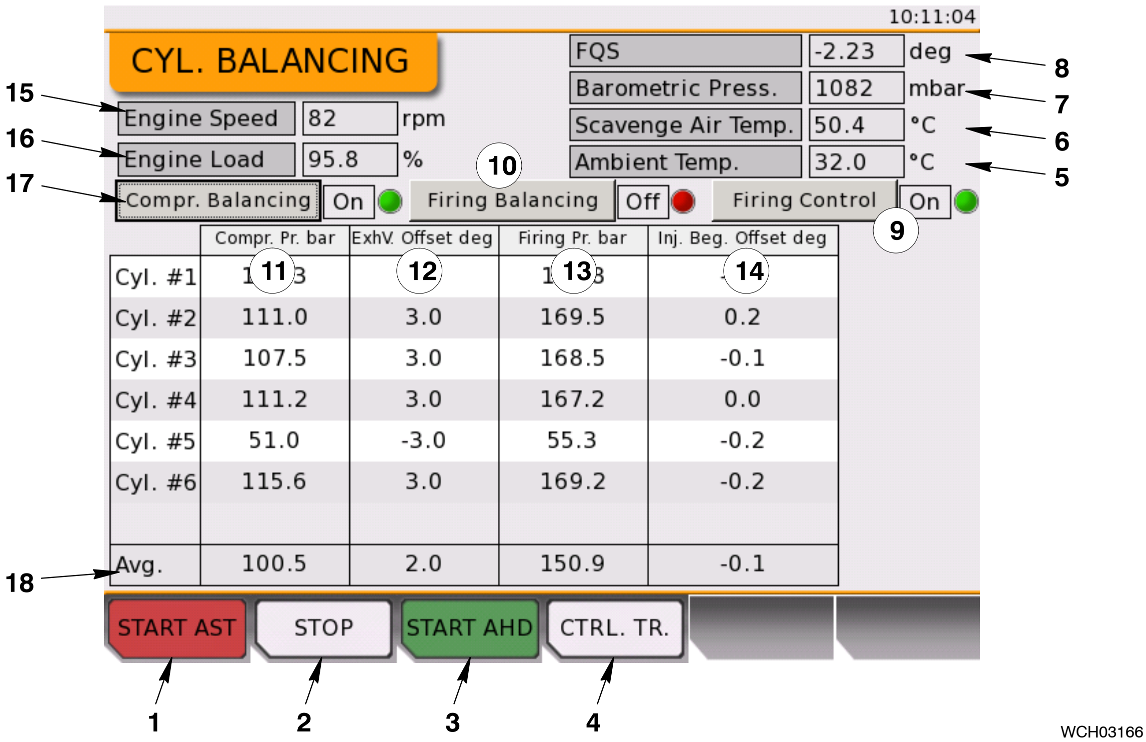

Fig. 8: Cylinder Balancing Page

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP tab	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU-20
5	Ambient temperature	Shows the suction air temperature in degree Celsius (°C)
6	Scavenge air temperature	Shows the scavenge air temperature in degree Celsius (°C)
7	Barometric pressure	Shows the barometric pressure in millibar (mbar)
8	Fuel quality setting (FQS)	Shows the used fuel quality setting (FQS). See also paragraph 3.10 User Parameters.
9	Firing control status	Shows either OFF or ON
10	Firing balancing status	Shows either OFF or ON

Item	Function	Effect / Procedure
11	Compression pressure	Shows the compression pressure for each cylinder in bar
12	Exhaust valve offset	Shows the exhaust valve closing time offset for each cylinder in degree
13	Firing pressure	Shows the firing pressure for each cylinder in bar
14	Injection begin offset	Shows the injection time offset for each cylinder in degree
15	Engine speed	Shows the engine speed in revolutions per minute (rpm)
16	Engine load	Shows the engine load in percent (%)
17	Compression balancing status	Shows either OFF or ON
18	Average value	Shows the average value of the related column

3.7 Fuel Injection

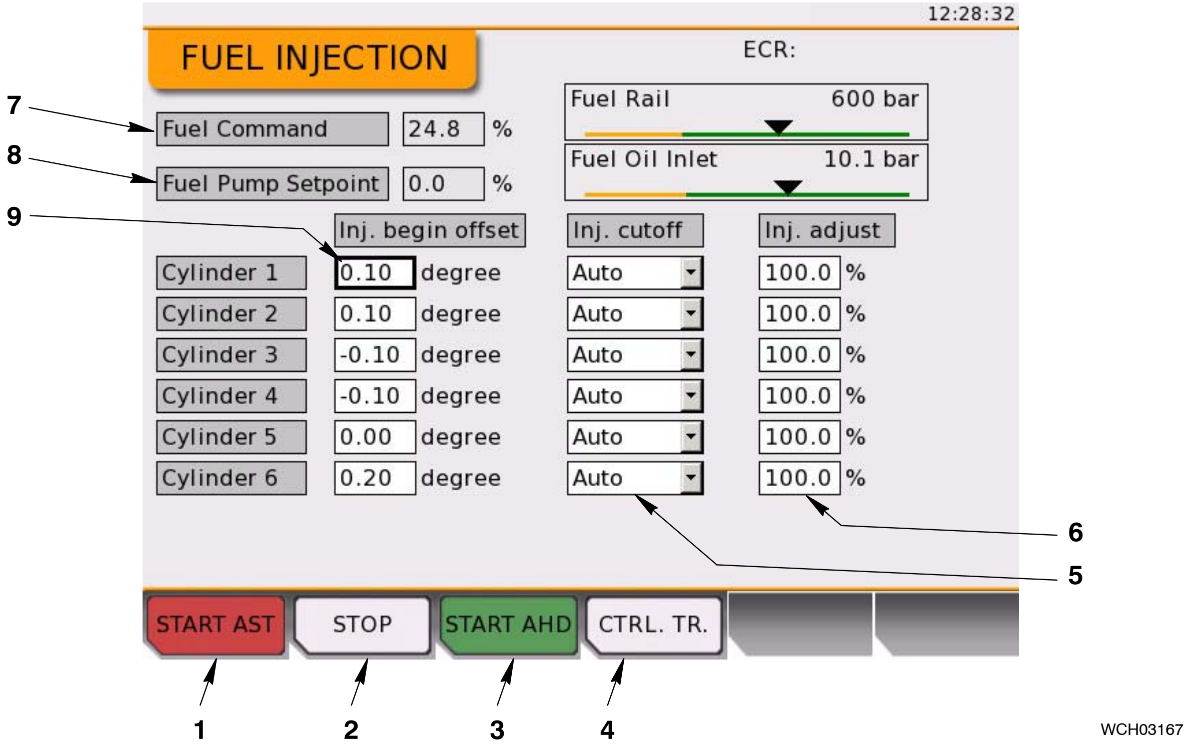

Fig. 9: Fuel Injection Page

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP tab	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Injection cutoff	0 = normal operation 1 = cylinder cutoff (no injection) Can be used to stop fuel injection to a specified cylinder if necessary (e.g. liner/piston ring problems or damaged injection system). The exhaust valve stays in normal operation.
6	Injection adjust	Used to fine-tune the total amount of injected fuel per cylinder. Can be adjusted from 80% to 110% 100% = usual injection quantity Can be decreased to 80% for each cylinder Used to operate in one cylinder or if there are operation problems in more than one cylinder
7	Fuel Command	Shows the used fuel command value for injection in percent (0% to 150%)
8	Fuel Pump Setpoint	Shows the capacity at which the fuel pumps must operate in percent (0% to 100%)
9	Injection begin offset	Adjustable parameter; ±1.5 degrees Cylinder pressure fine tuning in service: Lets you adjust the injection begin offset to balance the firing pressure (bar).

3.7.1 Procedure – Adjust the Diesel Fuel Injection Parameters

1) To adjust the diesel fuel injection parameters, turn the rotary button to move the cursor to the related text field (see Fig. 8). Push the rotary button to enter the edit mode.

2) Turn the rotary button to adjust the value (turn clockwise to increase, or counterclockwise to decrease). Push the rotary button again to go out of the edit mode.

3.8 Exhaust Valve

The manual exhaust valve operation is only available on the local LDU−20 (at the local control stand), while the engine is stopped.

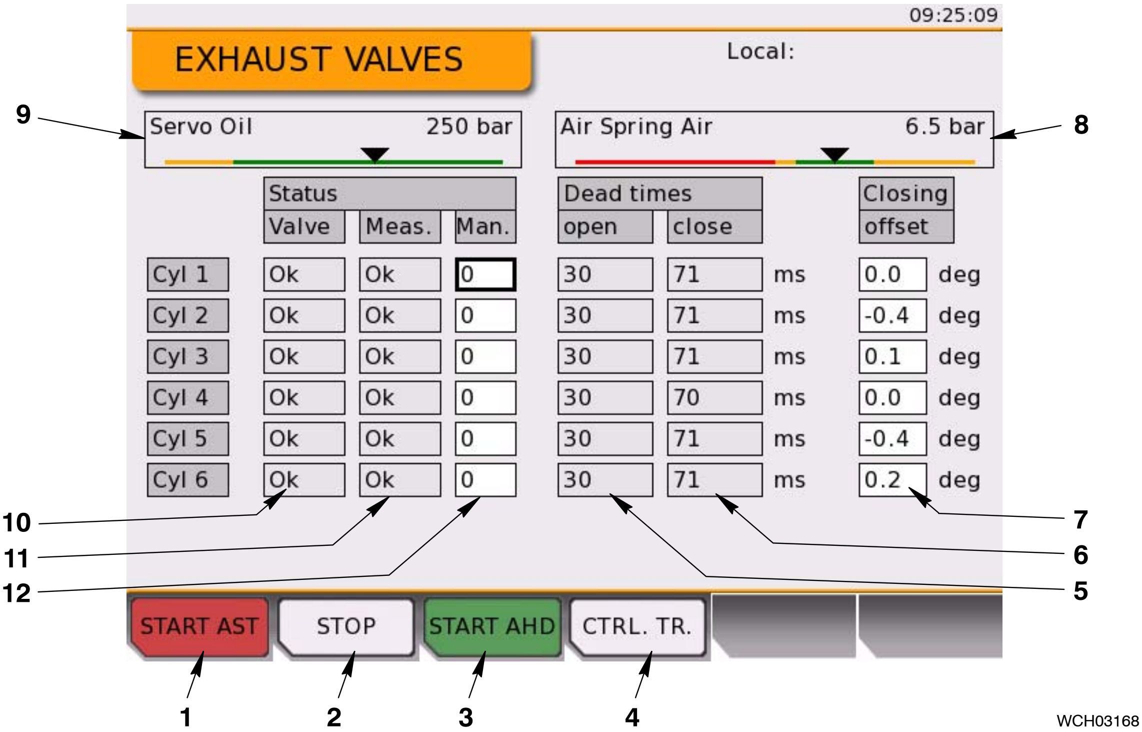

Fig. 10: Exhaust Valve Page

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Exhaust valve open dead times in milliseconds	The time between the open/close command to the solenoid valve of VCU and the exhaust valve stroke
6	Exhaust valve close dead times in milliseconds	The time between the open/close command to the solenoid valve of VCU and the exhaust valve stroke
7	Exhaust valve closing offset in degrees	The exhaust valve stroke moves more than 15% of the offset of the close commands
8	Air spring air	Shows the actual pressure of the air spring air in bar
9	Servo oil status	Shows the actual pressure of the servo oil in bar
10	Exhaust valve status	Shows the status of the exhaust valve. Either OK or FAIL (actuation or timing failure).
11	Meas. status	Shows OK, or FAIL (if the positioning stroke signal is lost)
12	Manual exhaust valve operation	0 = automatic, 1 = manually open

3.8.1 Procedure – Open the Exhaust Valve for Inspections

To open the exhaust valve for inspection, do steps 1) to 4).

1) Move the cursor to the related text field (6, Fig. 9), then push the rotary button to enter the edit mode.

2) Turn the rotary button to adjust the value to 1 to open the exhaust valve. Adjust the value to 0 to go back to automatic mode. Push the rotary button again to go out of the edit mode.

3) Use the manual exhaust valve operation to manually open and close an exhaust valve after the engine has stopped. (This can be used for tests and bleed procedures, e.g. after maintenance.)

4) The conditions that follow in step a) to b) are necessary:

   a) You must set to on the servo oil service pump to get some pressure in the servo oil rail (see 8016−1 Lubrication Oil System, paragraph 3).

   b) Make sure that there is air spring air pressure.

3.9 Cylinder Lubrication

Manual lubrication can be used to inject a specified number of lubricating oil pulses to the cylinders before engine start (see Fig. 10).

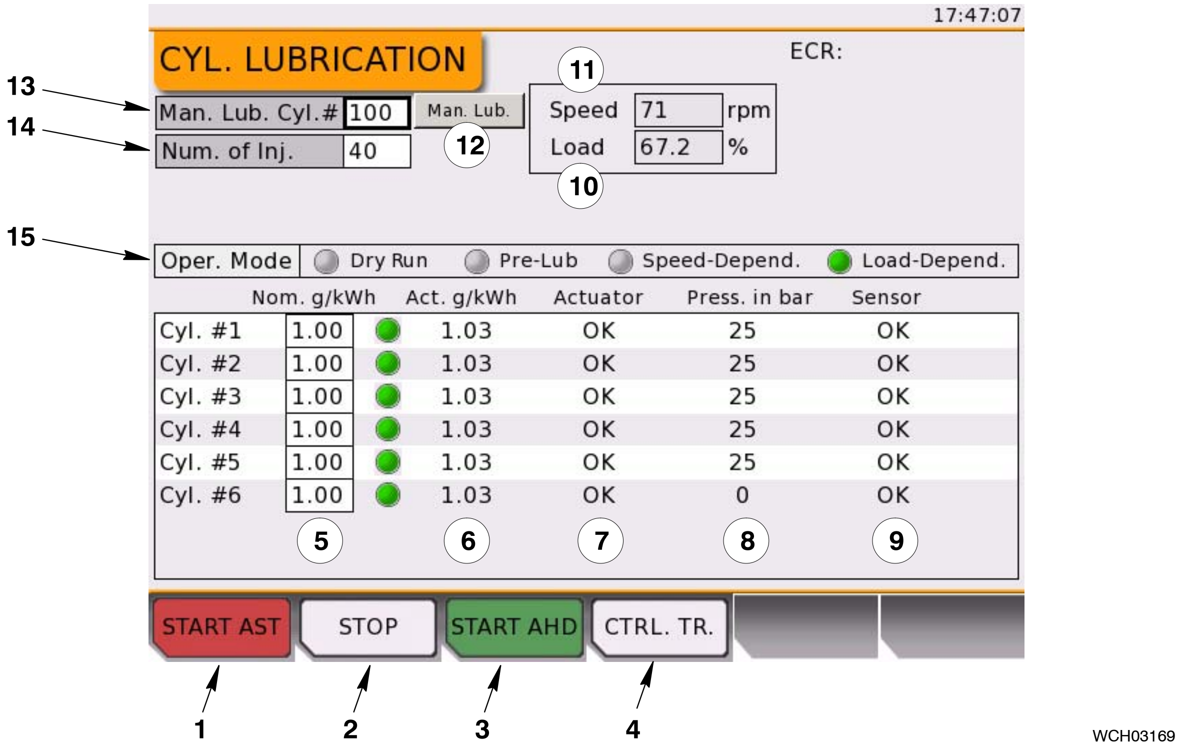

Fig. 11: Cylinder Lubrication

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Nominal feed rate of cylinder at CMCR	Sets the nominal lubrication feed rate in g/kWh. The value shown does not relate to the manual lube adjustment.
6	Actual feed rate per cylinder	Shows the actual feed rate in g/kWh. The value is calculated in relation to the engine load.
7	Actuator status	Shows the status of the actuator. Shows either OK or ERROR
8	Pressure	Shows the lubricating oil pressure in bar.
9	Sensor status	Shows the status of the sensor. Shows either OK or ERROR
10	Engine load	Shows the engine load in percent (%)
11	Engine speed	Shows the engine speed in revolutions per minute (rpm)

Item	Function	Effect / Procedure
12	Manual lubrication start	Move the cursor to the related button, then push the rotary button to start manual lubrication. To select a specified cylinder, see item 13.
13	Manual lubrication to specified cylinder	The operator can select a cylinder (1 to 6) or set the value to 100 for all cylinders. To start the manual lubrication, see item 12.
14	Number of manual lubrication pulses	Range 0 to 100
15	Operating Mode	Shows the operating mode status. When the related mode is active, the green indicator is on.

3.9.1 Speed/Load Mode Description

The number of revolutions until the next lubrication pulse is calculated in relation to the set parameters. The values for the dry protect mode are set during the commissioning. When the value is less than the set Dry Protect parameter (12), the speed/load mode becomes active. This is the standard mode during usual operation. For more data about the Mode Dry Protect, see paragraph 3.8.2.

3.9.2 Dry Protect Mode Description

The number of revolutions until the next lubrication pulse is calculated in relation to the set parameters. The values for the dry protect mode are set during the commissioning. When the calculated value is more than the set dry protect parameter, the dry protect mode becomes active.

3.10 User Parameters

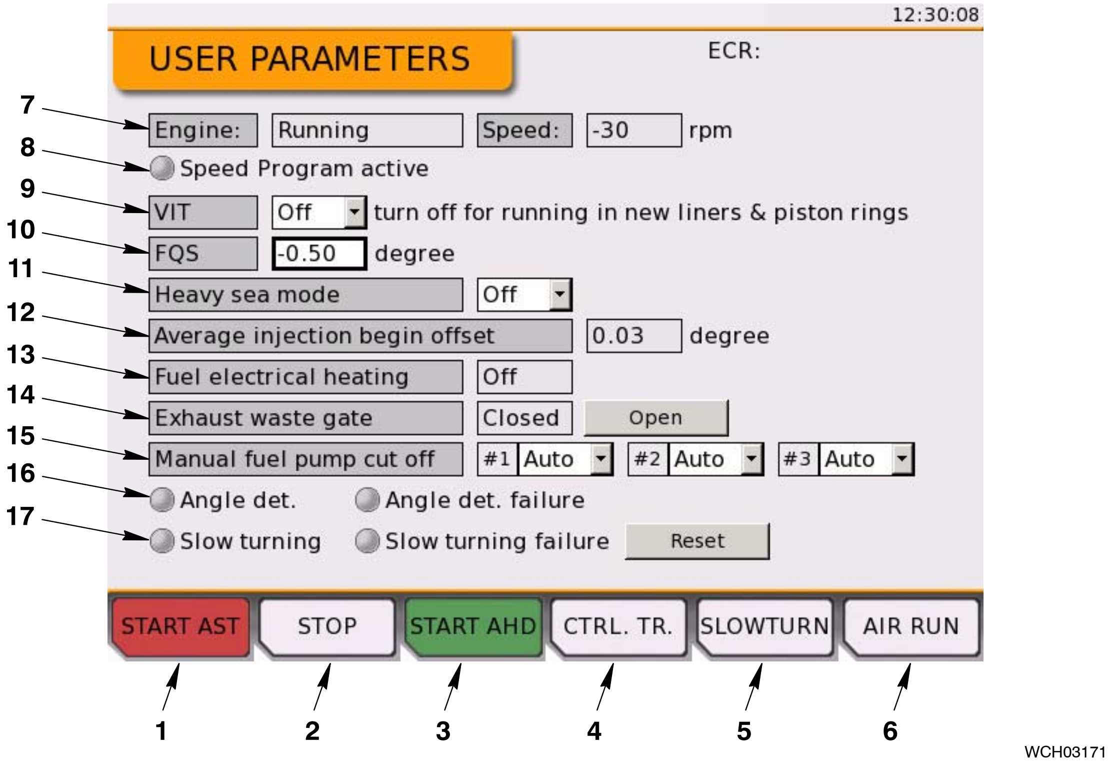

Fig. 12: User Parameters

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	SLOWTURN button	Put the engine in slow turning mode Push the button once to start slow turning Engine goes back to stopped mode after it has turned for some revolutions
6	AIR RUN button	Put the engine in air run mode Air run is active while the button is pushed
7	Engine status	Shows the engine status and the engine speed in revolutions per minute (rpm) Shows: Start interlock, Stopped, Slow turning, Air Run, Starting, Heavy Start, Running or Shutdown
8	Speed program indicator	Shows the speed program status. When the speed program is active, the green indicator is on.
9	Variable Injection Timing (VIT)	Use the cursor to select the drop-down menu. Push the rotary button to list the available values. Set to ON to activate the VIT. Set to OFF to deactivate the VIT. VIT must be deactivated for running-in of new cylinder liners or piston rings. Deactivate means the injection starts at the nominal angle independently of the engine power.

Item	Function	Effect / Procedure
10	Fuel Quality Setting (FQS)	Adjustable parameter range from −5° to +5° The FQS can be set to adjust maximum firing pressure to nominal value. A negative correction angle will advance the injection start and increase maximum pressure. A positive correction angle will retard the injection start and decrease maximum firing or combustion pressure.
11	Heavy sea mode	Use the cursor to select the drop-down menu. Push the rotary button to list the available values. Set to ON to activate heavy sea mode. Set to OFF to deactivate heavy sea mode. Can be set to on in heavy sea. This function sets the fuel rail pressure to a constant value. VIT function is off. Sequential injection is off and all injection nozzles are in operation. Pressure control becomes more stable. Set to off when weather conditions are usual and before manoeuvring.
12	Average injection begin offset	Shows the average injection begin offset value in degree (deg)
13	Fuel electrical heating	Shows the status of the of the electrical trace heating. During operation with HFO, the electrical trace heating heats the fuel to operating temperature.
14	Exhaust waste gate	Shows the status of the exhaust valve. Use the cursor to select the OPEN button. Select OPEN to open the butterfly valve in the waste gate. Select CLOSE to close the butterfly valve in the waste gate. This function is only active for binary exhaust waste gates (EWG).
15	Manual fuel pump cut off	Adjustable parameter. Use the cursor to select the drop-down menu for the related fuel pump. Push the rotary button to list the available values. Set to ON to activate the manual fuel pump cut off. Set to OFF to deactivate the manual fuel pump cut off. Set to AUTO to set the manual fuel pump cut off to the automatic mode (usual operation).

Item	Function	Effect / Procedure
16	Angle detection / Angle determination failure indication	Shows the angle determination status. When the crank angle determination algorithm (ADA) mode is active, the related indicator is on. When there is a crank angle determination failure, the related indicator is on.
17	Slow turning / Slow turning failure indications	Shows the slow turning status. When the slow turning mode is active, the related indicator is on. When there is a slow turning failure, the related indicator is on. To reset a slow turning failure indication, move the cursor to the reset button. Then push the rotary button to reset the failure indication.

3.11 Performance Data

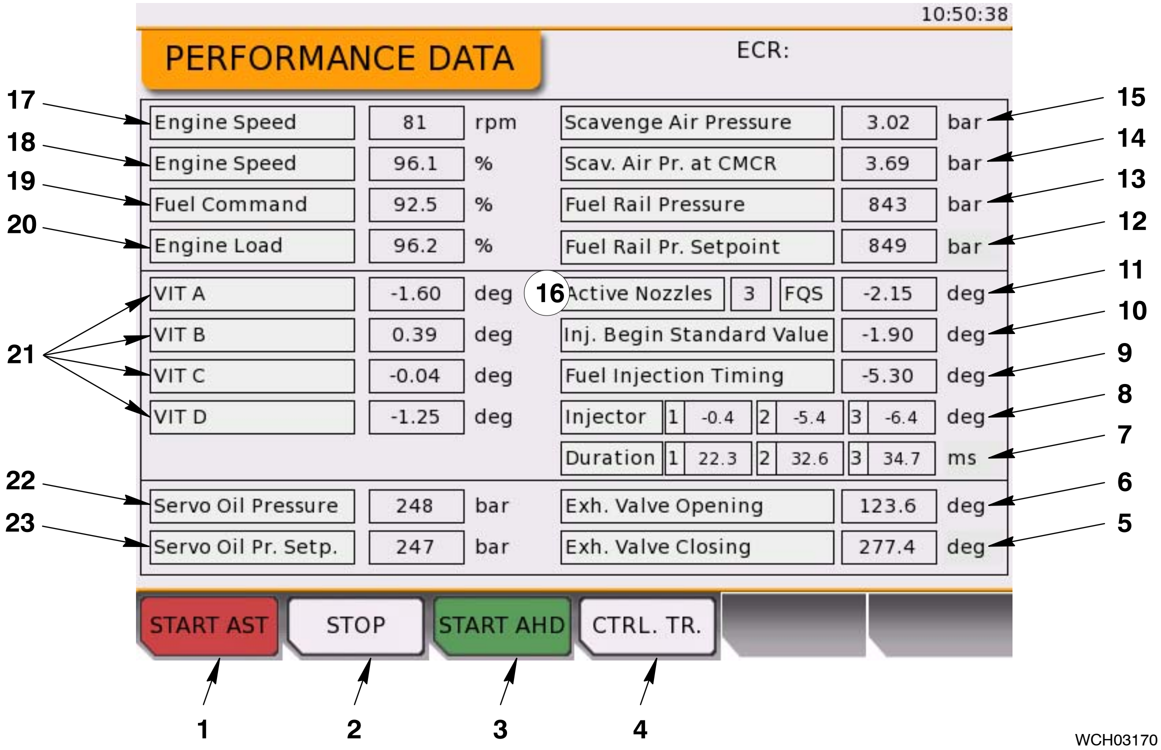

Fig. 13: Performance Data Page

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP tab	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Exhaust valve closing	Shows the exhaust valve closing angle in degree (deg)
6	Exhaust valve opening	Shows the exhaust valve opening angle in degree (deg)
7	Duration	Shows the duration of the fuel injection for main fuel injector#1, main fuel injector#2 and main fuel injector#3 in milliseconds (ms)
8	Injector timing	Shows the injection timing for main fuel injector#1, main fuel injector#2 and main fuel injector#3 in degree (deg)
9	Fuel injection timing	Shows the fuel injection timing (injection begin) in degree (deg)
10	Injection begin standard value	Shows the injection begin standard value in degree (deg)
11	Fuel quality setting (FQS)	Shows the used fuel quality setting (FQS)
12	Fuel rail pressure setpoint	Shows the fuel rail pressure setpoint in bar

Item	Function	Effect / Procedure
13	Fuel rail pressure	Shows the fuel rail pressure in bar
14	Scavenge air pressure at CMCR	Shows the scavenge air pressure at CMCR in bar
15	Scavenge air pressure	Shows the scavenge air pressure in bar
16	Active nozzles	Shows the number of active injection nozzles
17	Engine speed	Shows the engine speed in revolutions per minute (rpm)
18	Engine speed	Shows the engine speed in percent (%) of CMCR
19	Fuel command	Shows the used fuel command in percent (%)
20	Engine load	Shows the engine load or estimated engine power in percent (%)
21	Variable injection timing (VIT)	Shows the variable injection timing (VIT) in degree (deg), specified for different performance definitions (VIT A, VIT B, VIT C or VIT D)
22	Servo oil pressure	Shows the servo oil pressure in bar
23	Servo oil pressure setpoint	Shows the servo oil pressure setpoint in bar

3.12 Temperatures – Cylinder Liner Wall and Exhaust Gas

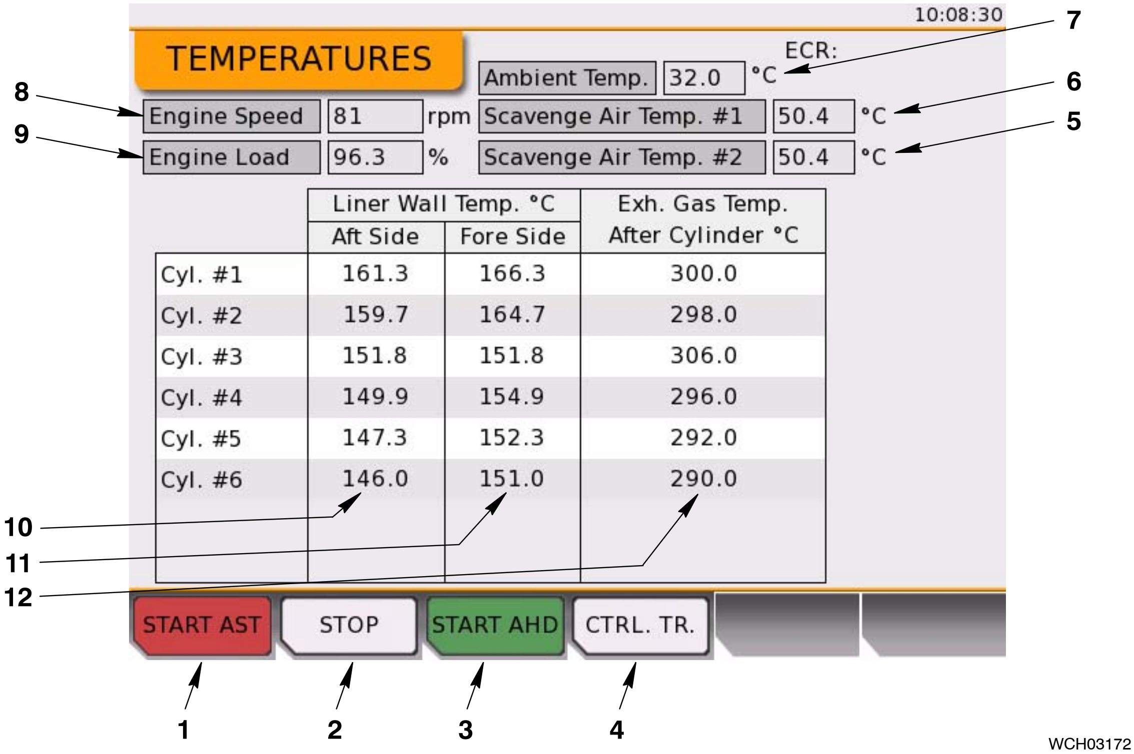

Fig. 14: Temperature – Cylinder Liner Wall and Exhaust Gas

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Scavenge air temperature #2	Shows the scavenge air temperature #2 in the scavenge air receiver in degree Celsius (°C)
6	Scavenge air temperature #1	Shows the scavenge air temperature #1 in the scavenge air receiver in degree Celsius (°C)
7	Ambient temperature	Shows the suction air temperature in degree Celsius (°C)
8	Engine speed	Shows the engine speed in revolutions per minute (rpm)
9	Engine load	Shows the engine load or estimated engine power in percent (%)
10	Liner wall temperature AFT side at cylinder #n	Shows the cylinder liner wall temperature at aft side of the engine for each cylinder.
11	Liner wall temperature FORE side at cylinder #n	Shows the cylinder liner wall temperature at fore side of the engine for each cylinder.
12	Exhaust gas temperature after cylinder #n	Shows the exhaust gas temperature after each cylinder.

3.13 Crank Angle

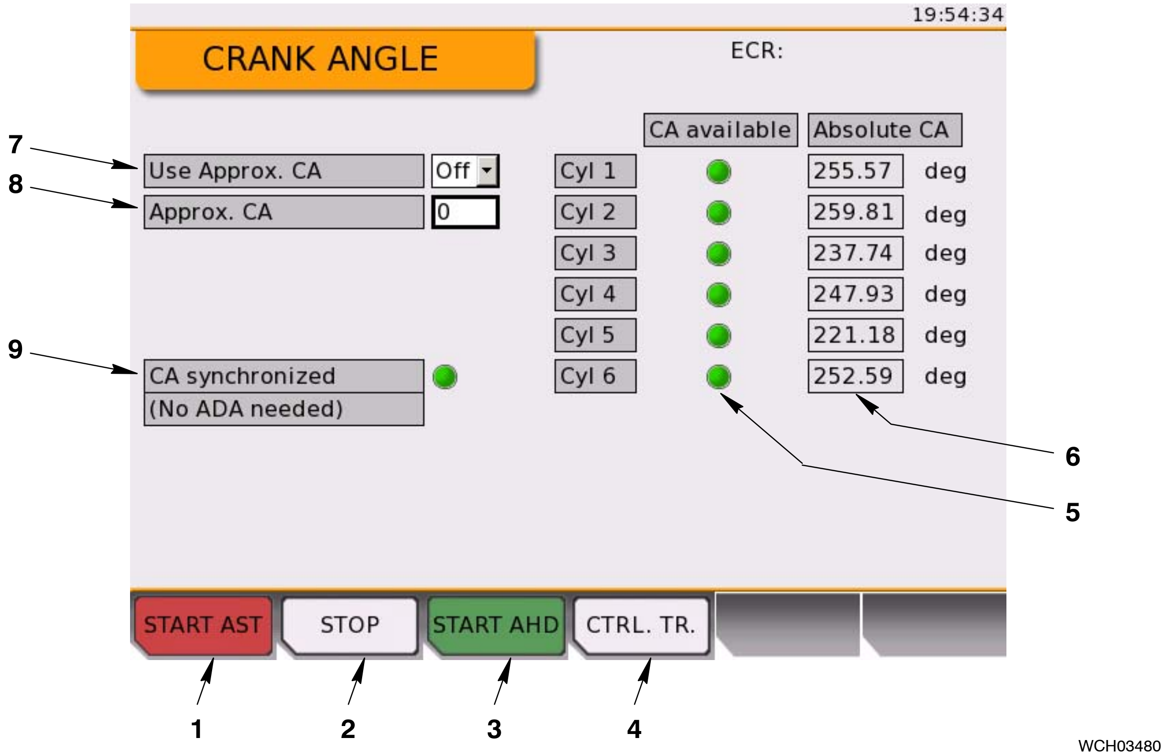

Fig. 15: Crank Angle Page

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP tab	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	CA available	Shows if the crank angle value for the related cylinder is available. A green indicator shows which item is available.
6	Absolute CA	Shows the absolute crank angle value for each cylinder in degrees (deg). **Note: The absolute crank angle value shown is only correct when the engine is stopped. When the engine operates, the data shown on the LDU-20 page can be incorrect. The correct data is shown after a short period.**
7	Use approximate CA	When the engine is stopped and the CA value is not available after system/module start, use the approximate crank angle (CA) value. Set the field (see item 7) to ON and set the approximate value (see item 8) manually to the related flywheel position. This gives the best results for the ADA process at engine start. Use the cursor to select the drop-down menu. Push the rotary button to list the available values. Set to ON to activate the approximate CA mode. Set to OFF to deactivate the approximate CA mode.

Item	Function	Effect / Procedure
8	Approximate CA	Shows the set approximate crank angle (CA) value (see also item 7).
9	CA synchronized (No ADA needed)	Shows the crank angle synchronization status, i.e. if the angle determination algorithm (ADA) process is necessary/on. When the CA is synchronized, a green indicator shows. When the CA is not synchronized, a red indicator shows.

3.13.1 ADA Start from the LDU-20 Local Control Panel or LDU-20 ECR

WARNING

Injury Hazard: After an air run, the crankshaft can turn suddenly when the pressurized air in the cylinder releases. There is a risk of death, serious injury or damage to components. Before you do maintenance on the engine, engage the turning gear, or start the Crank Angle Determination Algorithm (ADA) a second time:

1) Make sure that there is no pressurized air in the cylinder and the starting air pipes.

2) Make sure that you open the relief valves on all cylinder covers to release the pressure.

If you manually start the crank angel determination algorithm (ADA) from the LDU-20 Local Control Panel or the LDU-20 ECR do the step 1) and step 2):

Note: It is possible to do the ADA procedure with open or closed indicator valves.

1) On the LDU-20, select the USER PARAMETER page (see paragraph 3.10).

2) Push the AIR RUN button until the engine status changes from ADA to AIR RUN.

Note: It is also satisfactory if each cylinder was activated and has moved automatically at the ADA procedure (independently from the direction in which the engine turns).

If the ADA procedure is not successful, i.e. the absolute crank angle position could not be found, do step 3) and step 4):

3) Open the indicator valves on all cylinders to release the compressed air.

4) Do step 1) to step 2) above again.

3.14 Software Info

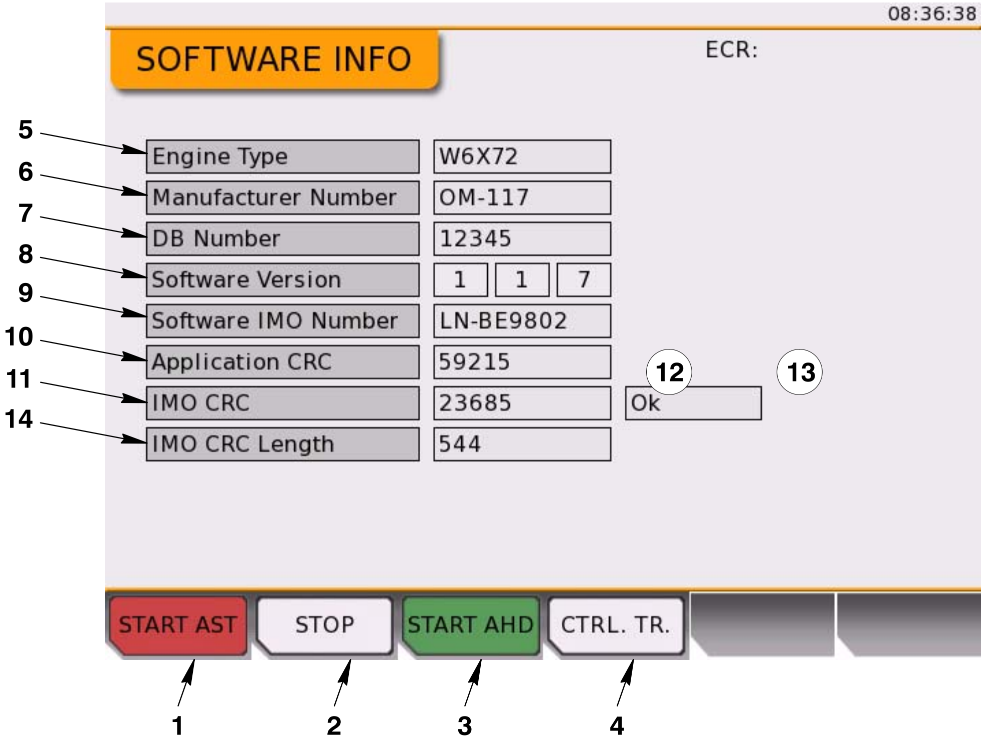

Fig. 16: Software Info

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Engine type	Shows the applicable engine type name
6	Manufacturer number	Shows the software (SW) manufacturer number
7	DB number	Shows the identification number of the installation
8	Software version numbers	[major][middle][minor] (for example 1.0.16)
9	Software identification number	As issued by IMO
10	Application CRC (Cyclic Redundancy Check)	Checksum of the application binary
11	IMO CRC	Checksum of the IMO parameters
12	Result of CRC check	Shows either OK or ERROR on the module that has an invalid IMO CRC
13	Identifier of invalid CRC	Shows which CCM-20 has the incorrect CRC
14	IMO CRC Length	Number of bytes that went into the CRC calculation

3.15 Log Messages

You can use the Filters field (7, Fig. 15) to filter the list of log messages to only show specified types of messages.

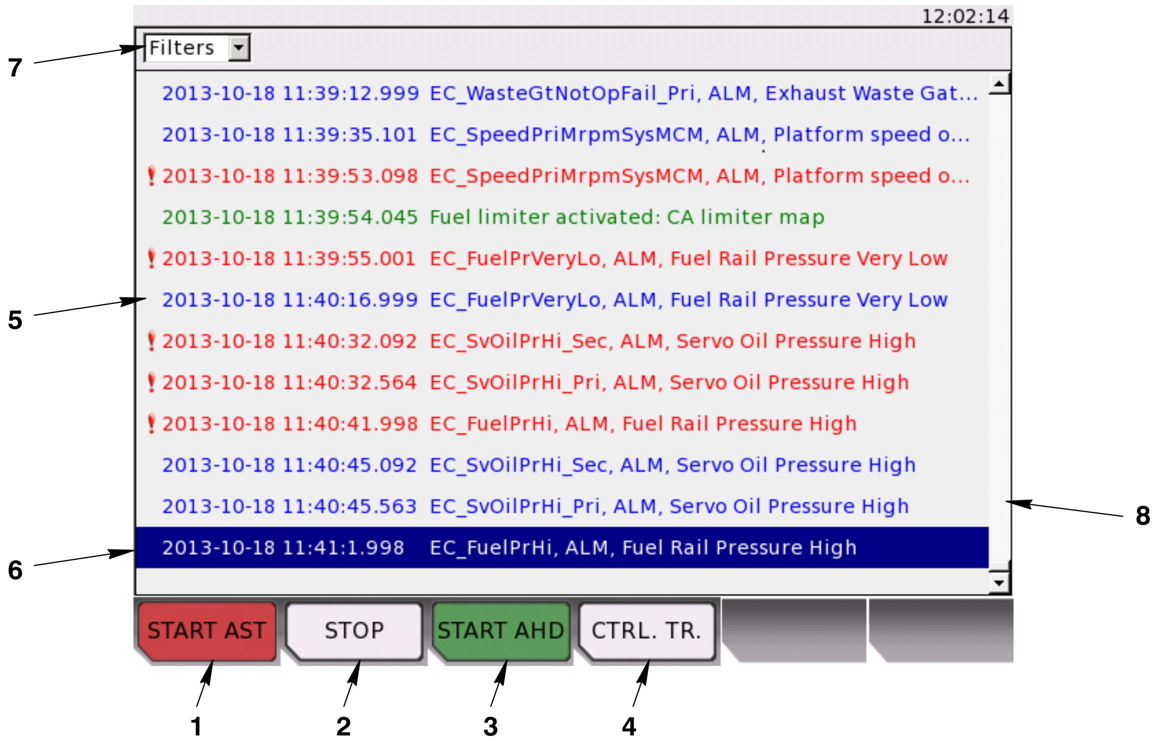

Fig. 17: Log Messages

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	List of log messages	Latest message on the bottom of the list
6	Selected log message	Highlighted with blue background
7	Filter setting	Use the BACK button
8	Scroll bar	Scroll through the log messages

To change the filter settings, do step 1) to 6).

1) Push the BACK button to put the cursor on the Filters field, then push the rotary button to display the list of available filters e.g. All/Safety/Event/Info/Error.
2) Use the rotary button to move the cursor up or down in the list of available filters.
3) Push the rotary button to select or deselect the filters.
4) Push the BACK button two times to move the cursor back to the list of log messages.
5) Use the rotary button to scroll the list up or down.
6) When the cursor (a blue highlight in the list) is on a selected log message, you push the rotary button. This shows a different screen, which has more data about this log entry (see Fig. 16).

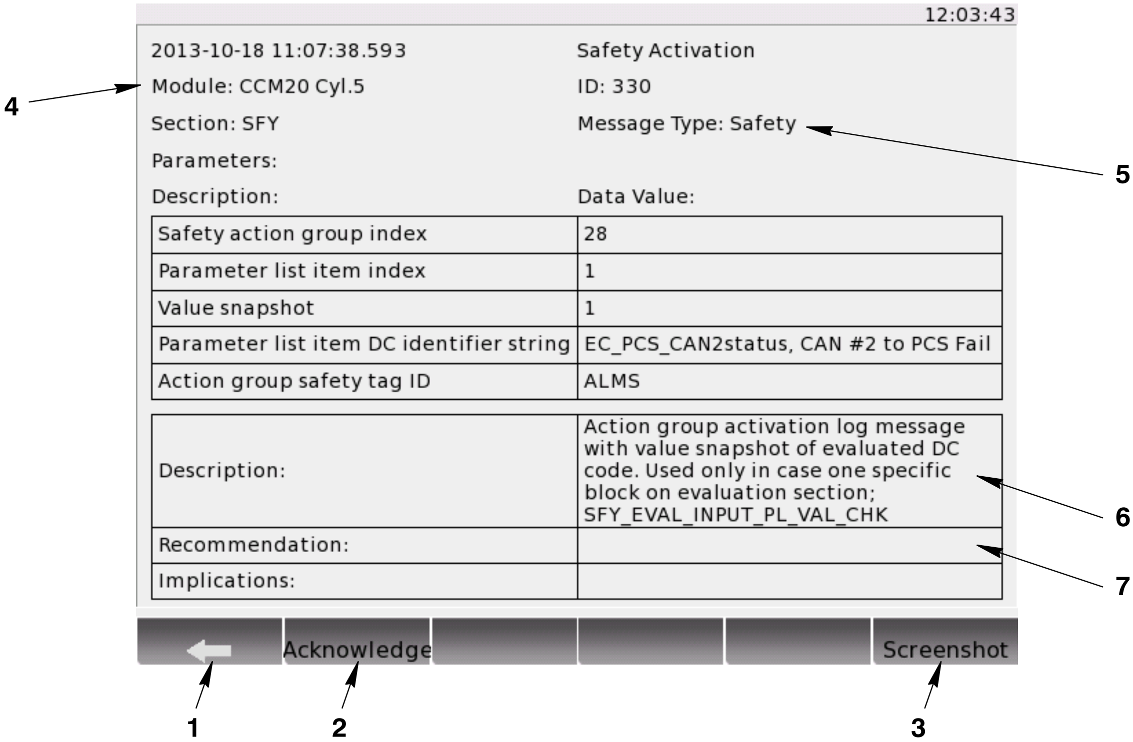

Fig. 18: Log Entry Data

Item	Function	Effect / Procedure
1	BACK button	When selected, the screen goes back to the message list
2	Acknowledge button	No function
3	Screenshot button	Saves a picture (in .png format) of this screen to a USB drive (if connected)
4	Module identifier	Shows the source module that sent this log entry
5	Message type	Info/Error/Event/Safety
6	Description	General data about the log entry
7	Recommended action	Recommended action that the operator can do to solve the problem

Note: Some data on this screen are only applicable to Wärtsilä SW developers, i.e. the ID and status flag numbers.

3.15.1 Procedure – Export a Screenshot of the Log Entry Page

1) If a serious problem occurs, do step a) to step d):

   a) Take a screenshot of this page.

   b) Connect a USB drive to the USB port on the rear of the LDU.

   c) Save the screenshot to the USB drive.

   d) Send the saved .png file to Wärtsilä service.

3.16 System Status

The LDU-20 have a full backup of all application and configuration files for all modules in the system (5, Fig. 17). When a module starts, all files are compared to the backup files in the LDU-20. Different versions found are highlighted with red in the status list.

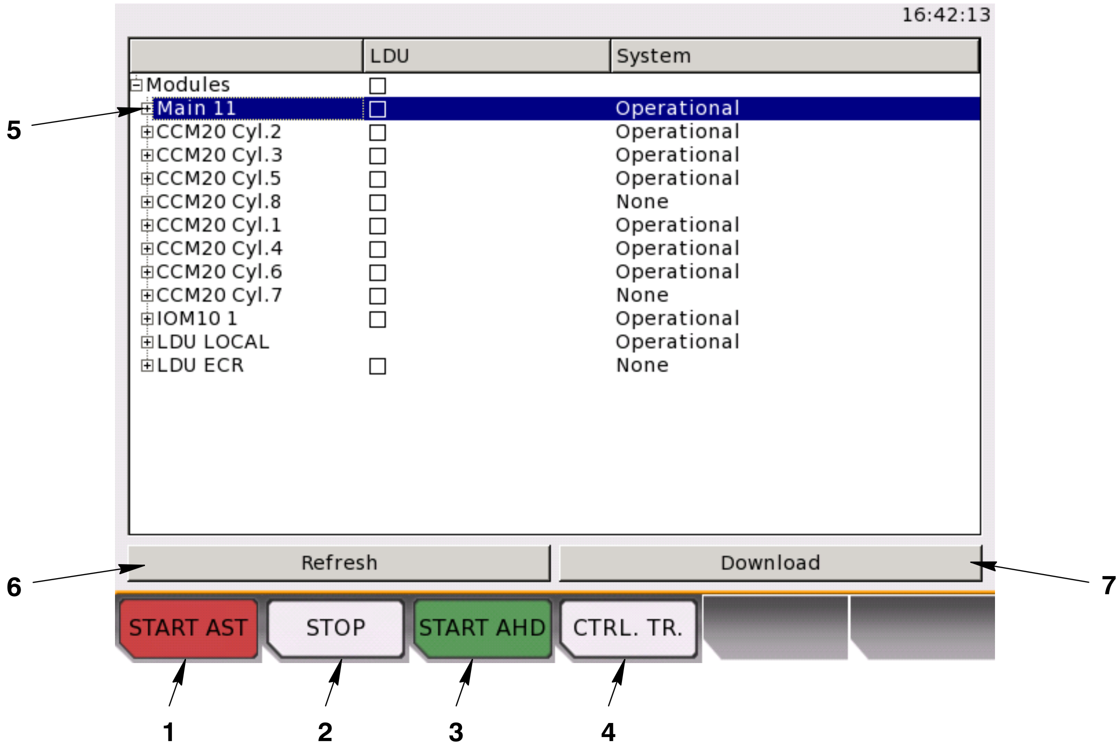

Fig. 19: System Status

Item	Function	Effect / Procedure
1	START AST button	Start the engine in astern direction
2	STOP button	Stop the engine
3	START AHD button	Start the engine in ahead direction
4	CTRL. TR. button	Request a control transfer to this LDU
5	Status indications for each module Possible states are:	Application running: Module operates normally No still alive: Module is set to off or disconnected from the CAN bus Difference found: Different version of application/ configuration/DSP is found SW download is necessary to synchronize the module with the rest of the system
6	Refresh button	Use the rotary button to select. Updates the module status list
7	Download button	Use the rotary button to select. Does a SW download on the selected modules

3.16.1 Procedure – Download Backup Files

1) Use the rotary switch (turn then push) to select the Download button. A dialog box is shown. This dialog box gives an option to download, or not to download the backup files to the selected modules.
2) Select Yes to start the download backup files procedure. Select No to cancel the procedure.

3.17 USB Page

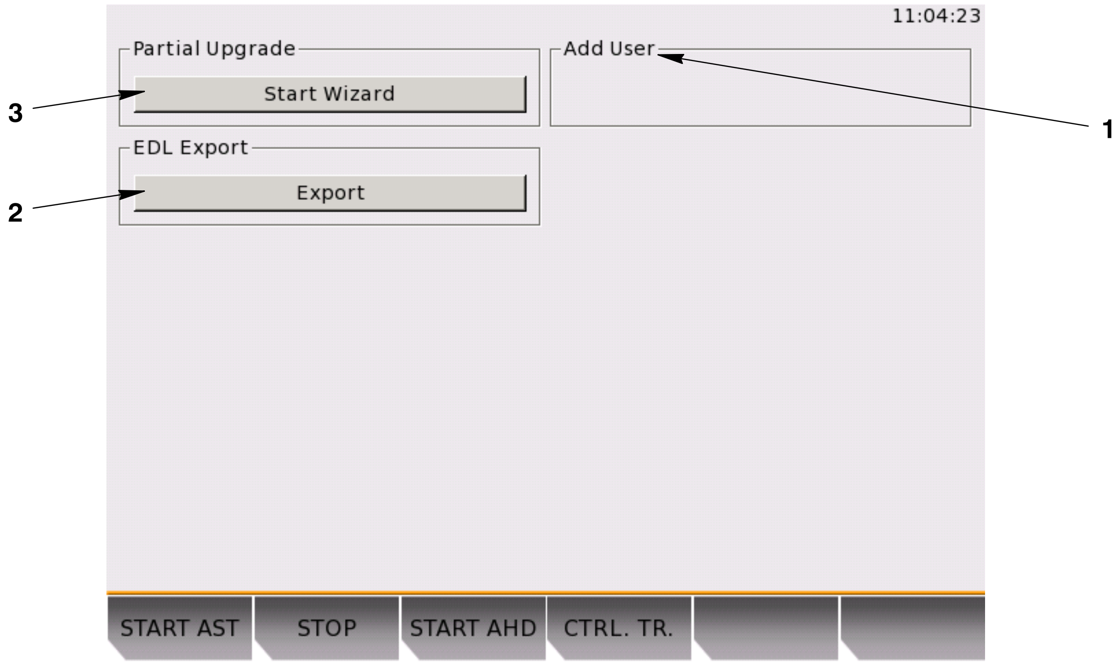

Fig. 20: USB Page

Item	Function	Effect / Procedure
1	Add User	Not used
2	Export button	Exports all log messages to a file on a USB drive (if connected)
3	Start Wizard button	Starts the partial upgrade wizard

3.17.1 Procedure − Export All Log Messages

1) Connect a USB drive to the USB port on the rear of the LDU before you select the Export button (2, Fig. 18).
2) Use the rotary button to put the cursor on the Export button 2. Push the rotary button to select Export.

The file name EDL Export YYYYMMDD_hhmmss.wxml will be saved to the USB drive. The timestamp display YYYYMMDD_hhmmss is shown as year/month/day_hours/minutes/seconds. This file has the full system log and can be sent to Wärtsilä service for troubleshooting.

Note: When the export is done, disconnect the USB drive from the LDU-20. This prevents an unwanted LDU-20 shutdown because of a too high power consumption.

You use the partial upgrade wizard to adjust software parameters, which the user does not usually have access. A file (from Wärtsilä) stored on a USB drive is necessary.

3) To apply the partial upgrade, connect the USB drive to the USB port on the back of the LDU.
4) Use the rotary button to put the cursor on the Start Wizard button (5).
5) Push the rotary button to select Start Wizard.

A screen shows you the available upgrade packages on the USB drive and helps you through the upgrade process (see Fig. 19).

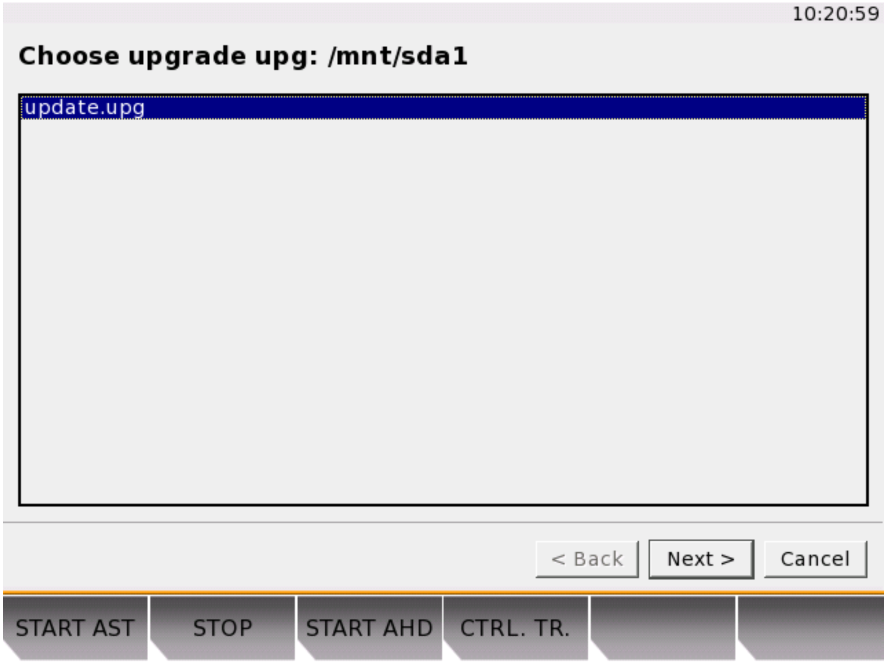

Fig. 21: Choose Upgrade Page

3.18 System Settings

This page contains three sub-pages to adjust the LDU-20 system settings (see Fig. 20).

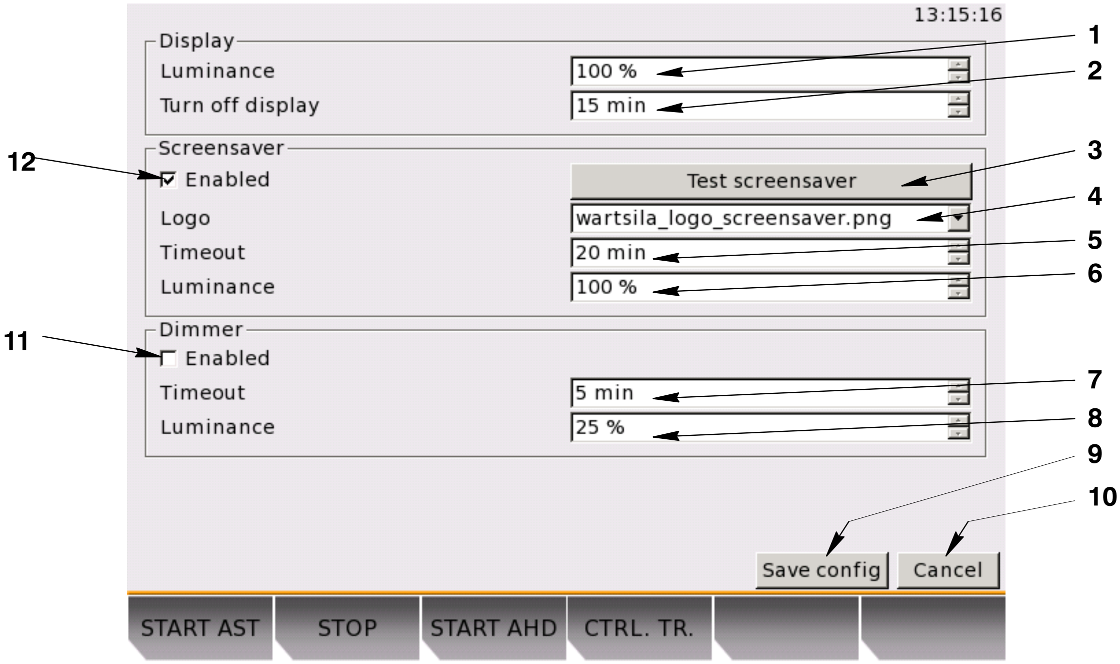

Fig. 22: System Settings Page

Item	Function	Effect / Procedure
1	Display luminance setting	Adjusts the brightness of the display: 1% to 100%
2	Turn off display	Adjusts the time period to turn off the display after inactivity Set to between 0 minutes and 100 minutes Set to 0 to never turn off the display
3	Test screensaver	Select to see the screensaver. Push a button to leave the test mode
4	Logo	Browse for picture selection. Select the picture to use in screensaver mode
5	Timeout	Adjusts the time period to turn off the display after inactivity. Set to between 1 min and 100 min
6	Screensaver luminance	Adjusts the display brightness for the screensaver mode from 1% to 100%
7	Timeout	Adjusts the time period to dim the display after inactivity. Set to between 1min and 100 mins
8	Dimmer luminance	Adjusts the display brightness for the dimmer mode from 1% to 100%
9	Save config button	Saves the configuration settings
10	Cancel button	Reject changes and go back to the last saved settings
11	Enable/Disable dimmer	Used to decrease the display brightness after a specified period of inactivity.
12	Enable/Disable screensaver	Put a check mark in the check box to enable the screensaver. Remove the check mark to disable.

3.19 Ethernet

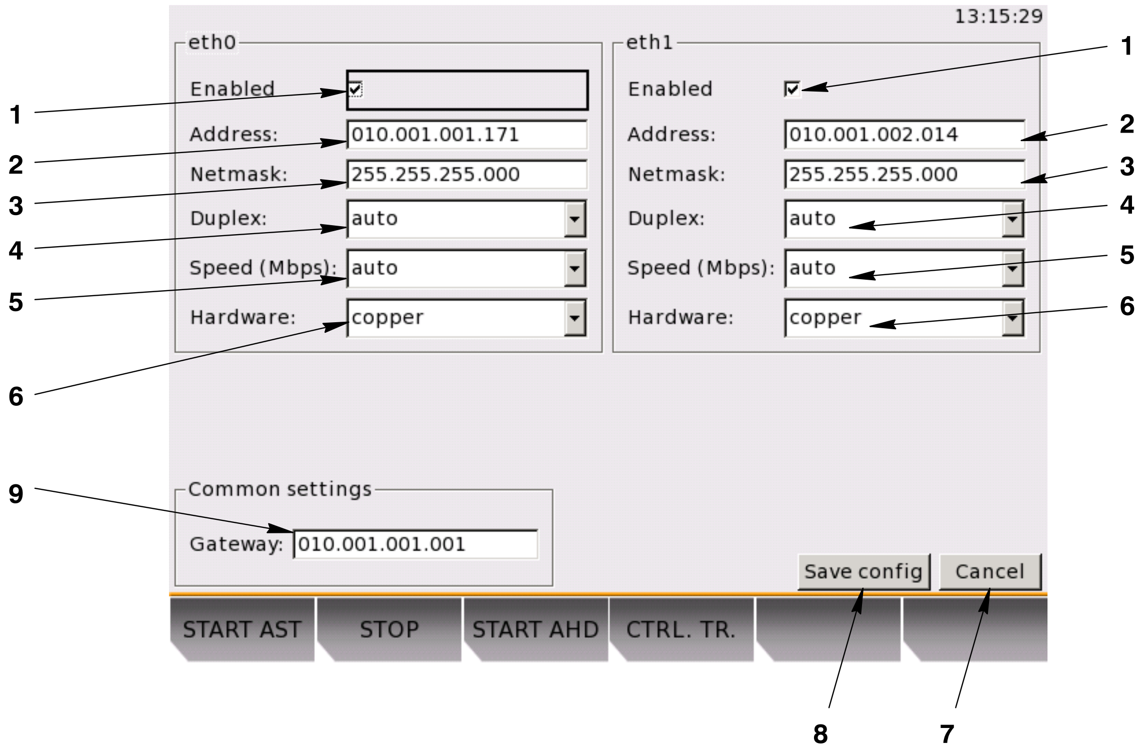

Fig. 23: Ethernet Page

Item	Function	Effect / Procedure
1	Enable/Disable ethernet ports	eth0 = plug X31 eth1 = plug X32 The two ports must be enabled by default
2	Address field	Configure TCP/IP address for each ethernet port Default settings: LDU−20 Local: eth0 = 10.1.1.171 eth1 = 10.1.2.14 LDU−20 ECR: eth0 = 10.1.1.173 eth1 = 10.1.2.14
3	Netmask field	Configure TCP/IP netmask Default 255.255.255.000 for the two ports on each LDU−20
4	Duplex field	Configure ethernet duplex mode Can be: half, full or auto Default is: auto
5	Speed (Mbps) field	Configure ethernet speed Can be: 10, 100 or auto Default is: auto
6	Hardware field	Choose ethernet hardware interface Can be: copper or fiber Default is: copper
7	Cancel button	Reject the changes and go back to the last saved settings
8	Save config button	Save the configuration settings
9	Gateway field	Configure TCP/IP gateway address Default is 10.1.1.1

3.20 Date

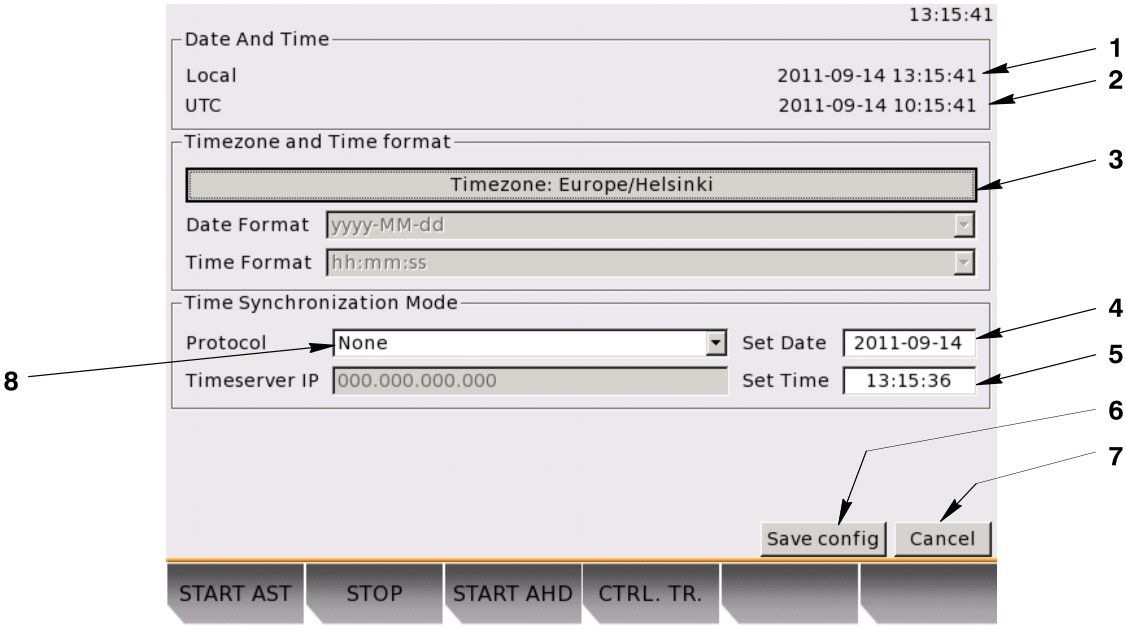

Fig. 24: Date Page

Item	Function	Effect / Procedure
1	Local time	Includes time offset from UTC
2	UTC time	Coordinated universal time
3	Select time zone	Use the rotary button to get a list with all available time zones
4	Set Date field	Use the rotary button to adjust the date setting
5	Set Time field	Use the rotary button to adjust the time setting
6	Save config button	Save the configuration settings
7	Cancel button	Reject changes and revert to the last saved settings
8	Configure time synchronization mode	Option to use Network Time Protocol (NTP). Not used

3.21 Screenshot

The last entry in the navigation menu is the screenshot function. This function saves a screenshot of the page to a USB drive (if connected). The saved screenshot is a 640 x 480 pixel image in the portable network graphic (.png) format, which can be opened with most image manipulation tools.

When you save a screenshot, the pop-up text Screenshot saved, shows on the bottom right-hand corner of the display. If no USB drive is connected, or if there was an error during the save process to the USB drive, the pop-up message shows USB Mounting failed.

Note: When the export is done, disconnect the USB drive from the LDU-20. This prevents an unwanted LDU-20 shutdown because of a too high power consumption.

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Engine Control

1. General

The Control Diagram is a schematic diagram of all control components and their connections.

All code numbers and names used in the data that follow are found in the control diagram, see 4003–2 Engine Control Diagram.

2. Engine Control Functions

The engine control system has the functions that follow:

- Engine start, operation, maneuvering and shut-down
- Engine speed control
- A function to monitor the engine
- Control transfer.

3. Engine Local Control

You can operate the engine from the local control panel (see 4002−2, Local Control Panel/Local Display Unit (LDU-20).

The speed controller is part of the ECS. If the MCM-11 becomes defective, the fuel command mode is selected automatically.

Note: The operator must not leave the local maneuvering stand. The operator must regularly monitor the engine speed so that the fuel supply can be immediately adjusted when necessary.

3.1 Preparation

1) On the LDU-20, select the CTRL. TR. button. The CONTROL LOC page shows (see 4002−2 Local Control Panel/Local Display Unit LDU-20, paragraph 3.4).
2) Select the Local button for mode transfer to local manual control.
3) Push the rotary button to go back to the MAIN page.

3.2 Engine Start

1) On the LDU-20, select the button ON/OFF to start the auxiliary blowers.
2) Use the rotary button to select the Fuel Command mode.
3) Turn the rotary button to set the manual fuel command setpoint to approximately 15%.
4) Select the button START AHD or START AST until the engine operates.
5) Turn slowly the rotary button to adjust the fuel injection quantity until the engine operates at the applicable speed. You can see the related value on the display and speed indicator.

Note: You can also use the the LDU-20 on the ECR control panel for the engine start procedure. But the buttons and rotary button operate only when the related LDU−20 has control (see 4002−2 Local Control Panel/Local Display Unit (LDU−20), paragraph 3.4).

3.3 Reverse

1) On the LDU-20, turn the rotary button to set the manual fuel command setpoint to approximately 15%.
2) Select the button START AHD or START AST until the engine operates in the correct direction.

Note: On ships under way, this procedure can be a long period because of propeller drag.

3.4 Engine Stop

1) Turn the rotary button to decrease the engine speed/load.
2) Push the STOP button.

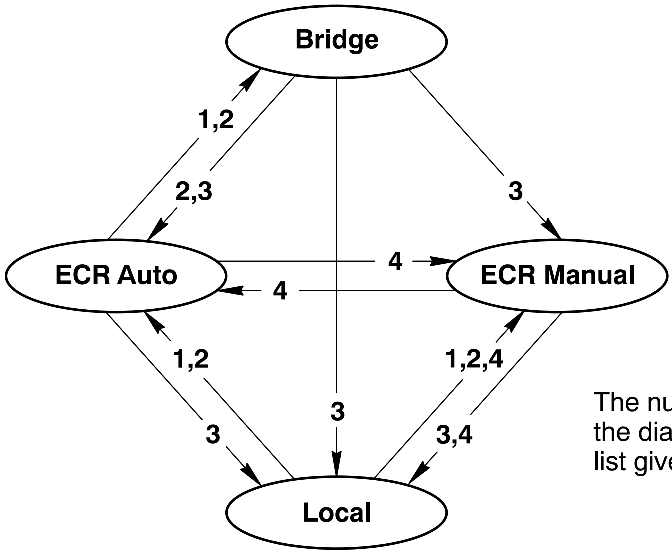
For more data about engine stop, see 0310−1 Engine Shutdown.

3.5 Control Transfer

There are different steps necessary to successfully transfer the signal from one control panel to another. Not all four different transfer modes are always applicable. For more details, refer to the schematic diagram shown in Fig. 1.

The list that follows shows the four possible transfer modes (with the related steps):

1) Target request ► Origin agreement ► Target acceptance
2) Origin proposal ► Target acceptance
3) Target acquisition ► Origin acknowledgment
4) Target acquisition



The numbers shown in the diagram refer to the list given above.

Fig. 1: Control Transfer − Schematic Diagram

4. Engine Control System Checks

If parts of the pneumatic control system were disassembled, removed or replaced during an overhaul, you must do a general check before commissioning.

CAUTION
Equipment Hazard: Leaks can cause faults in the engine control systems and damage to engine components. Leaks that are found during the engine control system checks must be repaired.

You can do checks on all functions. Interlocks give protection against, and prevent, maneuvering errors.

For data about the applicable pressure and temperature ranges, see 0250−1 Operating Data Sheet, Pressure and Temperature Ranges at Continuous Service Power MCR.

For data about alarms and safeguards, see 0250−2 Operating Data Sheet, Alarm and Safeguards at Continuous Service Power.

4.1 General

Note: For data about the item numbers (e.g. 30-4325_E0_1), see 4003−2 Control Diagram.

1) Open the indicator valves.
2) On the starting air bottles, close the shut-off valves 930−V03 and 930−V04.
3) Use the handwheel to close the starting air shut-off valve 30-4325_E0_1.
4) Open the ball valves 30-8605_E0_6 and 30-8605_E0_7 to release the pressure in the starting air manifold.
5) Open the ball valve 35-8353_E0_2 to remove air from the starting air supply pipe.
6) Release the pressure in the control air bottle 35-287HA.
7) Engage the turning gear.
8) Make sure that the servo oil service pump 20-8445_E0_1 is set to off (main switch).

4.2 Control Air Supply Unit

1) At the connection A2, open the 3/2-way valve 35-36HC to supply 30.0 bar to the control air supply unit.
2) Make sure that the 3/2-way shut-off valve 35-36HA is open.
3) Use the pressure reducing valve 35-19HA to set the air pressure to 6.0 bar for the air spring and control air.
   - Do a check of the pressure on the pressure gage PI4411L.
   - Do a check of the pressure on the LDU-20, MAIN page.
4) At connection A1, open the 3/2-way valve 35-36HB to supply 8.0 bar to the control air supply unit.
5) Use the pressure reducing valve 35-23HA to set the air pressure to 6.5 bar for the air spring and control air.
   - Do a check of the pressure on the pressure gage PI4401L.
   - Do a check of the pressure on the LDU-20, MAIN page.
6) Make sure that air flows to the 3/2-way valve 35-31HA.

4.3 ECS Start

1) In the power supply boxes E85.1 to E85.x, set all the knife switches to on.
2) On all the CCM-20, MCM-11, IOM-10 and the two LDU-20, make sure that all green LED indications come on.

4.4 Safety and Alarm System

1) Make sure that the remote control system (RCS), engine safety system (ESS), alarm and monitoring system (AMS) are set to on.
2) On the control room console and the local control panel, push the EMERGENCY STOP button. Make sure that the pressure control and safety valve 10-5562_E0_5 is electrically operated (i.e. the coil is energized). This causes an alarm (M/E Emergency Stop) in the AMS. The alarm is shown on the LDU-20 and the AMS.
3) Connect the pressure calibration hand-pump (tool 94050) to the applicable pipe (e.g. the pipe that has the pressure sensor PS1101S).
4) Use the pressure calibration hand-pump (tool 94050) to increase the pressure to more than the reference pressure given in Table 1.

Table 1: Pressure Calibration

Medium	Code No.	Pressure	Action	Time delay
Cylinder cooling water pressure (engine inlet)	PS1101S	less than 3.5 bar (contract closed)	Shutdown	60 s
Main bearing oil supply pressure	PS2002S	less than 3.3 bar (contract closed)	Shutdown	10 s
Air spring air pressure	PS4341S	less than 4.5 bar (contract closed)	Shutdown	0 s
ABB Turbocharger bearing oil pressure inlet	PS2611S and PS2612S	less than 0.6 bar (contract closed)	Shutdown	5 s
ABB Turbocharger bearing oil pressure inlet – independent oil supply	PS2611S and PS2612S	less than 0.9 bar (contract closed)	Shutdown	5 s
MET Turbocharger bearing oil pressure inlet	PS2611S and PS2612S	less than 0.4 bar (contract closed)	Shutdown	5 s

Note: The data shown above are for reference only. For the applicable settings, see 0250–2 Operating Data Sheet.

5) Make sure that the pressure switch opens.
6) Decrease the pressure in the pipe to set the pressure switch to the correct pressure (e.g. 3.5 bar). Make sure that the pressure switch stays open.
7) Disconnect the pressure calibration hand-pump (tool 94050) from the pipe.
8) Do the steps above for the pressure switches PS2002S, PS4341S, PS2611S and PS2612S.

9) To monitor the passive failures, connect an applicable resistor (see Table 3) between connections 2 and 3 of the pressure switches that follow:

- PS1101S
- PS2002S
- PS4341S.

The values of resistors that are related to the the different remote controls are given in Table 2.

Table 2: Resistor Values

Supplier	Resistor	Power
KONGSBERG Maritime	10 kOhm	0.6 W
NABTESCO	3.9 kOhm	0.6 W
SAM / Lyngsø	8.2 kOhm	0.6 W

4.4.1 Oil Mist Detector

1) To activate an alarm in the oil mist detection system, do steps a) to c):
   a) Remove a plug from the junction box, or start the Test Menu in the control unit.
   b) Connect the smoke test instrument (tool) to the test connection of a sensor.
   c) Simulate oil mist to activate an alarm in the safety system.

4.4.2 Speed Pick-ups and Crank Angle Sensor Unit (TDC/BDC)

WARNING

Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel. Obey the data given in 0210–1 Safety Precautions and Warnings.

1) Do a check of the pick-ups for speed measurement and crank angle sensor unit as follows:
   a) Engage the turning gear.
   b) Use the turning gear to turn the crankshaft.
   c) Make sure that all LED on the speed pick-ups and the crank angle sensor unit come on and go off when the crank angle mark and a flywheel tooth move across the proximity sensor face.
   d) Disengage the turning gear.

4.4.3 Level Switches

1) Do a check of the level switch in the condensate collectors as follows:
   a) Manually operate the float switch to activate a high-level alarm.
2) Do a check of the level switch in the leakage oil return as follows:
   b) Manually move the selector switch on the sensor to Min to activate a high-level alarm.

4.5 Auxiliary Blowers

CAUTION

Equipment Hazard: Without applicable lubrication, damage can occur to components. Before you operate the auxiliary blowers make sure that the main lubrication oil and the turbocharger lubricating oil supply are set to on. Do a check of the necessary lubrication oil pressure, refer to 0250−1 Operating Data Sheet.

1) Set to on the electrical power supply for each auxiliary blower.
2) On the LDU−20 MAIN page, select the button CTRL. TR. to get control at the local control panel (see 4002−2 Local Control Panel / Local Display Unit, paragraph 3.4).
3) Select the button START AUX. Make sure that:
    a) Auxiliary blower 1 starts immediately.
    b) Auxiliary blower 2 starts after an interval of between 3 seconds to 6 seconds.
4) Make sure that the two auxiliary blowers turn in the correct direction.
5) Do step 3 again from the LDU-20 in the ECR.
6) Connect the pressure calibration hand-pump (tool 94050) to the pressure transmitters PT4043C and PT4044C. This will simulate a scavenge air pressure (0 bar to 6.0 bar).
7) On the MCM−11 (PT4043C), disconnect the cable from X41 terminal 1
8) On the IOM−10 (PT4044C) disconnect the cable from X13 terminal 2.
9) Connect an ampere meter between the connection and the related cable.
10) Make sure that the transmitter output (4 mA to 20 mA) is related to the simulated pressure (0 bar to 6.0 bar). If necessary replace the transmitter(s).
11) On the MCM−11 (PT4043C), connect the cable to X41 terminal 1.
12) On the IOM−10 (PT4044C), connect the cable to X13 terminal 2.

Note: The auxiliary blower start/stop hysteresis (0.8 bar to 1.0 bar) is adjusted in the ECS.

13) Disconnect the pressure calibration hand-pump (tool 94050).

4.5.1 Test of Auxiliary Blowers from LDU−20 ECR

1) On the MCM-11, disconnect terminal X33.
2) Start the auxiliary blowers.

Note: Command and feedback of auxiliary blowers must continue to operate.

3) If the auxiliary blowers do not operate, do a check of the wiring to the starter box.
4) On the MCM-11, connect terminal X33.
5) On the IOM-10, disconnect terminal X11.
6) Start the auxiliary blowers.

Note: Command and feedback of auxiliary blowers must continue to operate.

7) If the auxiliary blowers do not operate, do a check of the wiring to the starter box.
8) On the IOM-10, connect terminal X11.

4.5.2 Test of Auxiliary Blower from LDU20 Local

1) On the MCM-11, disconnect terminal X33.
2) Start the auxiliary blowers.

Note: Command and feedback of auxiliary blowers must continue to operate.

3) If the auxiliary blowers do not operate, do a check of the wiring to the starter box.
4) On the MCM-11, connect terminal X33.
5) On the IOM-10, disconnect terminal X11.
6) Start the auxiliary blowers.

Note: Command and feedback of auxiliary blowers must continue to operate.

7) If the auxiliary blowers do not operate, do a check of the wiring to the starter box.
8) On the IOM-10, connect terminal X11.

4.6 Servo Oil System

1) Start the main bearing oil pump and make sure that the operating pressure is correctly adjusted.
2) Start the servo oil service pump 20−8445_E0_1.
3) Adjust the pressure in the servo oil rail 20-5610_E0_6 to between 90 bar and 100 bar. The LDU−20 shows the related value.

4.7 Exhaust Valve Drive

1) In the LDU−20, get the EXHAUST VALVES page, (see 4002−2, paragraph 3.8 Exhaust valve).
2) In the Exh. valve pos. Column, use the rotary button to set the Cylinder 1 value to 1. This will manually open the exhaust valve 50-2751_CX_1 of cylinder No. 1
3) When the exhaust valve opens, record the value shown in the Open/close deadtimes column.

Note: You must record this value immediately after the exhaust valve opens, because the valve automatically closes slowly.

4) Close the exhaust valve 50-2751_CX_1 of cylinder No. 1.
5) When the exhaust valve closes, record the value shown in the Open/close deadtimes column.
6) Do steps 1) to 5) above for each exhaust valve.

Note: The values shown must be approximately the same for all cylinders. If the values are not the same, the exhaust valve is not fully open, or the sensors are defective.

7) In the LDU−20, Exh. valve pos. column, use the rotary button to set the value to 0 for each exhaust valve.

4.8 Cylinder Lubrication

1) Release the air in all cylinder lubrication pumps 25-7206_C1_1 to 25-7206_C#_1 (see the Maintenance Manual, 7218−1).
2) Release the air in the pipes to the lubricating quills (see the Maintenance Manual, 7218−1).
3) In the LDU−20 get the CYL. LUBRICATION page (see 4002−2, paragraph 3.9 Cylinder lubrication).
4) In the Manual lub. to Cyl. # field, use the rotary button to enter the applicable cylinder number.

Note: You can change the number of lube pulses (range 0 to 200 lube pulses) in the # of Manual Lub. Pulses field.

5) In the Feed Rate column, set the parameter for the feed rate, e.g. 1.2 g/kWh, for running-in (see 7218−1 Cylinder Lubrication and 0410−1 Running-in New Cylinder Liners and Piston Rings).

Note: You change the parameter in the Feed Rate column to get different feed rates in the related cylinders.

4.9 Fuel System

1) Set to on the fuel booster pump 910-D015.
2) Make sure that the pressure retaining valve 10-8704_E0_2 is set to give a return pressure of 3.0 bar to 5.0 bar.

The inlet pressure and outlet pressure of the pressure retaining valve is shown on the pressure gages PI3421L and PI3431L (for the setting values, see the Operating Data Sheet 0250−1).

3) Push all the EMERGENCY STOP buttons to activate a shut-down signal.

The pressure control valve 10-5560_E0_1 must open immediately, and the pressure in the fuel rail 10-5562_E0_3 must decrease to approximately 4.0 bar. This pressure decrease is shown on the LDU−20.

4) Set the EMERGENCY STOP buttons so the system can operate again.

4.10 Starting System and Start Interlock

4.10.1 Start Interlock

1) Make sure that the shut-off valve for starting air 30-4325_E0_1 is closed and pressure is released in the starting air supply pipes.
2) Do the check that follows when you engage and disengage the turning gear:
   a) Make sure that while the clearance between the flywheel tooth and the turning gear pinion is not more than 10 mm, no air comes out of the pipe.
3) Engage the turning gear.
4) At E6, loosen the pipe connection to the valve unit **E**. Make sure that no air comes out of the pipe.
5) Slowly disengage the turning gear.
6) At E6, tighten the pipe connection.

4.10.2 Starting Air Shut-off Valve

1) On the valve unit **E**, remove the check valve 35-115HA. Make sure that the three O-rings do not fall out of the valve.
2) In the LDU−20, get the CONTROL LOC. Page, then select the button CTRL. TR. to get control.
3) In the LDU−20, get the USER PARAMETERS page, then select the button AIR RUN (see 4002−2, paragraph 3.10 User parameters) and make sure that:
   - The solenoid valves ZV7013C and ZV7014C are energized (use a screwdriver or a magnet tester).
   - In the valve unit **E**, control air comes out at each outer bore at the check valve position.
4) Make sure that:
   - The shut-off valve 30-4325_E0_1 is manually closed.
   - No shut-down signals are released.
   - The turning gear is disengaged.
5) In the LDU−20, get the MAIN page.
6) Select the button ON/OFF to set the auxiliary blowers to off.
7) In the LDU−20 MAIN page, select the button START AHD. Make sure that Auxiliary Blowers Stopped is shown. No start command is released.
8) Select the button START AST and do steps 3 to 7 again.
9) Select the button ON/OFF to set the auxiliary blowers to on then:
   a) Select START AHD and do steps 3 to 7 again.
   b) Select START AST. and do steps 3 to 7 again.

The auxiliary blowers start and in the valve unit **E**, control air comes out of each outer bore at the check valve position.

10) Make sure that the O-rings are in position in the check valve 35-115HA.
11) Install the check valve 35-115HA in the valve unit **E**.

4.10.3 Turning Gear Interlocks

1) Make sure that the turning gear is engaged.
2) Make sure that the pressure transmitter PT5017C and the switch ZS5016C do not operate (open contacts).

Note: The pressure transmitter PT5017C operates at 2.0 bar.

3) Make sure that the indication Turning Gear Engaged shows on each LDU−20 (at the control room console and local maneuvering stand).
4) Make sure that the engine is ready for operation as follows:
    a) Make sure that the starting air shut-off valve 30-4325_E0_1 is in the CLOSED position.
    b) Make sure that there is no air in the starting air supply pipe.
5) On the LDU-20, select the button CTRL. TR. to get control.
6) Select the button START AHD.
7) Make sure that the indication Turning Gear Engaged is shown on each LDU-20. No start command is released.
8) Also, do steps 1) to 7) from the LDU-20 on the ECR manual control panel, and with the remote control.
9) Disengage the turning gear.

Note: On each LDU-20, the indication changes to Turning Gear Disengaged. The start command is canceled in the remote control.

4.11 Overspeed Limit

The overspeed monitor is included in the safety system.

4.12 Engine Start on Fuel

The engine is ready for operation (see 0110−1, paragraph 2 Prepare for operation).

1) In the LDU−20, get the USER PARAMETERS page, then select the button AIR RUN to turn the engine with air.
2) In the LDU−20, get the MAIN page.
3) Use the rotary button to select the Fuel Command button.
4) Use the rotary button to set the fuel injection quantity to approximately 15%.
5) Select the button START AHD to start the engine.
6) Use the rotary button to control the speed and fuel injection quantity. Operate the engine until all cylinders fire regularly.
7) Select the button STOP. The engine stops.
8) Select the button CTRL. TR. for mode transfer to the remote control.
9) Make sure that the control transfer and the operation from the ECR remote control and the bridge operates correctly.
10) After mode transfer, you can start the engine from the remote control.

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Control Diagram

1. General

The identification of parts include those given in: 4003–1, 4003–2, 4003–3, 4003–4, 4003–5, 4003–6, 4003–7, 4003–8, 4003–9, 4003–10 and 4003–11.

2. Area Codes in the Control Diagram

The area codes in the control diagram are shown in Table 1.

Table 1: Area Codes

A – Control air supply unit
B – Servo oil supply
D – Servo oil supply
E – Valve unit for start
K – Local control panel

3. System Codes

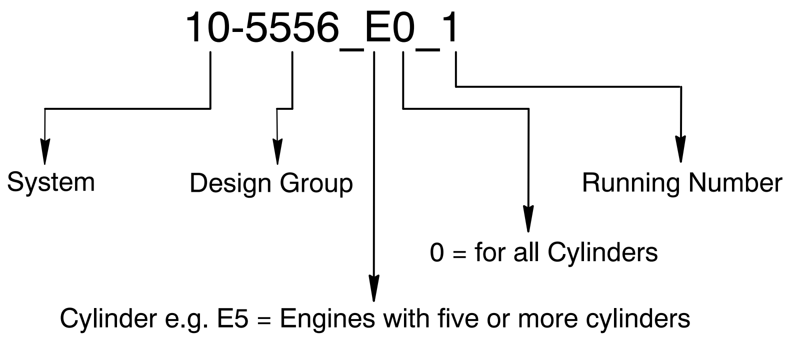
The system codes are shown in Table 2.

Table 2: System Codes

Code 10	–	Fuel System
Code 20	–	Oil System
Code 25	–	Cylinder Lubrication System
Code 30	–	Starting Air System
Code 35	–	Control Air System
Code 40	–	HT Cooling Water System
Code 48	–	Cylinder Cooling Water System CCO
Code 50	–	Exhaust Gas System
Code 70	–	Miscellaneous Systems
Code 80	–	Automation System
Code 99	–	Pipe Diagram
Code 900	–	Engine Room

4. Process Codes – Description

The process codes and their descriptions are shown in Fig. 1 and Table 3.



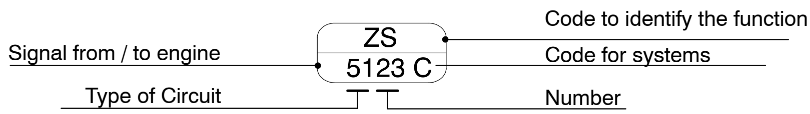


Fig. 1: Process Codes – Identification

Table 3: Process Codes – Descriptions

Process Code	Description
10–2710_CX_Y	Fuel injection valve (L'Orange)
10–5556_E0_1	Fuel pump 1
10–5556_E0_2	Fuel pump 2
10–5556_E0_3	Fuel pump 3
10–5562_E0_1	Single wall fuel rail
10–5562_E0_5	Pressure control valve
10–5562_C#_2	Flow limiter valve cyl. 1
10–5562_E0_2	Non return valve
10–5562_E0_3	Non return valve
10–5562_E0_4	Non return valve
10–8704_E0_2	Adjustable pressure retaining valve
20–5551_E0_1	Servo oil pump 1
20–5551_E0_2	Servo oil pump 2
20–5610_E0_6	Single wall servo oil rail
20–5612_CX_1	Valve control unit
20–5612_CX_2	4/2-way valve
20–5612_CX_3	Filter VCU
20–8423_E0_1	Injector oil supply valve
20–8423_E0_2	Ball valve
20–8423_E0_8	Filter, fuel pump 1
20–8423_E0_9	Filter, fuel pump 2

Process Code	Description
20−8445_E01	Servo oil service pump
20−8445_E0_2	Pressure safety vale
20−8445_E0_3	Pressure retaining vale
20−5610_E0_1	Non-return valve
20−5610_E0_2	Non-return valve
20−5610_E0_3	2-way shut-off valve
20−5610_E0_4	Pressure safety valve
20−5614_E0_1	Pressure reducing valve
20−5614_E0_4	Cylinder lubrication mini−rail
20−5614_E0_6	Pressure safety valve
20−8406_E0_5	Ball valve
20−8430_E0_1	Solenoid valve
20−8430_E0_2	Ball valve
20−8445_E0_1	Servo oil service pump
25−8475_E0_6	Filter
25−8475_E0_7	Filter
25−8472_E0_3	Ball valve
25−8475_E0_1	Ball valve
25−8475_E0_2	3/3-way valve
25−8475_E0_5	Ball valve
30−2728_CX_1	3/2-way valve
30−4325_E0_1	Shut-off valve, starting air
30−8605_E0_6	Ball valve
30−8605_E0_7	Ball valve
30−8650_E0_1	Pressure safety valve
30−8605_CX_1	Flame arrester
35−287HA	Control air bottle
35−351HA	Air filter
35−4606_E0_3	Bottle
35−8606_E0_3	Collector (leakage oil from air spring)
35−115HA	Double check valve
35−19HA	Pressure reducing valve
35−23HA	Pressure reducing valve
35−274HA	Pressure safety valve
35−274HD	Pressure safety valve
35−2751_CX_1	Non-return valve
35−2751_CX_2	Restrictor
35−31HA	3/2-way valve

Process Code	Description
35–36HA	3/2-way valve
35–36HB	3/2-way valve
35–36HC	3/2-way valve
35–4325_E0_2	3/2-way valve
35–4325_E0_3	3/2-way valve
35–4325_E0_5	2/2-way valve
35–4605_E0_6	2-way shut-off valve
35–4605_E0_8	2-way shut-off valve
35–4605_E0_9	Restrictor
35–4606_E0_2	2-way shut-off valve
35–4606_E0_4	Needle valve
35–8353_E0_2	Ball valve
35–8606_E0_4	Ball valve
50–2751_CX_1	Exhaust valve
50–8135_E0_1	2/2-way valve
50–8135_E0_2	3/2-way valve
910–D015	Fuel booster pump
910–V113	2-way shut-off valve
910–V121	2-way shut-off valve
925– B001	Cylinder lube oil tank
990 07	SAC-LT-cooling water inlet
990 08	SAC-LT-cooling water outlet
990 25	Main lubricating oil inlet
990 33	Cylinder lub oil inlet
990 34	Leakage oil driving end outlet
990 35	Leakage oil free end outlet
990 45	Control air supply inlet
990 49	Fuel inlet
990 50	Fuel return outlet
990 51	Fuel leakage rail unit outlet
990 52	Fuel leakage outlet
990 57	Various leakage outlet

5. Sensors and Transmitters

The sensors, transmitters and their descriptions are shown in Table 4.

Table 4: Sensors and Transmitters – Descriptions

	Sensors – Control and Safety		Sensors – Alarm
PS1101S	Cylinder cooling water inlet	PS3121A	Cyl. lube oil filter diff. pres.
PS1101S	Main bearing oil supply	PS5017C	Pressure switch, valve unit for start
PS2611S	Turbocharger bearing oil inlet		
PS4341S	Air spring air pressure	PT1101A	Cylinder cooling water inlet press.
PS5017C	Turning gear disengaged	PT1361A	Scavenge air cool. press. water inl. cooler
		PT2001A	Main bearing oil inlet press.
		PT2611A	Turbocharger bearing oil inlet
		PT2711A	Geislinger damper oil inlet
		PT2721A	Axial detuner oil aft side
		PT2722A	Axial detuner oil fore side
		PT2021A	Crosshead lubrication
		PT2021C	Crosshead lubrication
PT1101C	Cylinder cooling water inlet press.	PT3151A	Cyl. lube oil press. downstream of supply unit
PT2001C	Main bearing oil inlet press.	PT3421A	Fuel pressure upstream of supply unit
PT2002C	Bearing oil pressure, inlet engine	PT4341A	Air spring air pressure
PT2003C	Bearing oil inlet press. Upstream of inj.	PT4341A	Air spring air pressure
PT2071–72C	Servo oil rail pressure	PT4401A	Control air normal pressure inlet
PT3131–38C	Cyl. lube oil Cyl. 1–8	PT4411A	Control air stand-by pressure inlet
PT3421C	Fuel pressure before supply unit	PT4421A	Control air pressure inlet
PT3461–62C	Fuel rail pressure		
PT4043–44C	Scavenge air pressure in air receiver	AE2401–08A	Oil mist concentration in crankcase
PT4301C	Starting air upstream of shut-off valve	AE2415A	Oil mist concentration in gear box
PT4341C	Air spring air pressure		
PT4421C	Control air pressure inlet	FS2061–62A	Servo oil pump 1–2 (flow)
AS2401S	Oil mist concentration in crankcase	LS2055A	Servo oil supply unit, leak
		LS3444A	Rail unit general leak
FS2521–28S	Piston cooling oil flow	LS3446A	Fuel pipe leak
		LS4071A	Scav. air cond, water level water sep.
ST5101–04C	Engine speed	LS4075A	Scav. air cond, water level bef. water sep.
ST5111–12S	Too much engine speed	LS4351–52A	Air spring air leakage oil level
ST5131–32C	Crank angle pick–up 1–2 (A–B)		

	Sensors – Control and Safety		Sensors – Alarm
ST5133–34C ST5201C	Crank angle pick–up 3–4 (C–D) Turbocharger speed	TE1111A TE1121–28A TE1371A	Cylinder cooling water inlet Cylinder cooling water outlet each cyl. Scav. air cool. water inlet cooler
ZS5016C ZS5018C ZS5123C ZS5124C ZS5372C	Turning gear disengaged Start air shut-off valve man. closed Engine TDC signal Engine BDC signal Butterfly valve, exhaust waste gate	TE1381A TE2011A TE2101A TE2102–10A TE2501–08A	Scav. air cool. water outlet cooler Main bearing oil inlet Thrust bearing temp. outlet Main bearing temp. outlet Piston cooling oil outlet each cyl.
ZT5421–28C	Exhaust valve 1–8, open and close positions	TE2601A TE3101A TE3411A	Turbocharger bearing oil outlet Cyl lub temp inlet supply unit Fuel temp. upstream of supply unit
TE3701–08A	Exhaust gas downstream of each cylinder	TE3431 TE3721A–3A	Fuel temp. fuel pump outlet Exhaust gas temp. upstream of TC
TS4521S TS4522S	Thrust bearing temp. Front Thrust bearing temp. Rear	TE3731A TE4031A	Exhaust gas temp. downstream TC Scav. air temp. downstream of air cooler
TE4801–08C TE4841–48C	Cylinder liner wall temp. aft side Cylinder liner wall temp. fore side	TE4081–88A TE4521A	Scav. air temp. piston underside Thrust bearing oil temp. Front

6. Actuators and Valves

The actuators, valves and their descriptions are shown in Table 5.

Table 5: Actuators and Valves – Descriptions

	Actuators		Local Indications
CV2003C	Inj lub shut-off valve	PI1361L	Scav. air cool. press. water inl. cooler
		PI2611L	Turbocharger bearing oil inlet
		PI2711L	Geislinger damper oil inlet
CV7013C	Solenoid valve 1 (start valve unit)	PI2721L	Axial detuner oil – rear
CV7014C	Solenoid valve 2 (start valve unit)	PI2721L	Axial detuner oil –rear
CV7076C	Exh waste gate Ctrl Valve	PI2722L	Axial detuner oil – front
CV7131–38C	Cyl. lub. valve comm. 1 Cyl. 1–8	PI3421L	Fuel upstream of pressure retaining valve
CV7151–58C	Cyl. lub. valve comm. 2 Cyl. 1–8	PI3431L	Fuel downstream pressure retaining valve
CV7201–08C	Exhaust valve setpoint Cyl. 1–8	PI4001L	Scav. air press. upstream of air cooler
CV7201–08D	Injection command 1 Cyl. 1–8	PI4021L	Scav. air press. downstream of air cooler
CV7201–08E	Injection command 2 Cyl. 1–8	PI4401L	Control air normal pressure inlet
CV7221–22C	Servo oil pump actuator No. 1–2	PI4411L	Control air stand-by pressure inlet
CV7231–32C	Fuel pump setpoint 1–2		
CV7241–48C	Start air pilot valve Cyl. 1–8		
ZV7061S	EMERGENCY STOP	TI1121–28L	Cylinder cooling water outlet each cyl.
	(Fuel Shutdown pilot valve)	TI1371L	Scav. air cool. water inlet cooler
		TI1381L	Scav. air cool. water outlet cooler
		TI2011L	Main bearing oil inlet
		TI2601L	Turbocharger bearing oil outlet
		TI3431L	Fuel temp. upstream of supply unit
		TI3701–08L	Exhaust gas downstream of each cylinder

	Actuators		Local Indications
		TI3721L	Exhaust gas temp. upstream of TC
		TI3731L	Exhaust gas temp. downstream of TC
		TI4031L	Scav. air temp. downstream of air cooler
		TI4521L	Thrust bearing oil temp. – front
		SI5101M	Engine speed

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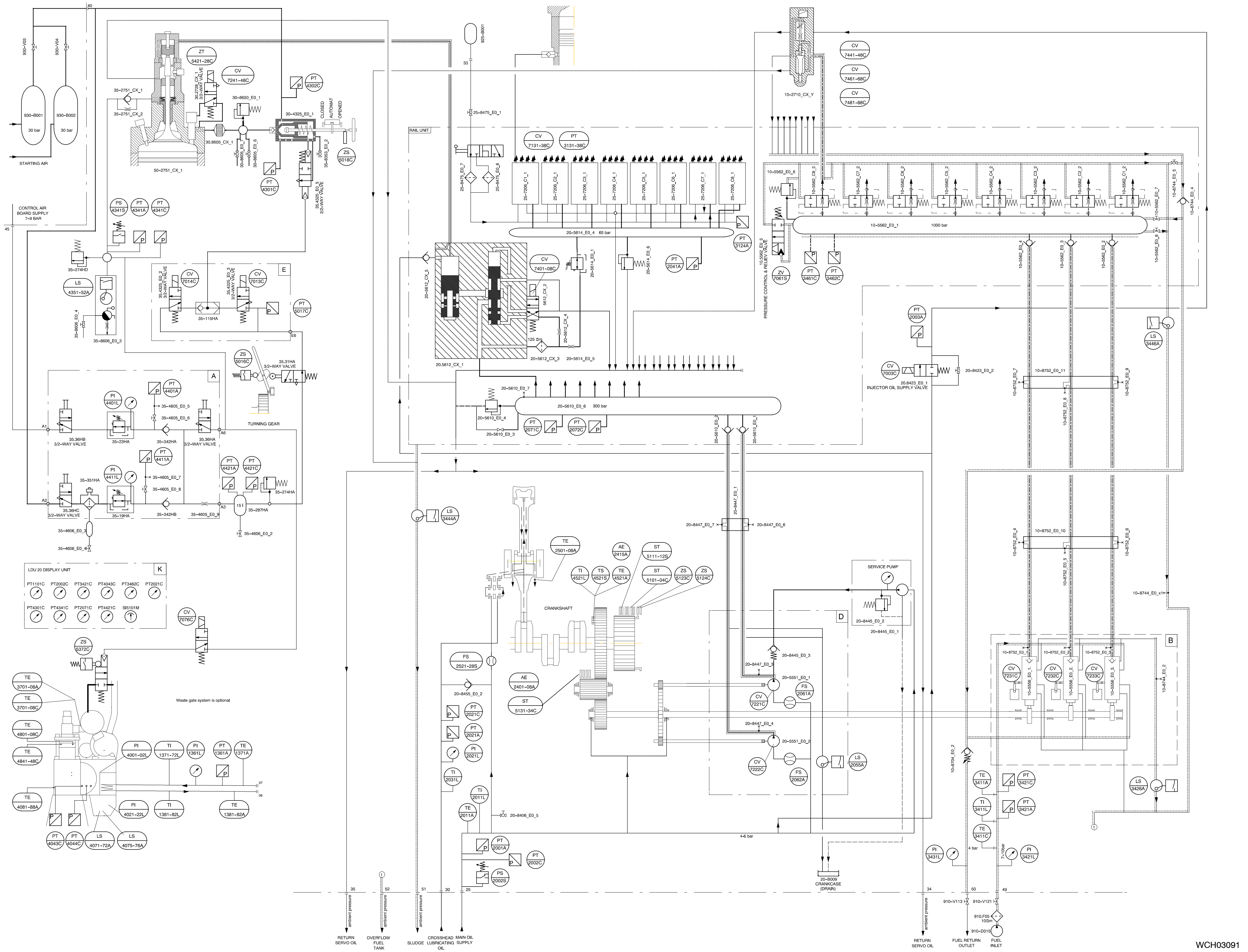
Control Diagram



A Control air supply unit

B Fuel supply

D Servo oil supply

E Valve unit for start

K Local control panel

Circuits:

- Starting air
- Control air
- Low pressure oil
- High pressure oil
- Low pressure fuel
- High pressure fuel
- Heating

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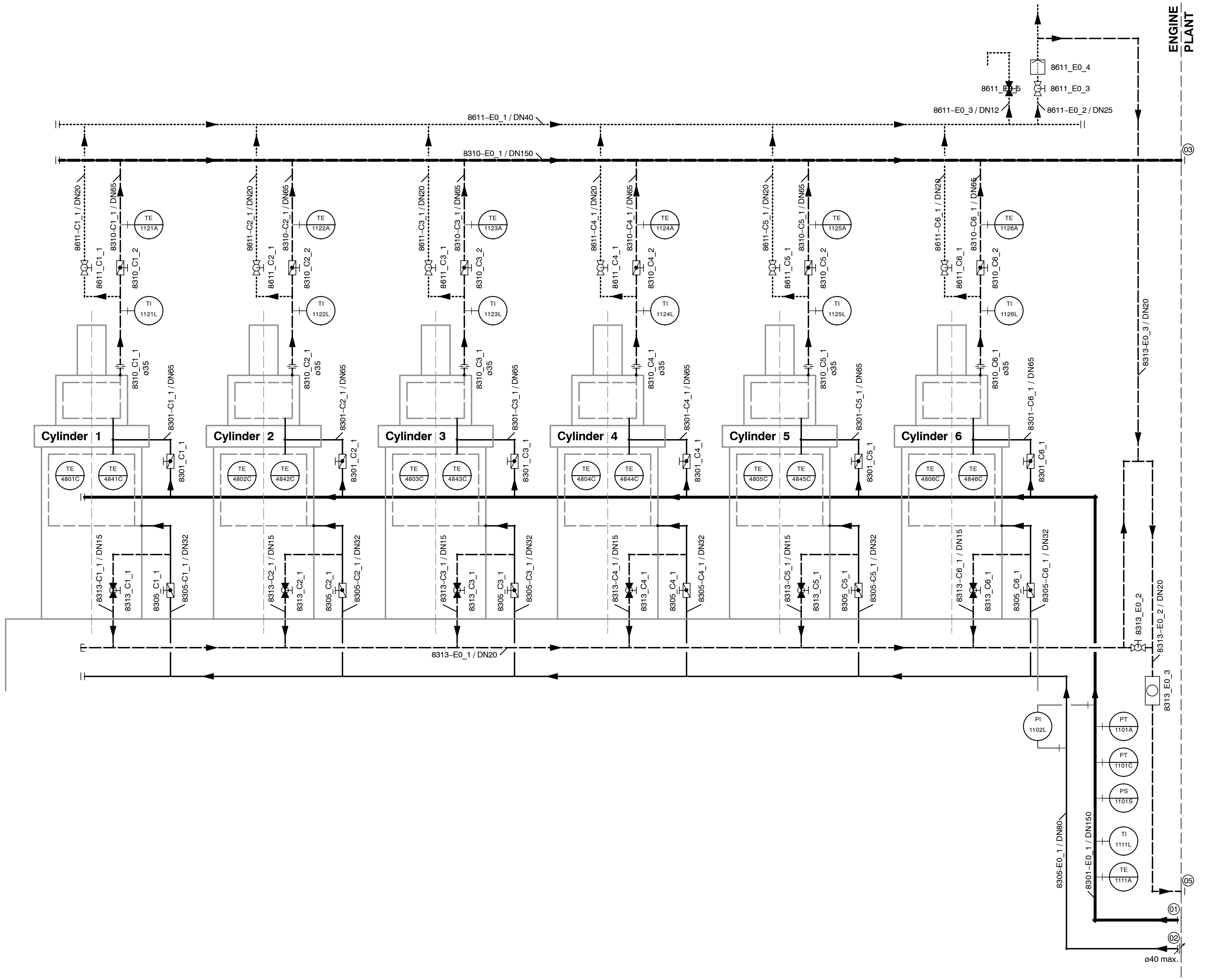
Pipe Diagram – Water Systems (Cylinder Cooling)



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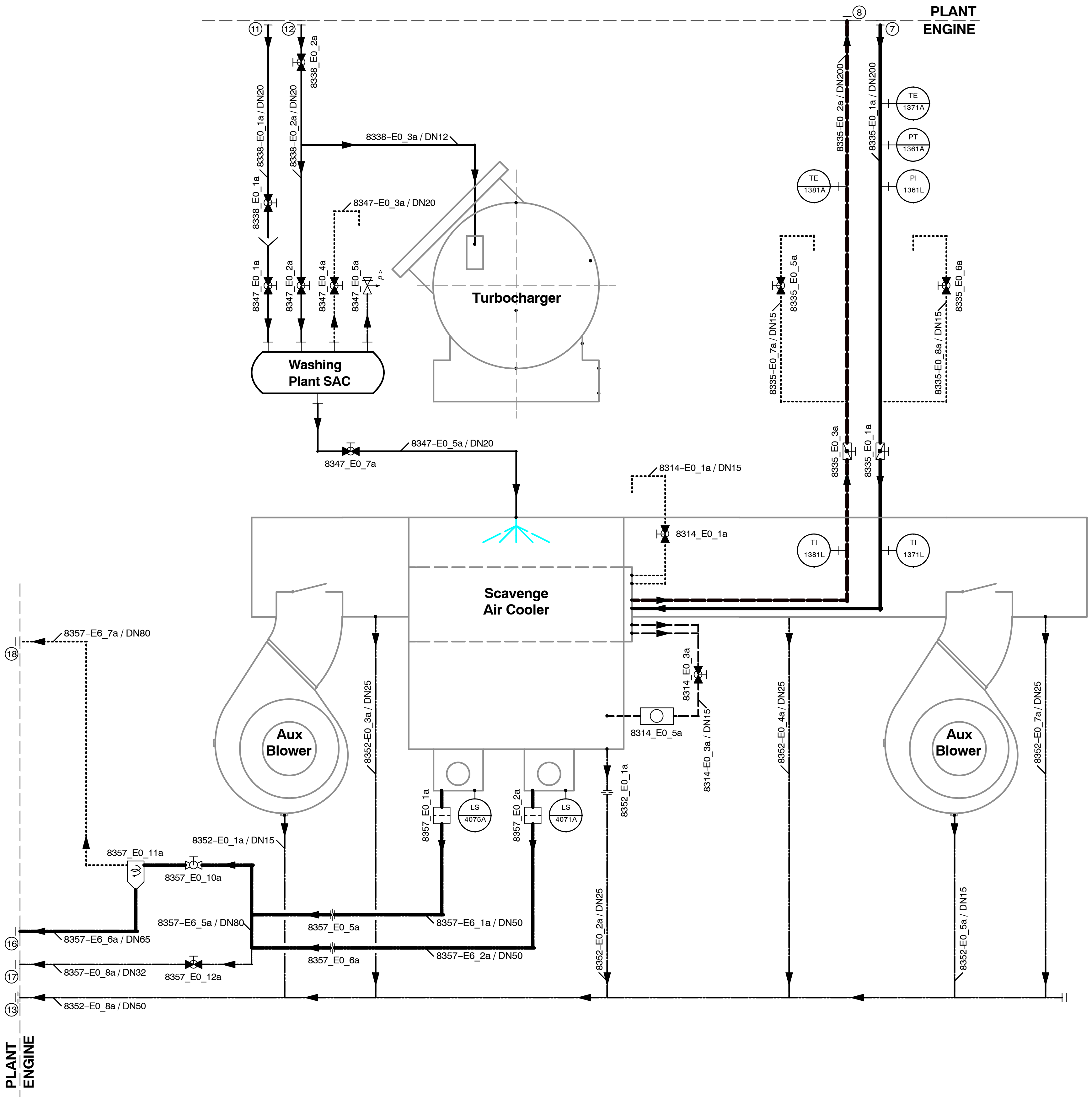
Pipe Diagram – Water Systems (Scavenge Air Receiver and Turbocharger)



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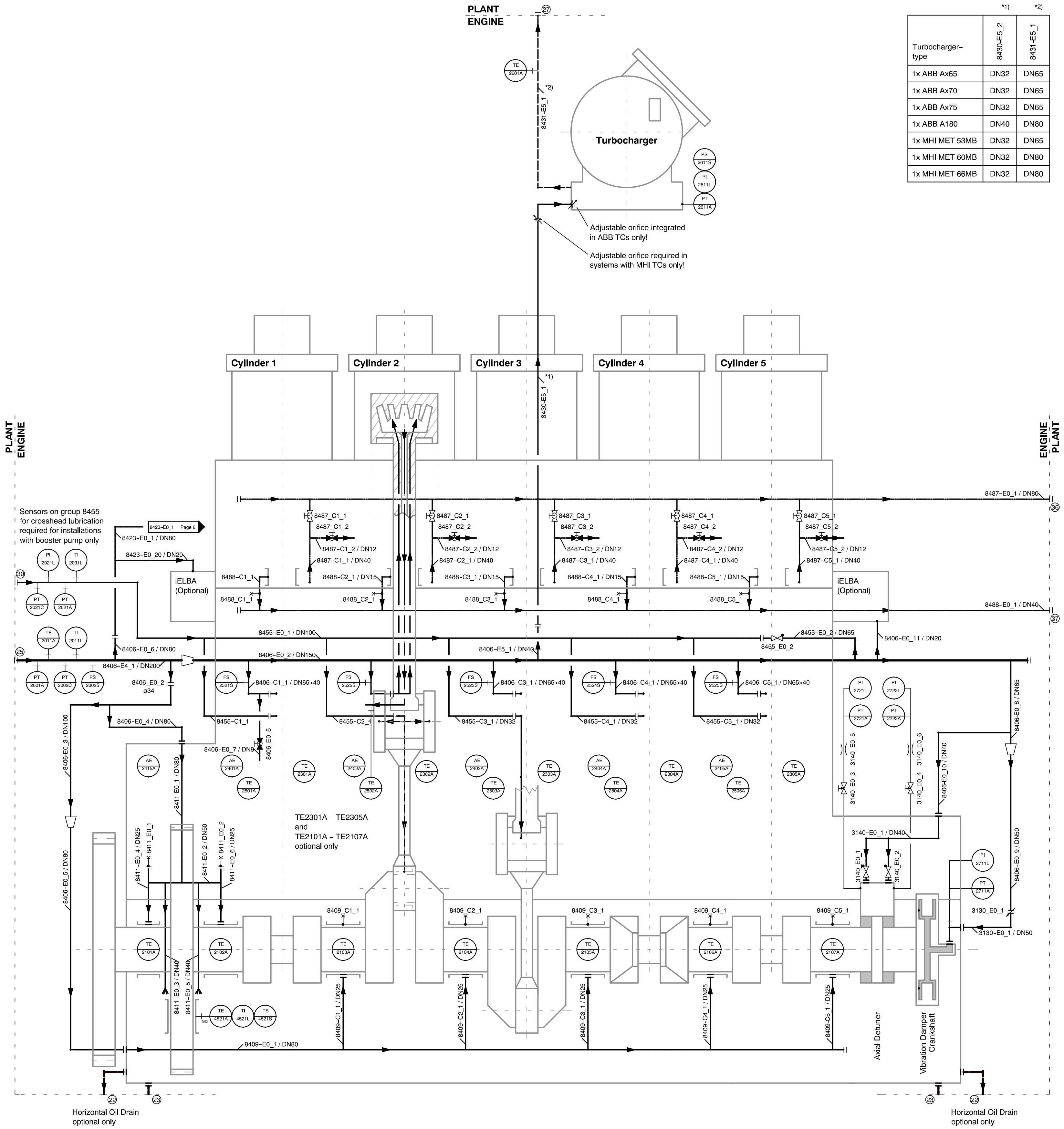
Pipe Diagram – Oil Systems (System Oil, Internal TC Oil Supply)



Turbocharger-type	8430-E5_2 *1)	8431-E5_1 *2)
1x ABB Ax65	DN32	DN65
1x ABB Ax70	DN32	DN65
1x ABB Ax75	DN32	DN65
1x ABB A180	DN40	DN80
1x MHI MET 53MB	DN32	DN65
1x MHI MET 60MB	DN32	DN80
1x MHI MET 66MB	DN32	DN80

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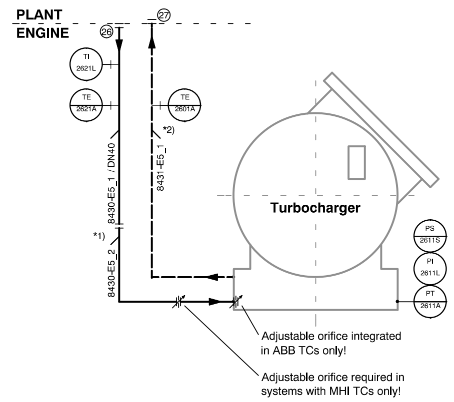
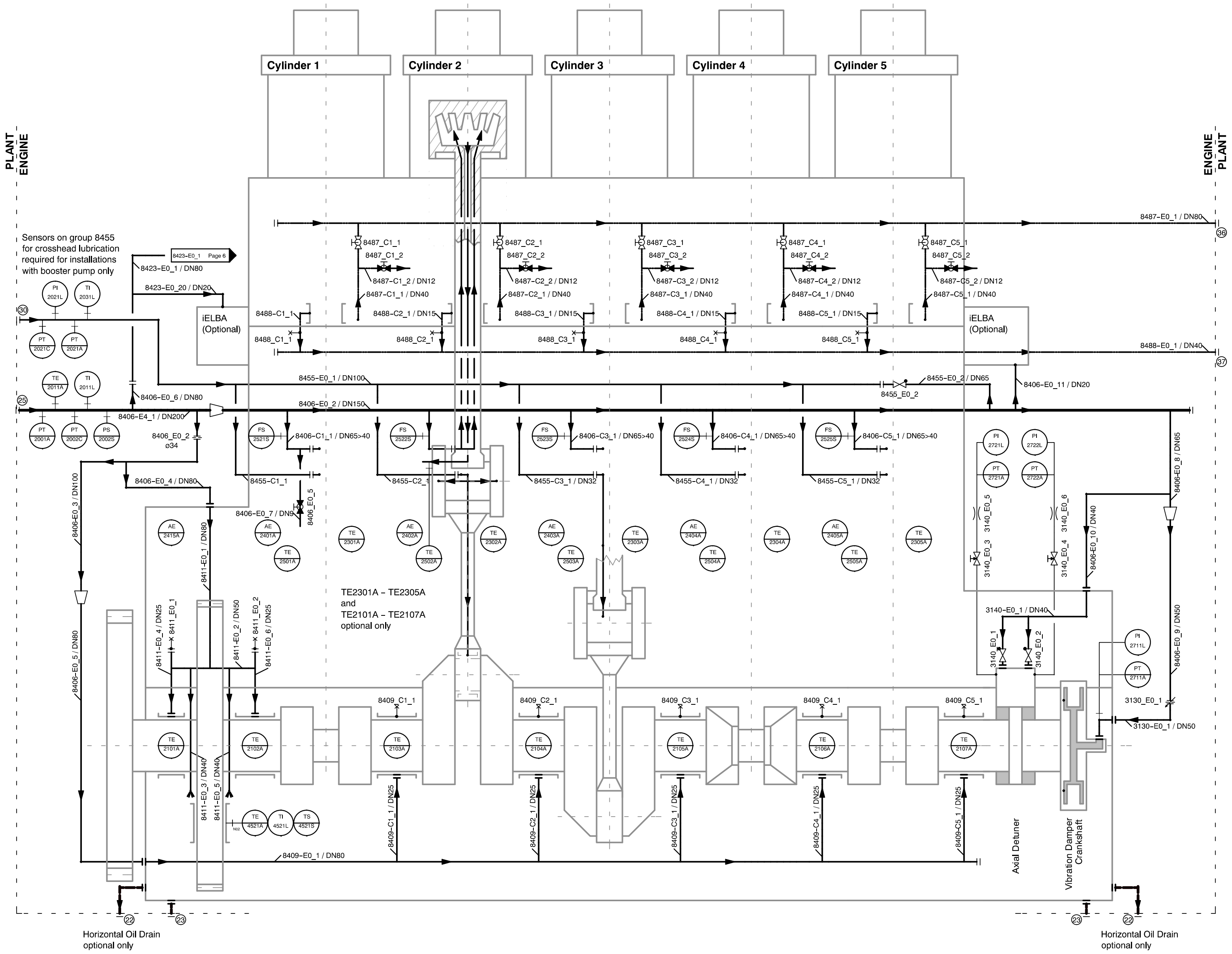
Pipe Diagram – Oil Systems (System Oil, External TC Oil Supply)



Turbocharger–type	8430–E5_2 *1)	8431–E5_1 *2)
1x ABB Ax65	DN32	DN65
1x ABB Ax70	DN32	DN65
1x ABB Ax75	DN32	DN65
1x ABB A180	DN40	DN80
1x MHI MET 53MB	DN32	DN65
1x MHI MET 60MB	DN32	DN80
1x MHI MET 66MB	DN32	DN80



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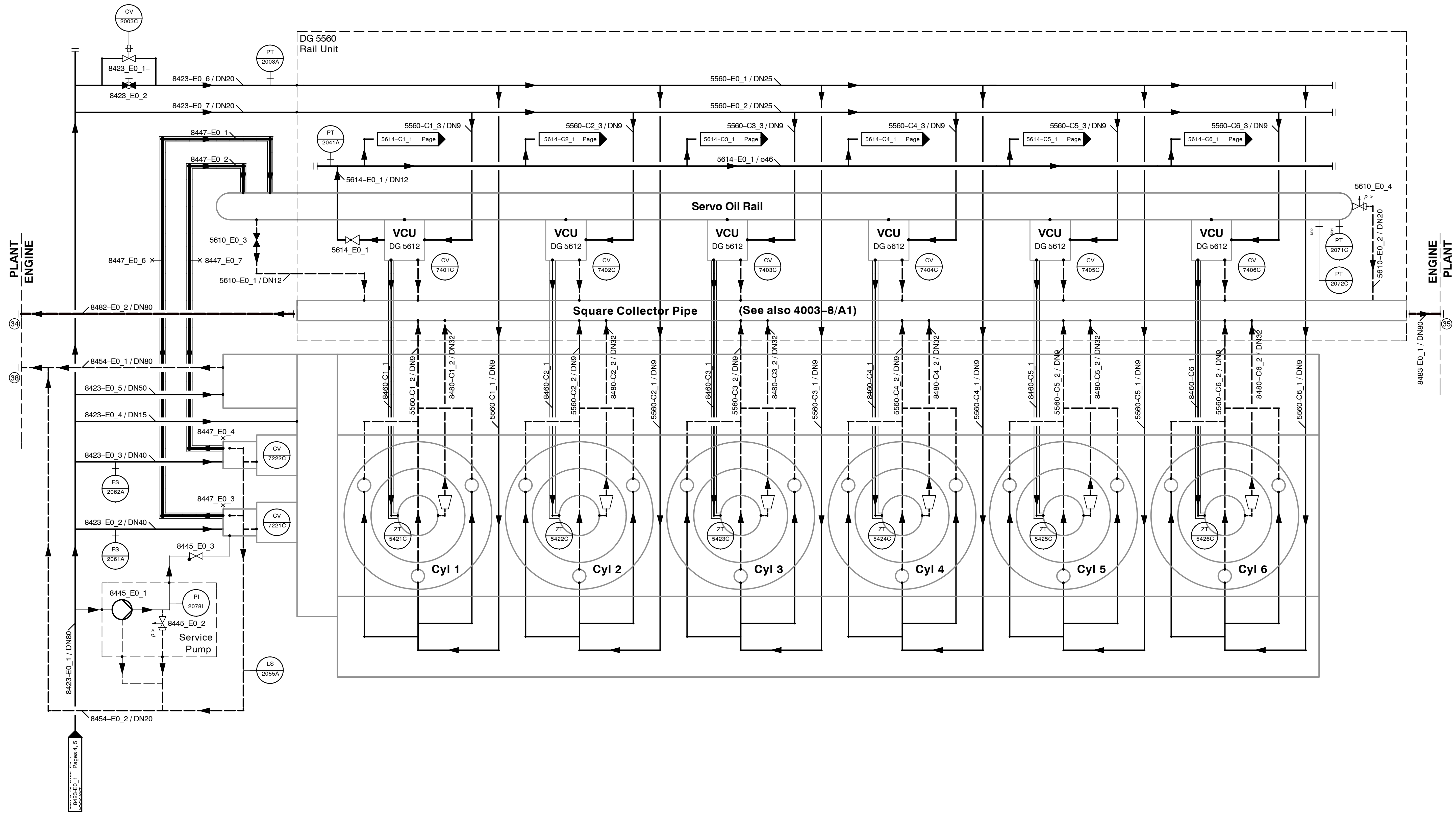
Pipe Diagram – Servo Oil



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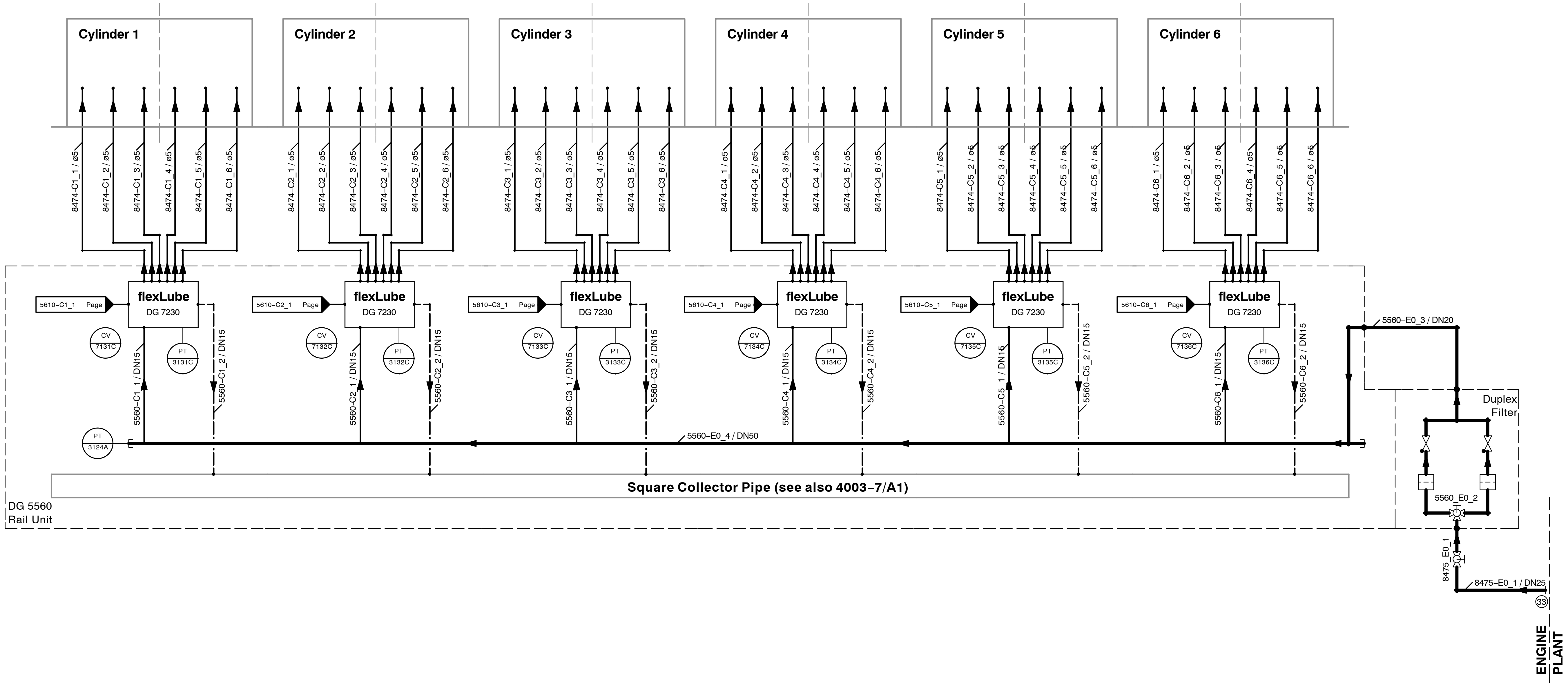
Pipe Diagram – Oil Systems (Cylinder Lubrication)



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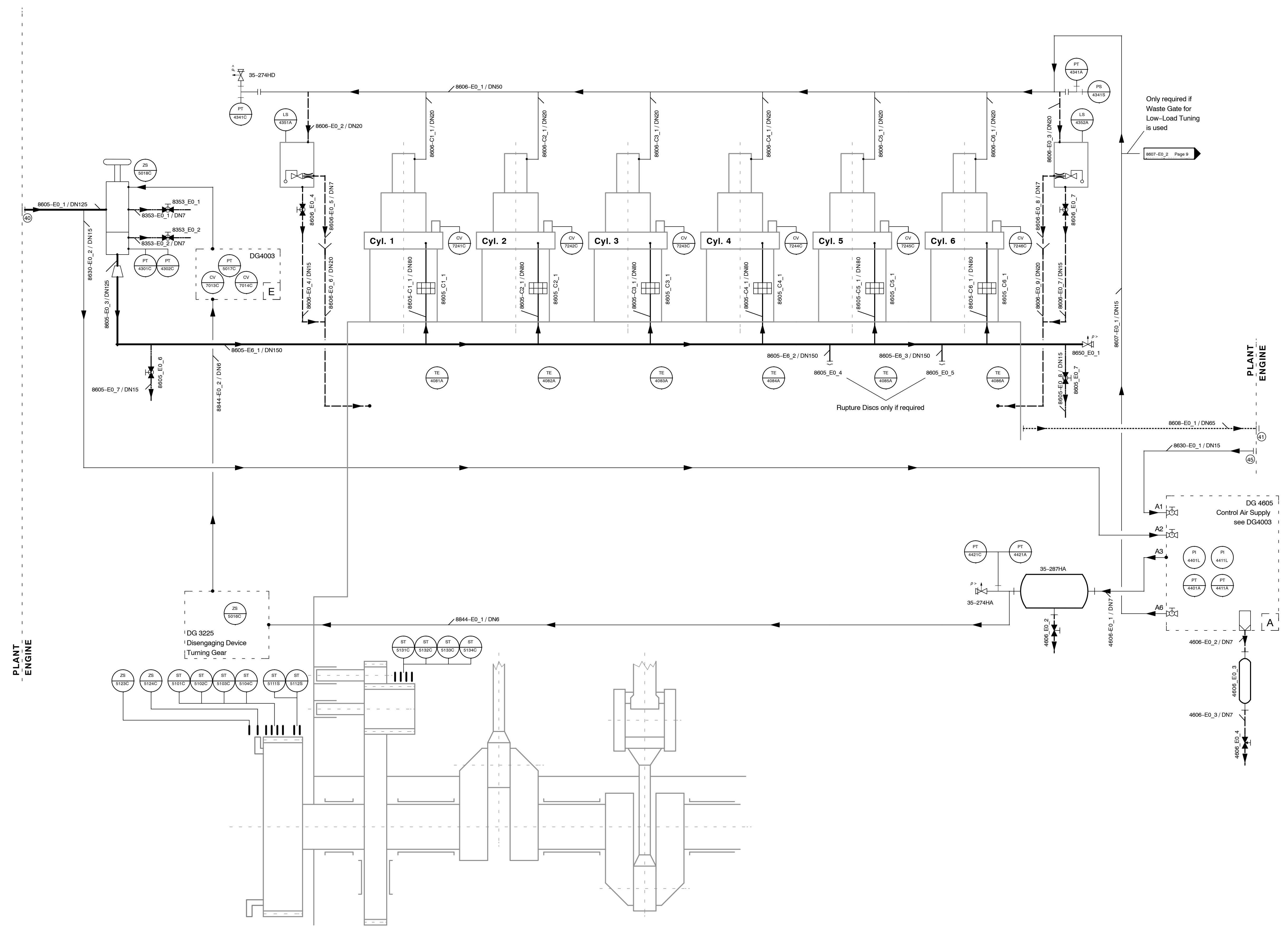
Pipe Diagram – Air Systems (Starting Air and Control Air)



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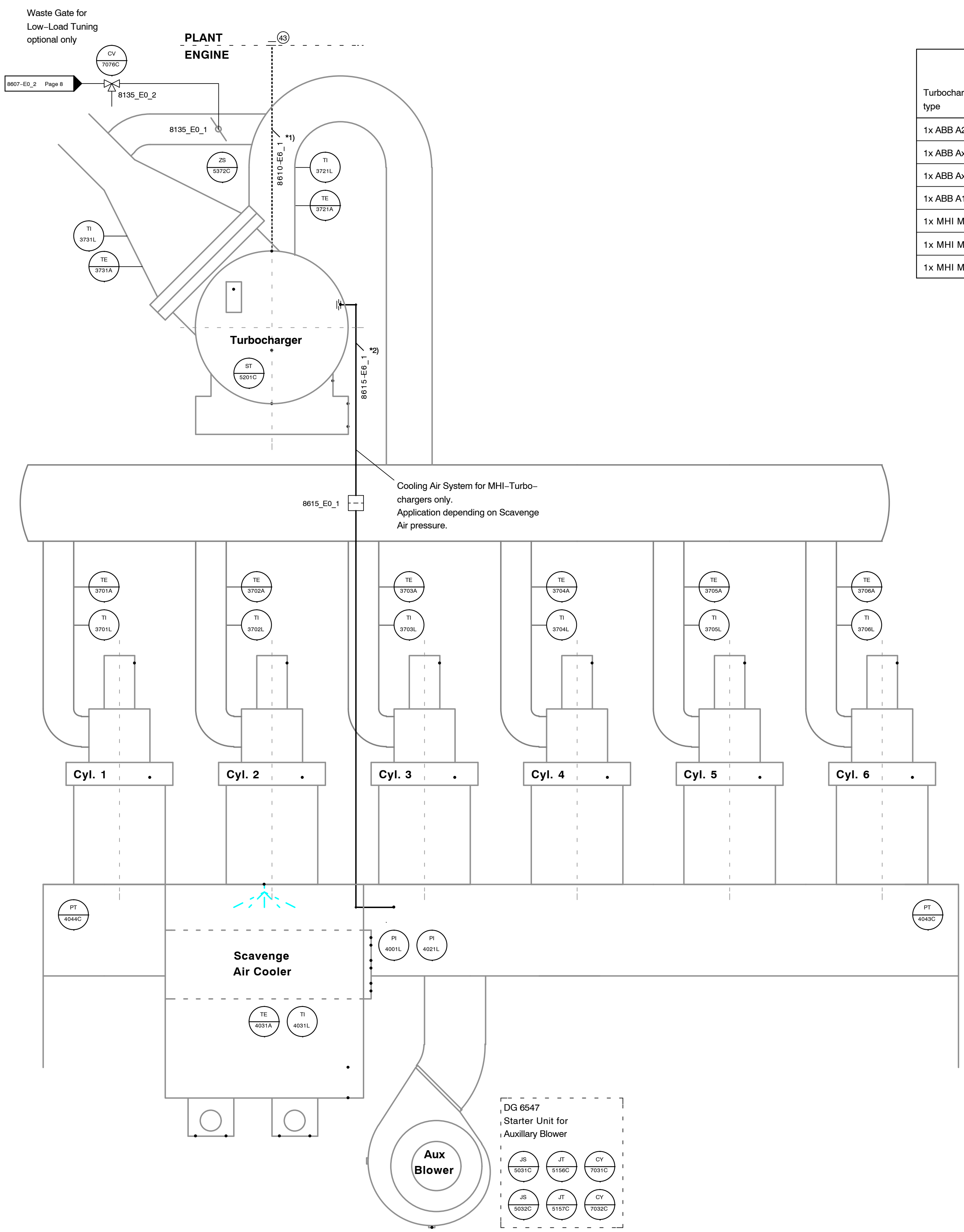
Pipe Diagram – Air Systems (Exhaust Gas and Scavenge Air)



Turbocharger–type	8610–E6_1 *1)	8615–E6_1 *2)
1x ABB A265	DN65	n.a.
1x ABB Ax70	DN65	n.a.
1x ABB Ax75	DN65	n.a.
1x ABB A180	DN80	n.a.
1x MHI MET 53MB	DN65	DN40
1x MHI MET 60MB	DN80	DN40
1x MHI MET 66MB	DN80	DN50

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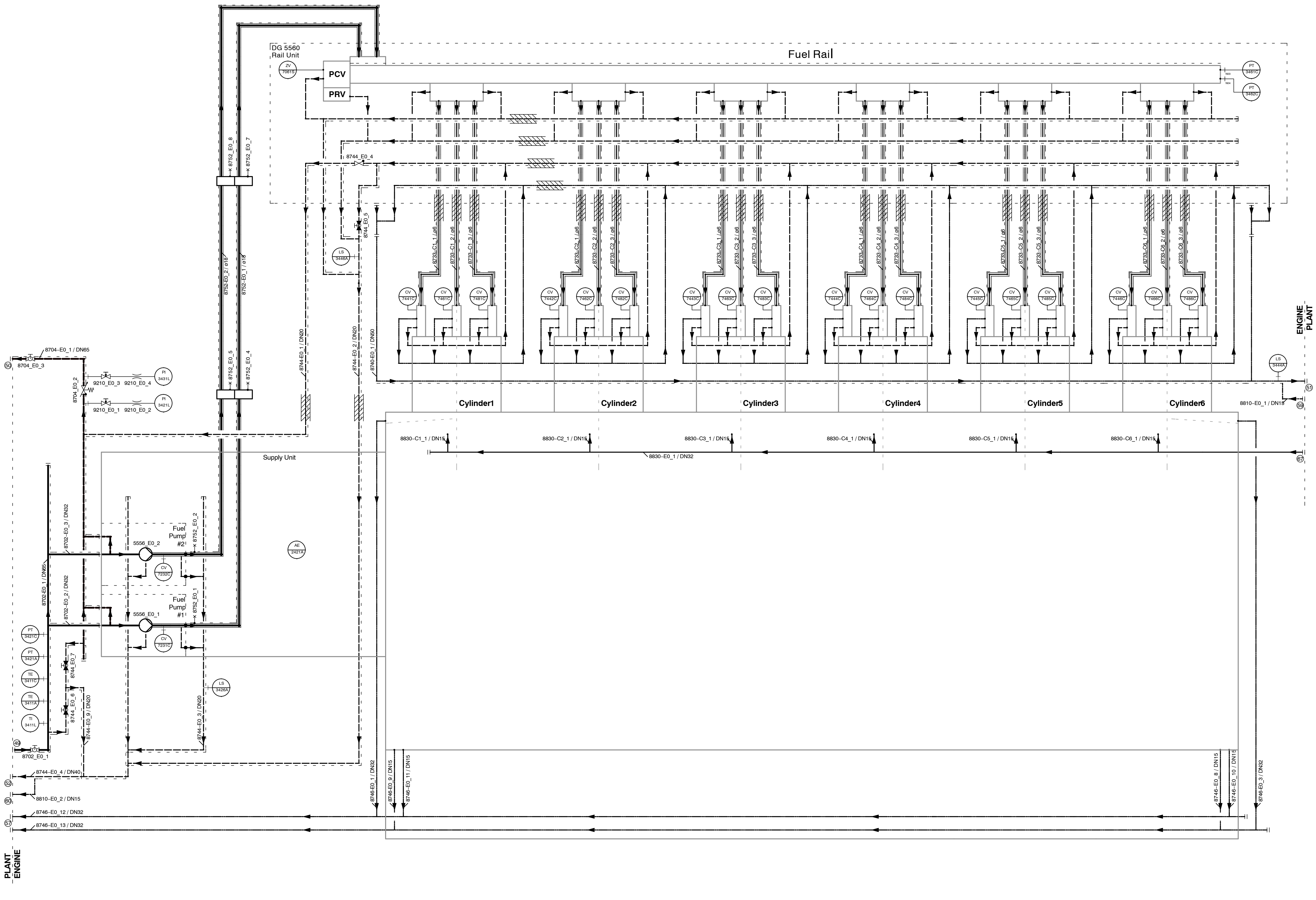
Pipe Diagram – Fuel, Drain and Extinguishing Systems



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Supply Unit Drive

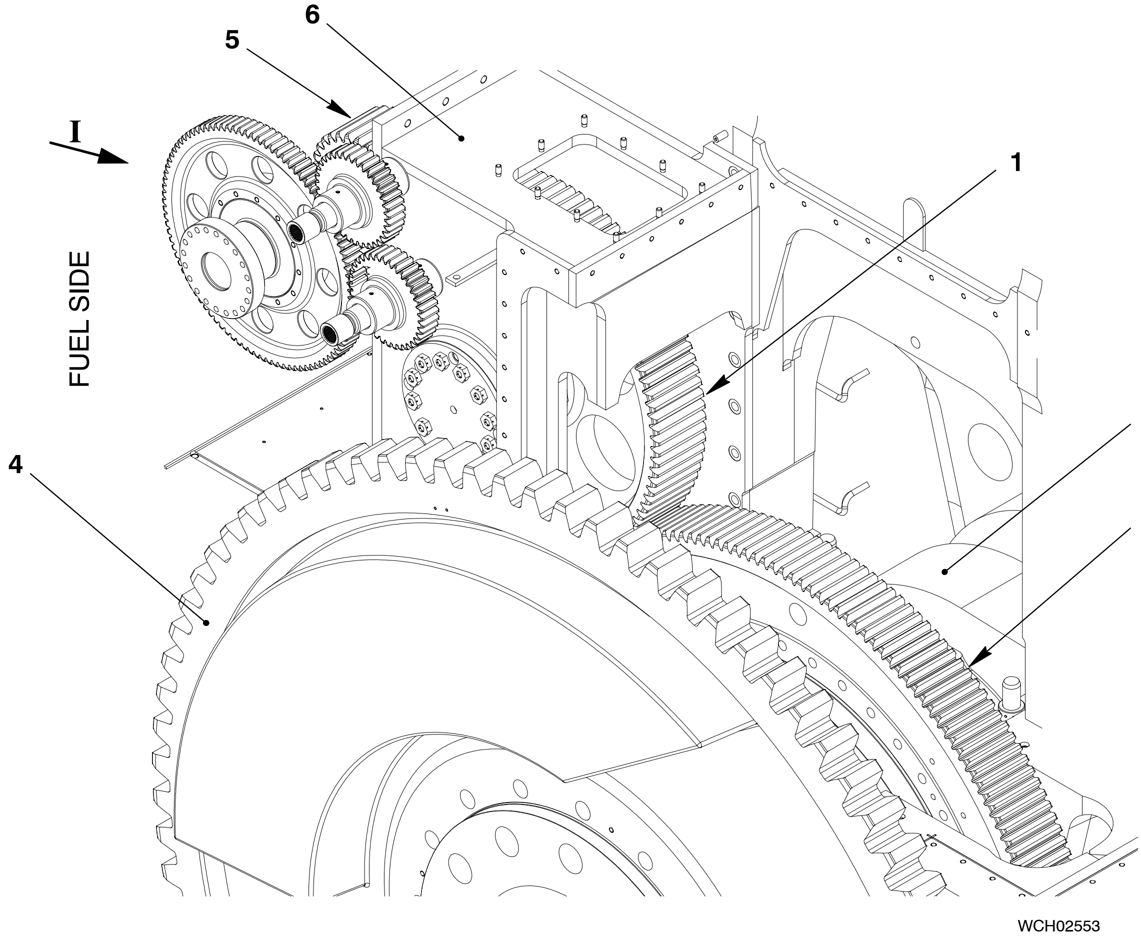
1. General

The supply unit drive is installed at the driving end of the engine on the fuel side.

The crankshaft gear wheel (3, Fig. 1) moves the intermediate wheel (1) and the intermediate wheel (5).

You must do regular checks of the tooth profile condition. Also, it is very important that you do frequent checks of new gear wheels after a short running-in period.

If you hear unusual noises from the area of the gear train, you must find the cause immediately.



For View I see Fig. 2

Fig. 1: View of Supply Unit Drive

1	Intermediate wheel (supply unit drive)	4	Flywheel
2	Crankshaft	5	Intermediate wheel (supply unit)
3	Crankshaft gear wheel	6	Bearing housing

2. Lubrication

The intermediate wheel (3, Fig. 2) operates the gear wheels (1) and (2) for the servo oil pumps. The camshaft of the intermediate wheel (4) also operates the fuel pumps.

The bearings of the gear wheels (1) and (2) are lubricated through an oil inlet. Oil flows through the nozzles (3) in the bearing housing to lubricate the teeth of the gear wheels (1), (2) and the intermediate wheel (4).

For more data, see 5552−1 Supply Unit and 8016−1 Lubricating Oil System.

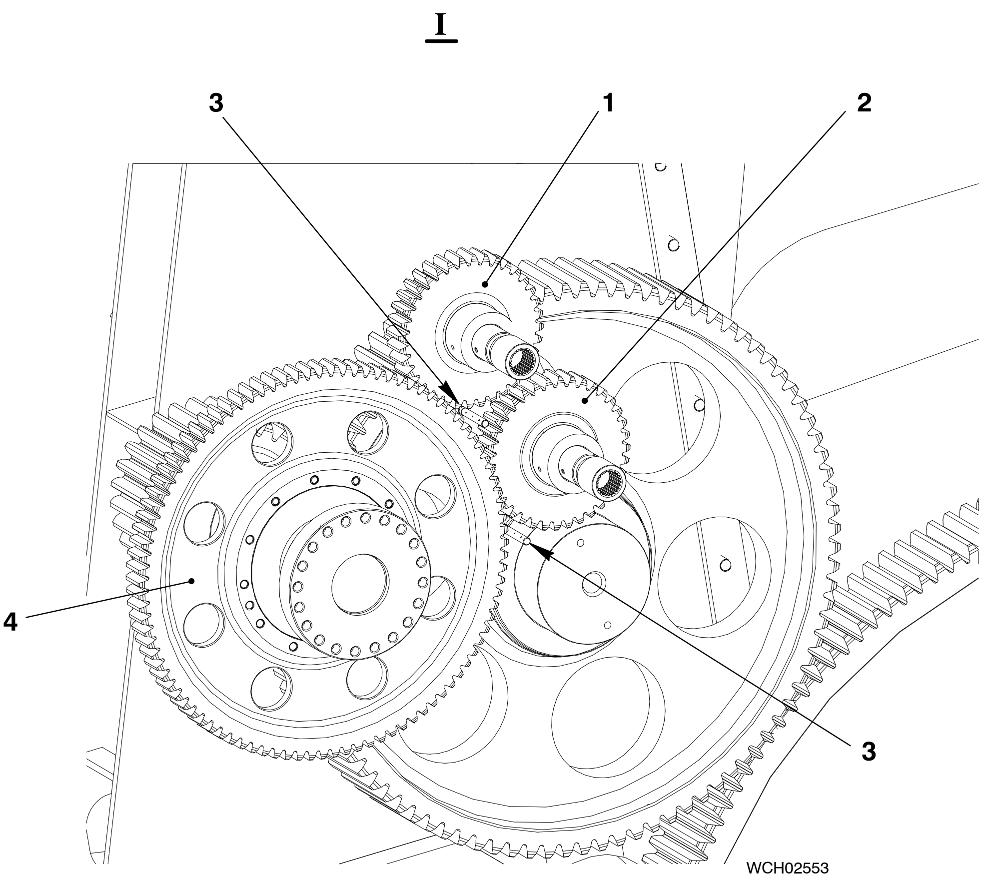


Fig. 2: View of Gear Wheels

1 Gear wheel (for servo oil pump No.1)
2 Gear wheel (for servo oil pump No.2)
3 Nozzles
4 Intermediate wheel

Starting Air Shut-off Valve

1. General

The starting air shut-off valve (shut-off valve) stops or releases the starting air to the engine. You use the handwheel (3, Fig. 1) to put the shut-off valve in the positions that follow:

- CLOSED
- AUTOMAT
- OPENED.

When the engine is in stand-by mode or during operation, the shut-off valve is in the AUTOMAT position. The lever (14) holds the shut-off valve in this position.

To do a test of the shut-off valve, you must operate the ball valve 35–8353_E0_2 (see step 1).

1) Operate the ball valve 35–8353_E0_2 to make sure that the valve (5) opens. The shut-off valve opens, which you can hear clearly, but the engine will not start.
2) When the engine is not in operation, do step a) to step e).
   a) Close the shut-off valves 930-V03 and 930-V04 on the starting air bottles (plant).
   b) Push the lever (14) down, then use the handwheel (3) to move the shut-off valve to the position CLOSED.
   c) Open the vent valve to release the pressure in the shut-off valve and air supply pipes.
   d) Open the vent valve to release the pressure in the starting air supply pipes.
   e) Engage the turning gear.

After each maneuvering period, open the vent valves in the supply pipe to drain the condensate water (see also 8018–1 Starting Air Diagram).

For more data, see the Control Diagram 4003–2.

2. Function

2.1 Ready to Start

Starting air flows through the inlet pipe (IP) into the inlet chamber (8), then through the balance bore (6) into the space (9). The spring (4) and the pressure in the space (9) keep the valve (5) closed.

2.2 Start Sequence

The related CCM–20 module operates the solenoid valve (11) or (13) (see also 4002–1, paragraph 3 Engine-Control System – Functions).

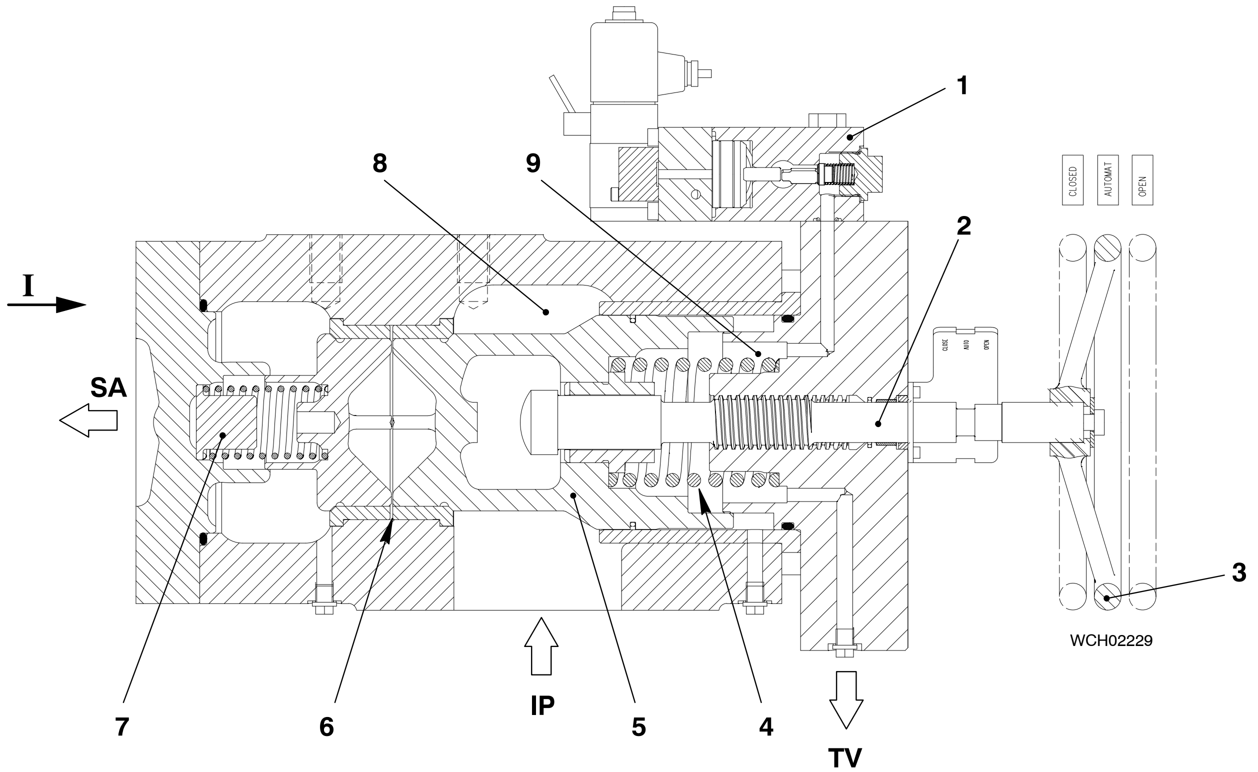
The control air (CA) opens the control valve (1) through the solenoid valve CV7014C (11) and releases the pressure in the space (9). The valve (5) opens and starting air from the inlet chamber (8) flows through the non-return valve (7) into the starting air supply pipe (SA).

2.3 End of Start Sequence

When the control valve (1) closes, starting air flows through the balance bores (6) and fills the the inlet chamber (8) again. The valve (5) closes.

2.4 Function Check

When the control valve operates on the ready-to-start engine, the pressure in the space (9) is released. You can hear the valve (5) as it opens.



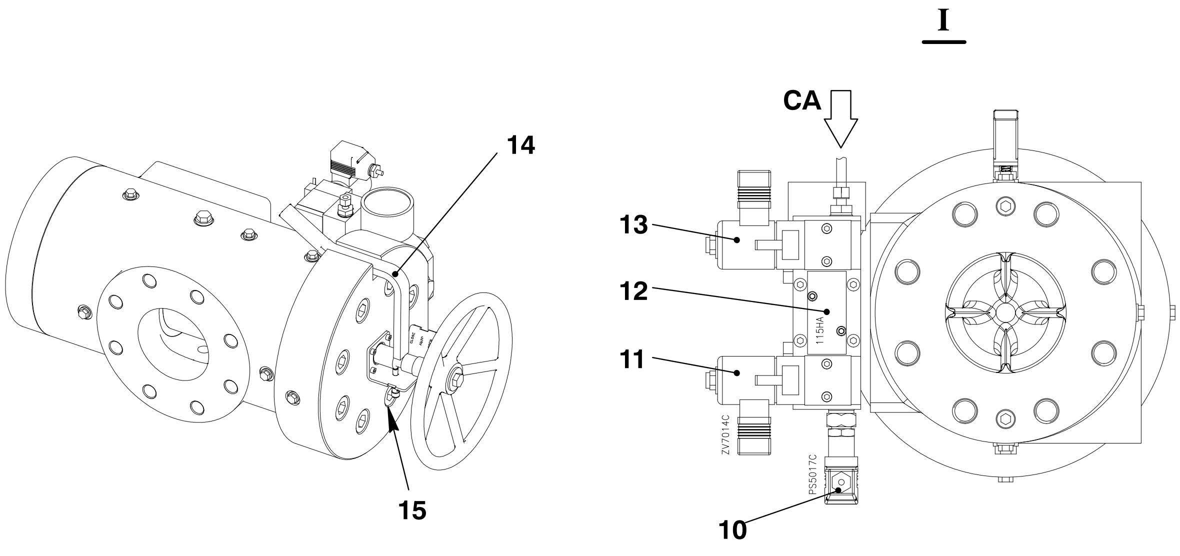


Fig. 1: Starting Air Shut-off Valve

1	Control valve	12	Double check valve 35-115HA
2	Spindle	13	Solenoid Valve CV7013C
3	Handwheel	14	Lever
4	Spring	15	Proximity sensor ZS5018C
5	Valve		
6	Balance bore		
7	Non-return valve	IP	Inlet pipe
8	Inlet chamber	SA	To starting air supply pipe and valves 30-2728_CX_1 to CX_#
9	Valve space		
10	Pressure switch PS5017C	CA	Control air
11	Solenoid Valve CV7014C	TV	To test valve

Control Air Supply

1. General

The compressed air necessary for the air springs in the exhaust valves and the turning gear interlock comes from the control air board supply. The air must be clean and dry to prevent blockages in the control units.

If the control air board supply system becomes defective, a decreased quantity of compressed air will come from the starting air system.

The shut-off valves, pressure reducing valve, filters etc. that are necessary to supply air to the different units are shown in the control air supply unit **A** (see Fig. 1, Fig. 2 and Fig. 3).

The alpha-numeric titles (e.g. 35-36HB) used to identify the parts in the illustrations are the same as those in the Control Diagram (4003−2).

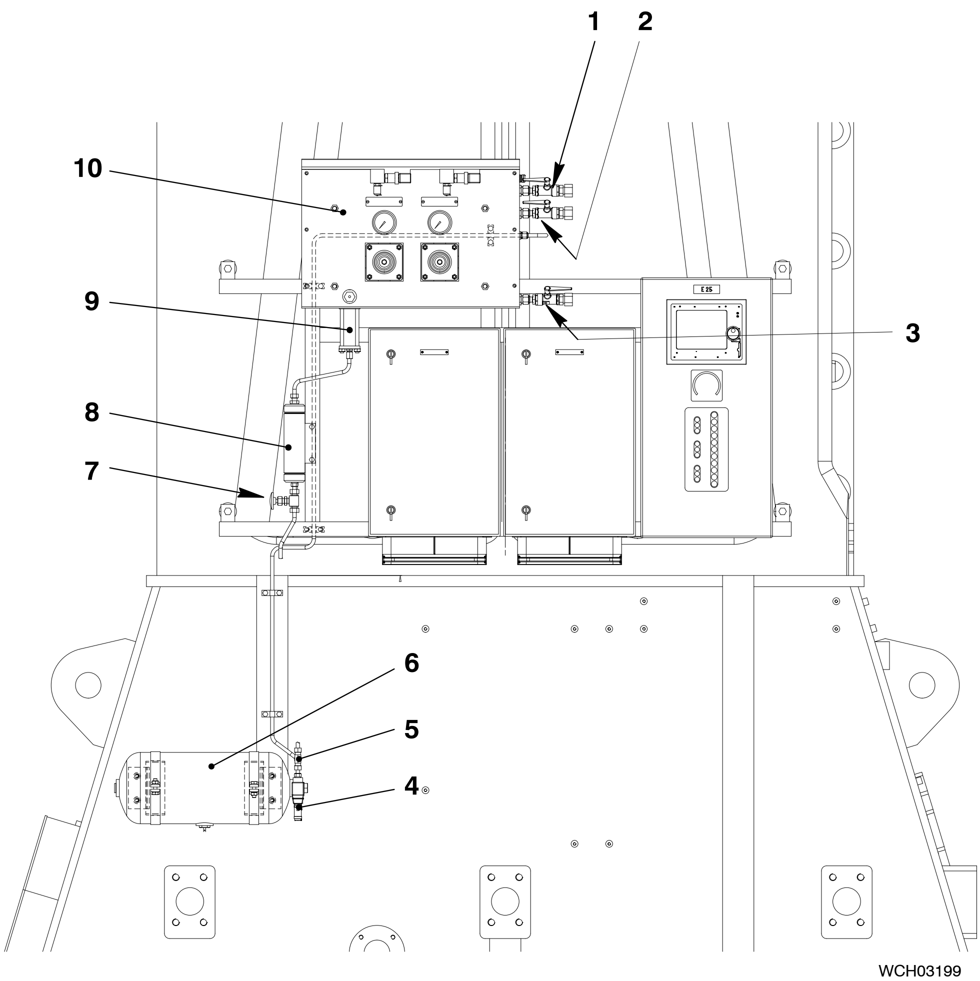


Fig. 1: Location of Control Air Supply

1 3/2−way valve 35-36HB (control air)
2 3/2−way valve 35-36HC
3 3/2−way valve 35-36HA
4 Pressure transmitter PT4421C
5 Pressure transmitter PT4421A
6 Air tank
7 Needle valve
8 Bottle
9 Filter 35-351HA
10 Control air supply unit **A**

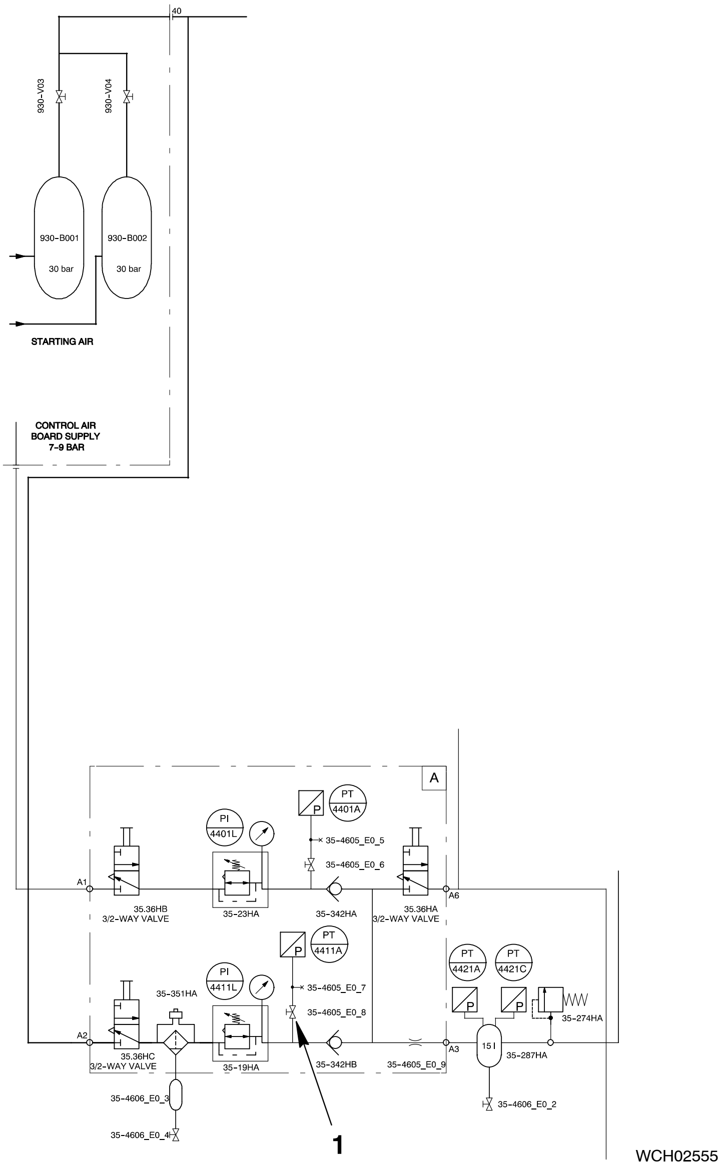


Fig. 2: Schematic Diagram − Control Air Supply Unit

1 2-way shut-off valve 35-4605_E0_8

A1 Control air from board system
A2 Starting air from starting air system
A3 Connection to air tank 287HA
A6 Air supply to air spring

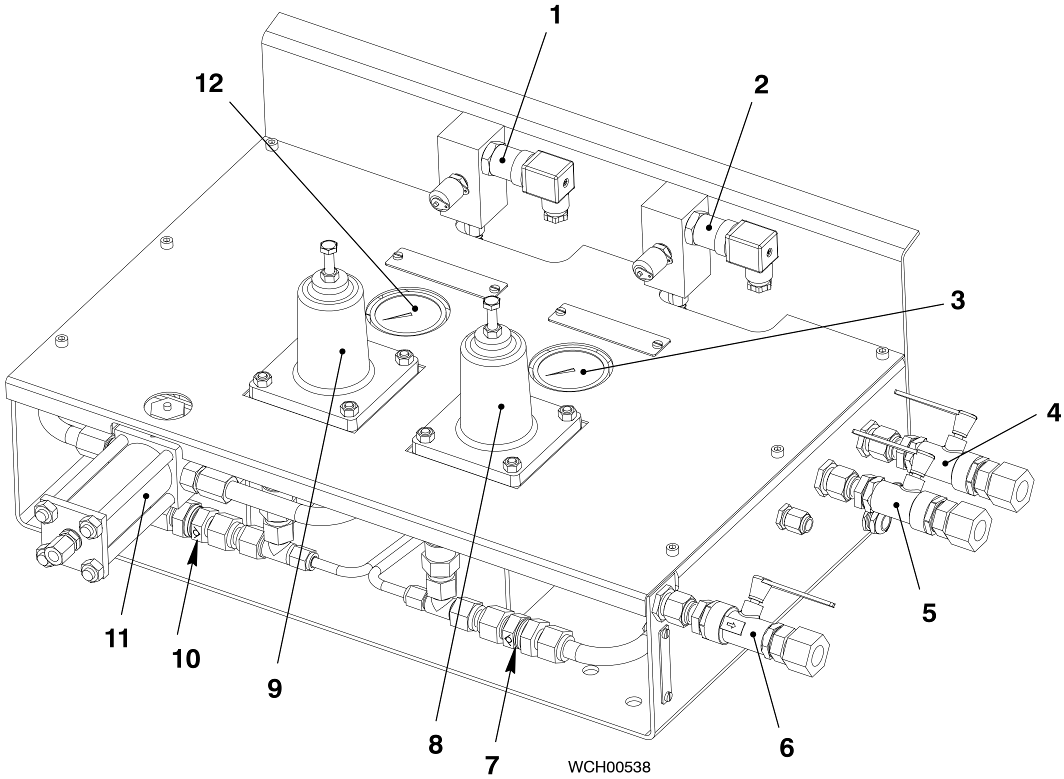


Fig. 3: Control Air Supply Unit

1 Pressure transmitter PT4411A
2 Pressure transmitter PT4401A
3 Pressure gauge PI4401L
4 3/2-way valve 35-36HB
5 3/2-way valve 35-36HC
6 3/2-way valve 35-36HA
7 Non-return valve 35-342HA
8 Pressure reducing valve 35-23HA
9 Pressure reducing valve 35-19HA
10 Non-return valve 35-342HB
11 Filter 35-351HA
12 Pressure gauge PI4411L

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Control Air Supply (for Engines with Built-in ELBA)

1. General

The compressed air necessary for the air springs in the exhaust valves and the turning gear interlock comes from the control air board supply. The air must be clean and dry to prevent blockages in the control units.

If the control air board supply system becomes defective, a decreased quantity of compressed air will come from the starting air system.

The shut-off valves, pressure reducing valve, filters etc. that are necessary to supply air to the different units are shown in the control air supply unit **A** (see Fig. 1, Fig. 2 and Fig. 3).

The alpha-numeric titles (e.g. 35-36HB) used to identify the parts in the illustrations are the same as those in the Control Diagram (4003–2).

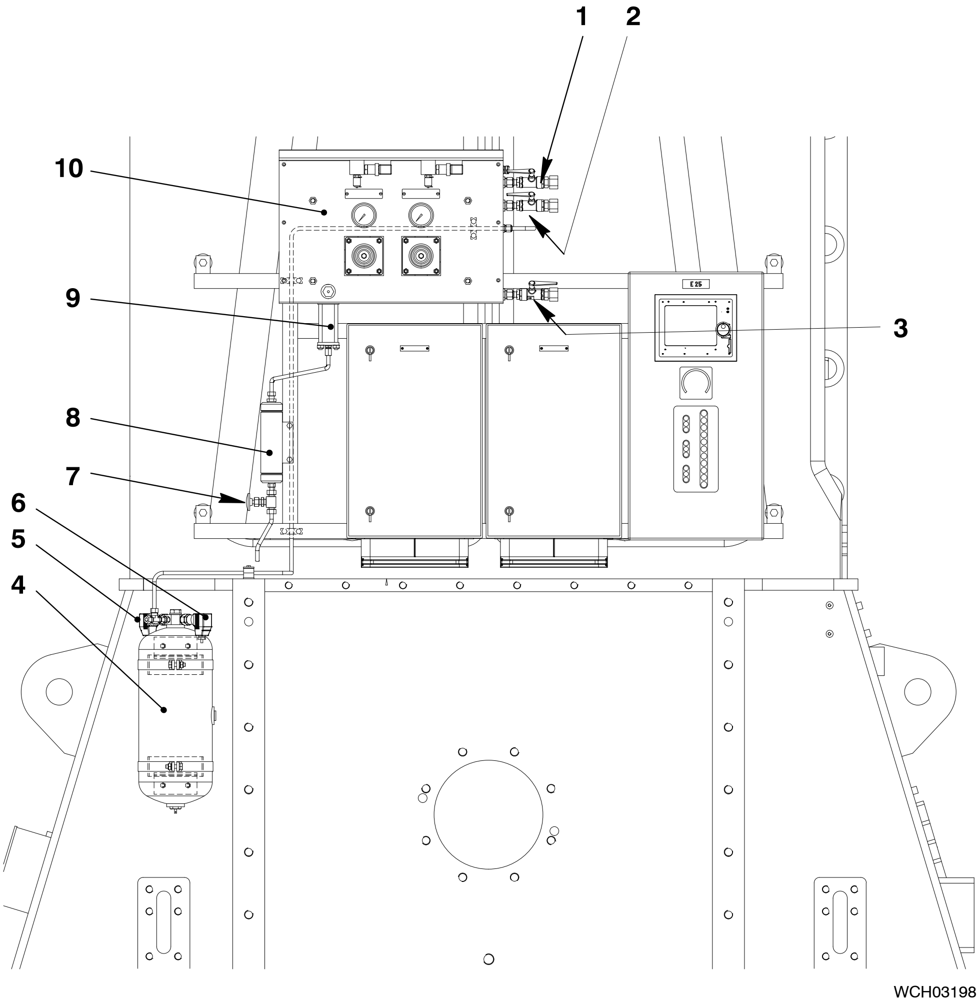

Fig. 1: Location of Control Air Supply

1 3/2–way valve 35-36HB (control air)
2 3/2–way valve 35-36HC
3 3/2–way valve 35-36HA
4 Air tank
5 Pressure transmitter PT4421C
6 Pressure transmitter PT4421A
7 Needle valve
8 Bottle
9 Filter 35-351HA
10 Control air supply unit **A**

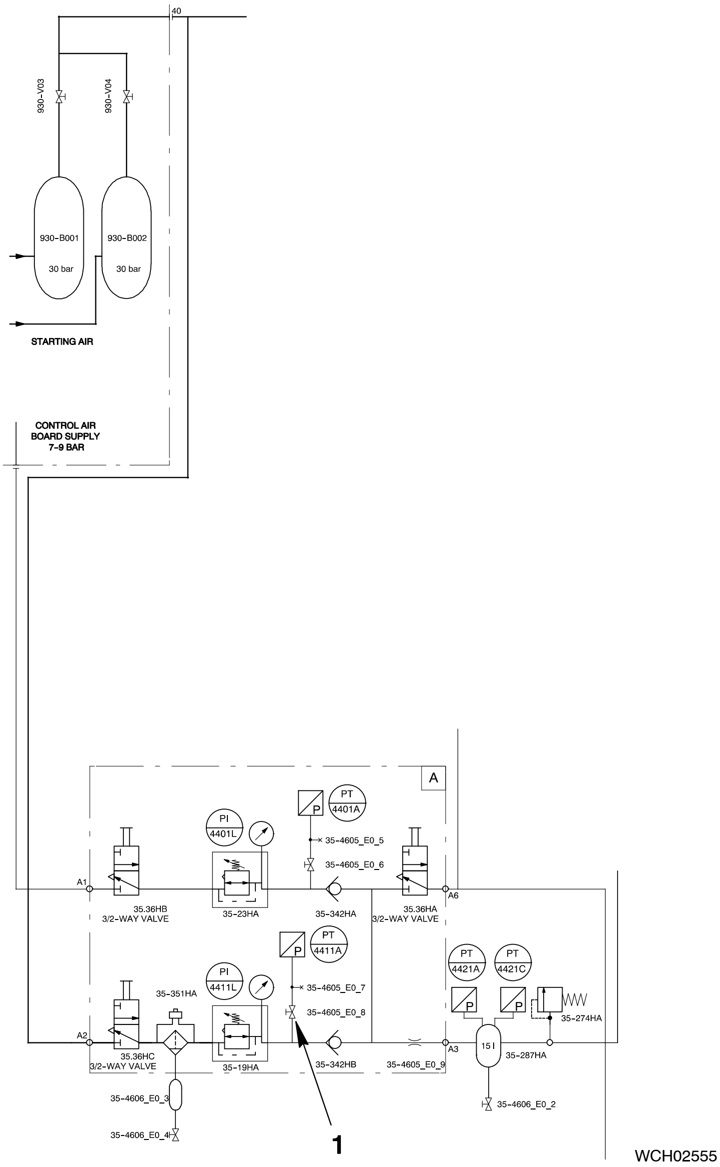

Fig. 2: Schematic Diagram - Control Air Supply Unit

1 2-way shut-off valve 35-4605_E0_8

A1 Control air from board system
A2 Starting air from starting air system
A3 Connection to air tank 287HA
A6 Air supply to air spring

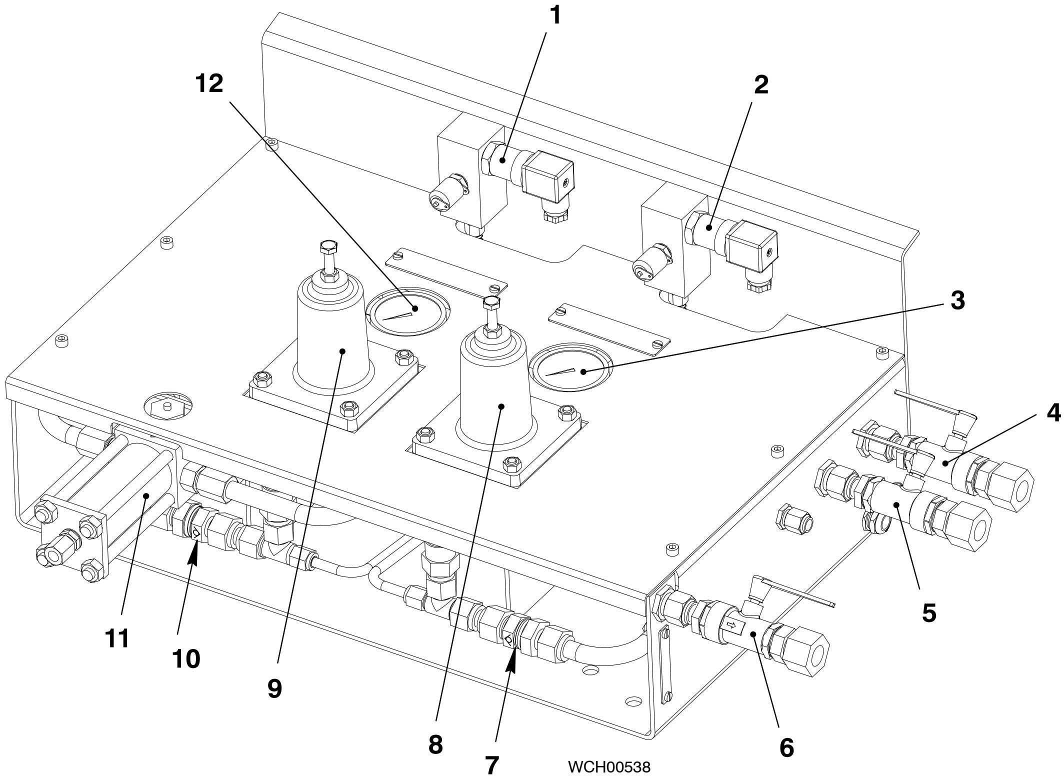

Fig. 3: Control Air Supply Unit

1	Pressure transmitter PT4411A	7	Non-return valve 35-342HA
2	Pressure transmitter PT4401A	8	Pressure reducing valve 35-23HA
3	Pressure gauge PI4401L	9	Pressure reducing valve 35-19HA
4	3/2-way valve 35-36HB	10	Non-return valve 35-342HB
5	3/2-way valve 35-36HC	11	Filter 35-351HA
6	3/2-way valve 35-36HA	12	Pressure gauge PI4411L

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Pick-up for Speed Measurement

1. General

To measure the engine speed (rpm), six proximity sensors are installed in a speed pick-up unit, attached to the support of the fuel pump unit.

For safety, there are three electrically isolated proximity sensor groups as follows:

- Speed identification in the remote control system (RCS)
- Overspeed safety system
- Speed control system.

2. Function

The proximity sensors (5, 6, 7, 9, 10 and 11 Fig. 1) measure the speed of the flywheel (1). When the flywheel turns, the proximity sensors sense the movement of the teeth. Signals are sent through the engine control system (ECS) to the RCS to monitor the load and speed-related functions. Data are also sent to the speed indication instruments.

Note: The top view I shows the proximity sensors with the cover 4 removed.

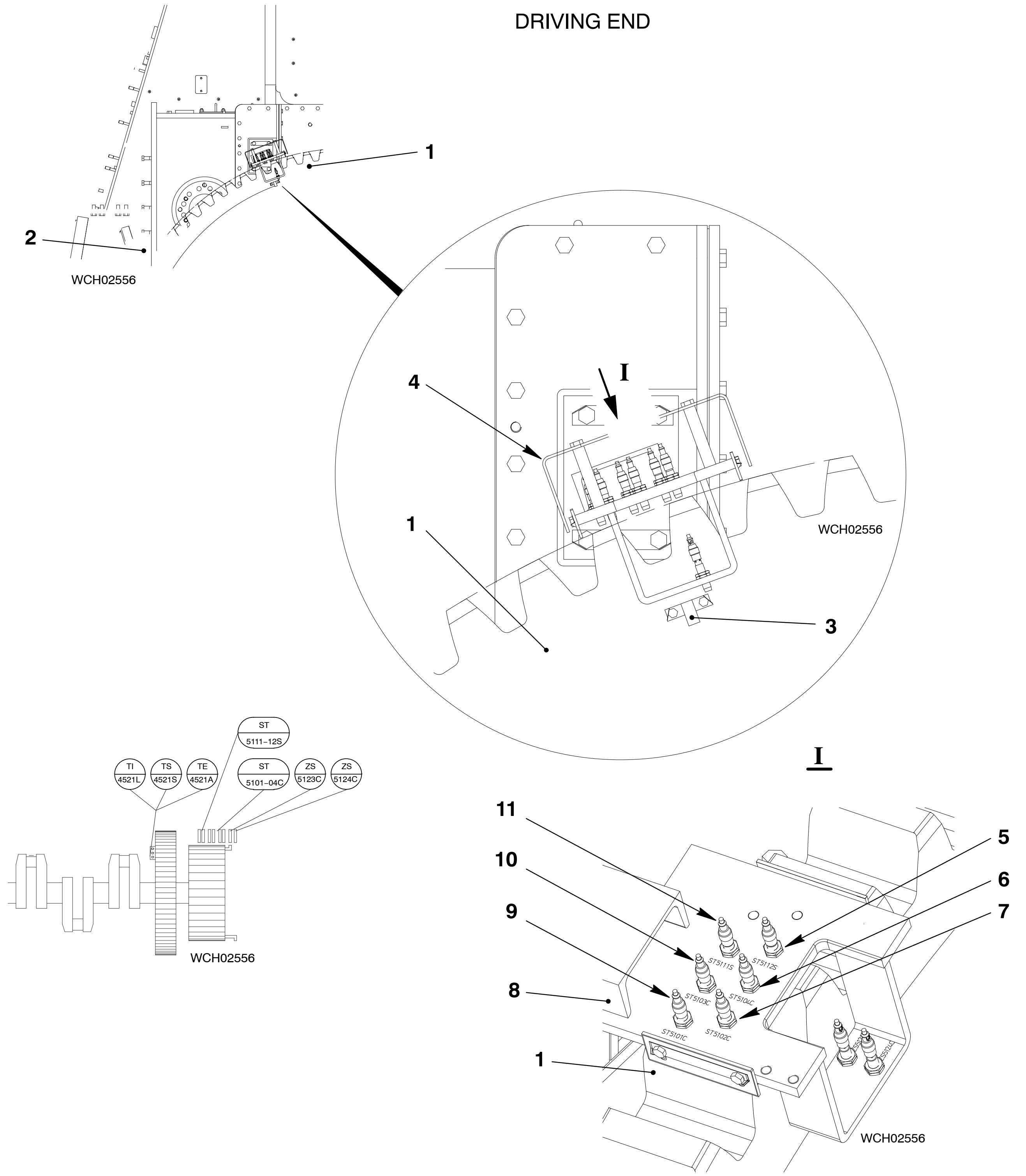

Fig. 1: Location of Proximity Sensors

1	Flywheel	7	Proximity sensor ST5102C
2	Bedplate	8	Pick-up holder
3	Crank angle mark	9	Proximity sensor ST5101C
4	Cover	10	Proximity sensor ST5103C
5	Proximity sensor ST51412S	11	Proximity sensor ST51412S
6	Proximity sensor ST5104C		

Supply Unit, Servo Oil Pump and Fuel Pump — Group 5

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Servo Oil Pump

1. General

The servo oil pumps (3 and 5, Fig. 1) are attached to, and part of, the supply unit (6). These pumps supply servo oil to open the exhaust valves.

For more data about the supply unit, see 5552–1.

The flow sensors (1 and 4), monitor the oil supply in each inlet pipe (2) of the servo oil pumps. A malfunction of a servo oil pump will show in the alarm and monitoring system.

2. Function

CAUTION
Damage Hazard: If a servo oil pump becomes defective, do not operate the engine for too long. If the other pump becomes defective, the engine cannot operate. You must replace the defective servo oil pump as soon as possible (see the Maintenance Manual 5552–1).

During usual operation, the servo oil pumps supply hydraulic pressure equally for the full load range.

The nominal pressure value is related to the engine load. The electrically controlled system adjusts the system pressure for the full load range, i.e. high pressure (approximately 300 bar) at high engine load, and decreased pressure at low engine load.

Note: If a servo oil pump cannot turn, the safety device (4, Fig. 2) will break. This will prevent too much damage to the intermediate wheel (6).

If one pump becomes defective, the engine will continue to operate at full load.

For more data, see the Maintenance Manual 5551–2.

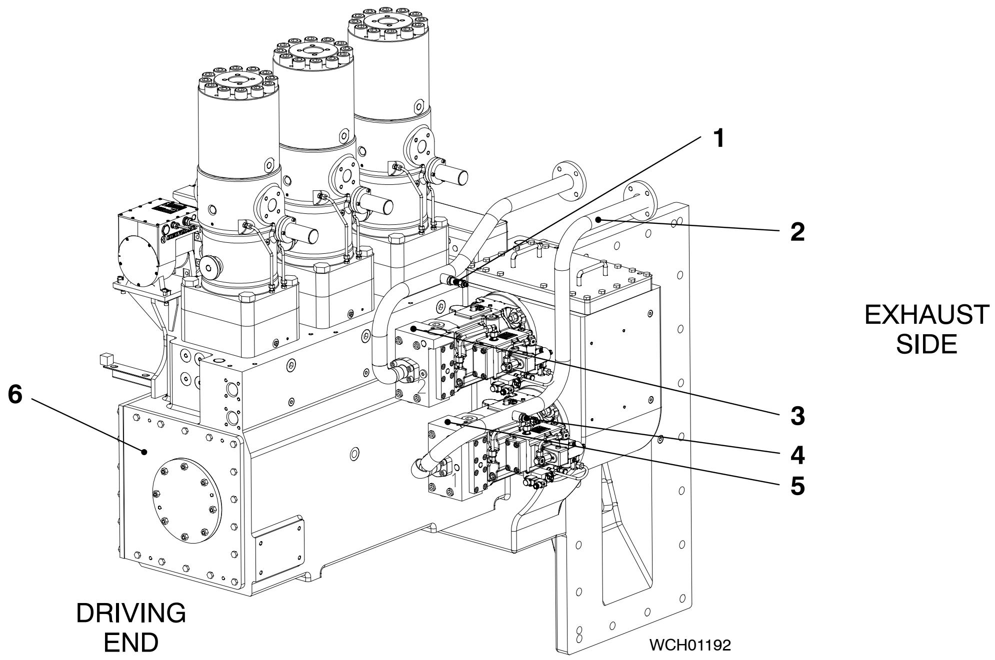


Fig. 1: Location of Servo Oil Pumps

1 Flow sensor FS2062A
2 Inlet pipe
3 Servo oil pump No.2
4 Flow sensor FS2061A
5 Servo oil pump No.1
6 Supply unit

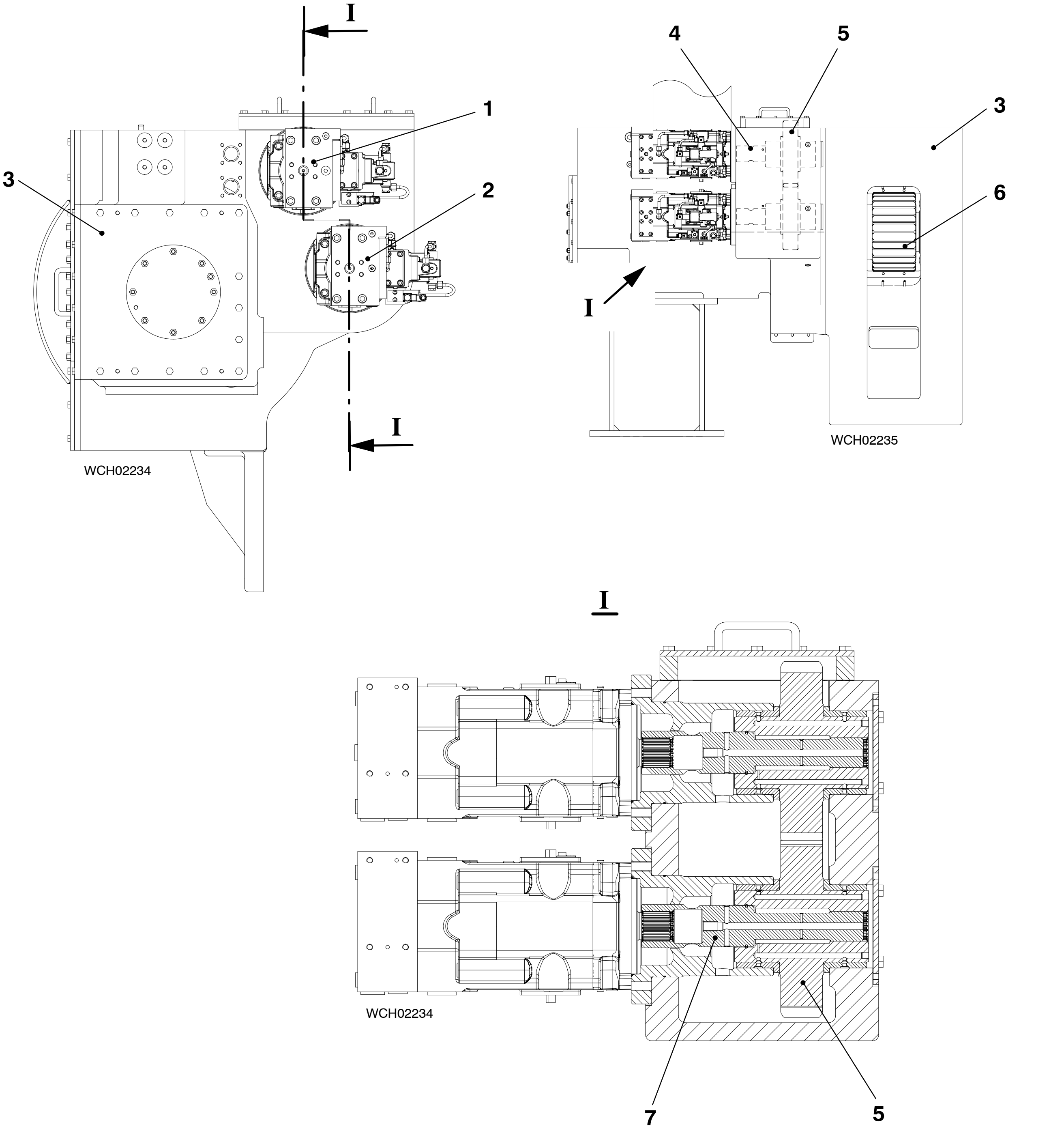


Fig. 2: Servo Oil Pumps − Operation

1 Servo oil pump (20-5551_E0_1)
2 Servo oil pump (20-5551_E0_2)
3 Supply unit
4 Safety device (waisted part)
5 Pinion
6 Intermediate wheel (supply unit)
7 Shaft

Supply Unit

1. General

The supply unit is installed on the column at the driving end (see 4104–1 Supply Unit Drive).

The supply unit has the servo oil supply, fuel supply, gear wheels and drive wheels. The components in paragraph 1.1 and paragraph 1.2 are part of, or attached to the housing.

1.1 Servo Oil Pumps

Two servo oil pumps (not shown) are attached to the front of the supply unit. The intermediate wheel (2, Fig. 1) operates the servo oil pumps (see 4104–1 Supply Unit Drive).

For more data about the servo oil pumps, see 5551–1 Servo Oil Pump.

1.2 Fuel Pumps

Three fuel pumps (1) are attached to the supply unit. For more data about the fuel pumps, see 5556–1, Fuel Pump.

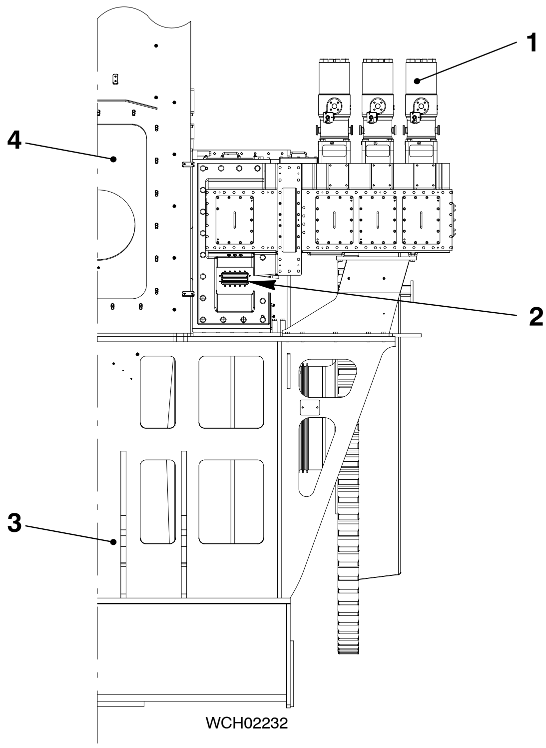


Fig. 1: Supply Unit

1	Fuel pump	3	Bedplate
2	Intermediate wheel	4	column

2. Lubrication

Oil flows through bores in the casing (8, Fig. 2) to lubricate the bearings and fuel pumps. Oil also flows through the nozzles (6) to lubricate the intermediate wheel (7) and the gear wheel (5).

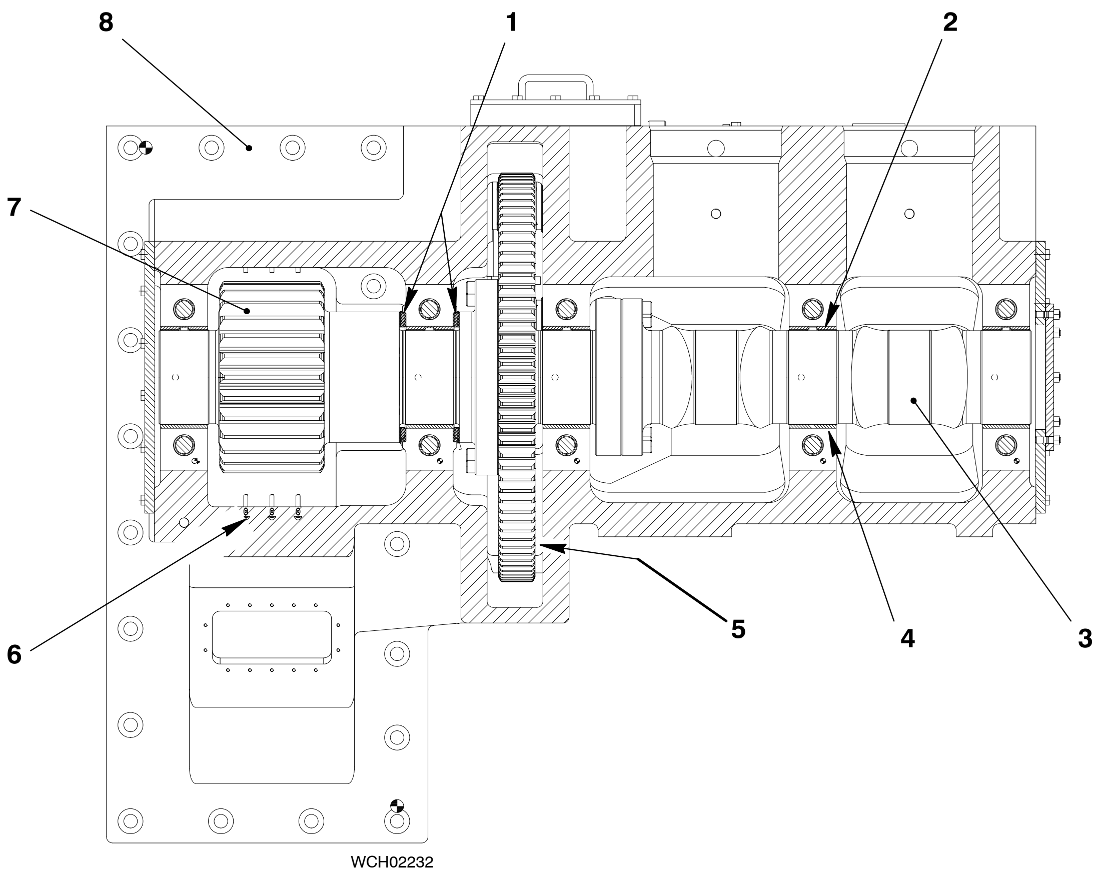


Fig. 2: Location of Items

1 Thrust bearing ring half
2 Top bearing shell half
3 Camshaft
4 Bottom bearing shell half
5 Gear wheel
6 Nozzle
7 Intermediate wheel
8 Casing

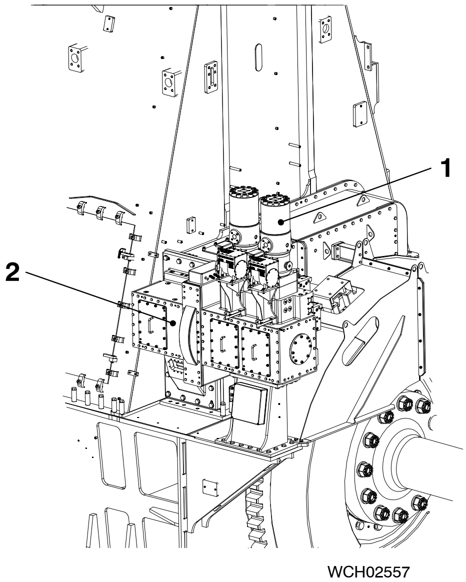
Fuel Pump

1. General

The fuel pumps (1, Fig. 1) are part of the supply unit (2).

The fuel pumps supply fuel through high pressure pipes to the fuel rail (see 8019−1, Fuel System). The fuel pumps are controlled to supply the necessary load-related fuel pressure (up to 1000 bar) in the fuel rail.

For more data about he supply unit, see 5552−1



Date for 4-cylinder to 7-cylinder

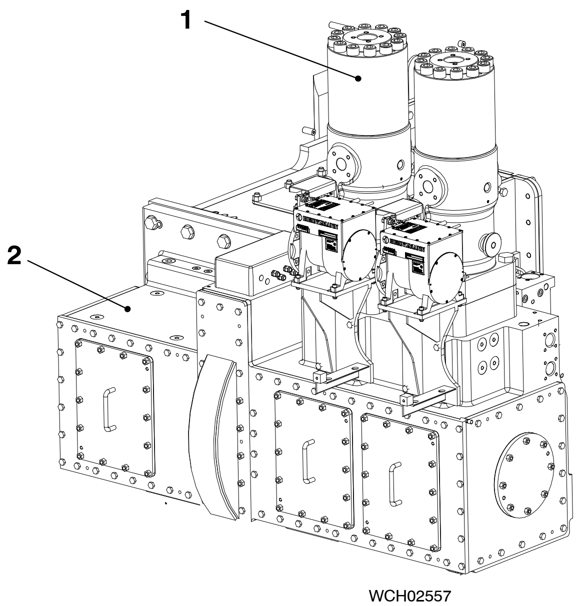


Fig. 1: Location of Fuel Pumps

1 Fuel pump

2 Supply unit

2. Function

The compression spring (9, Fig. 2) keeps the bottom spring carrier (2) against the guide piston (6), which keeps the roller (4) against the cam (5). When the cam (5) moves the roller (4) up, the guide piston (6) moves up and the bottom spring carrier (2) compresses the compression spring (9). The pump plunger (18) then moves up. The control grooves in the pump plunger (18) control the fuel quantity.

When the toothed rack (12) moves, the teeth engage with the teeth on the regulating sleeve (17) and the regulating sleeve turns. The regulating sleeve (17) turns the driver (10) and thus the pump plunger (18).

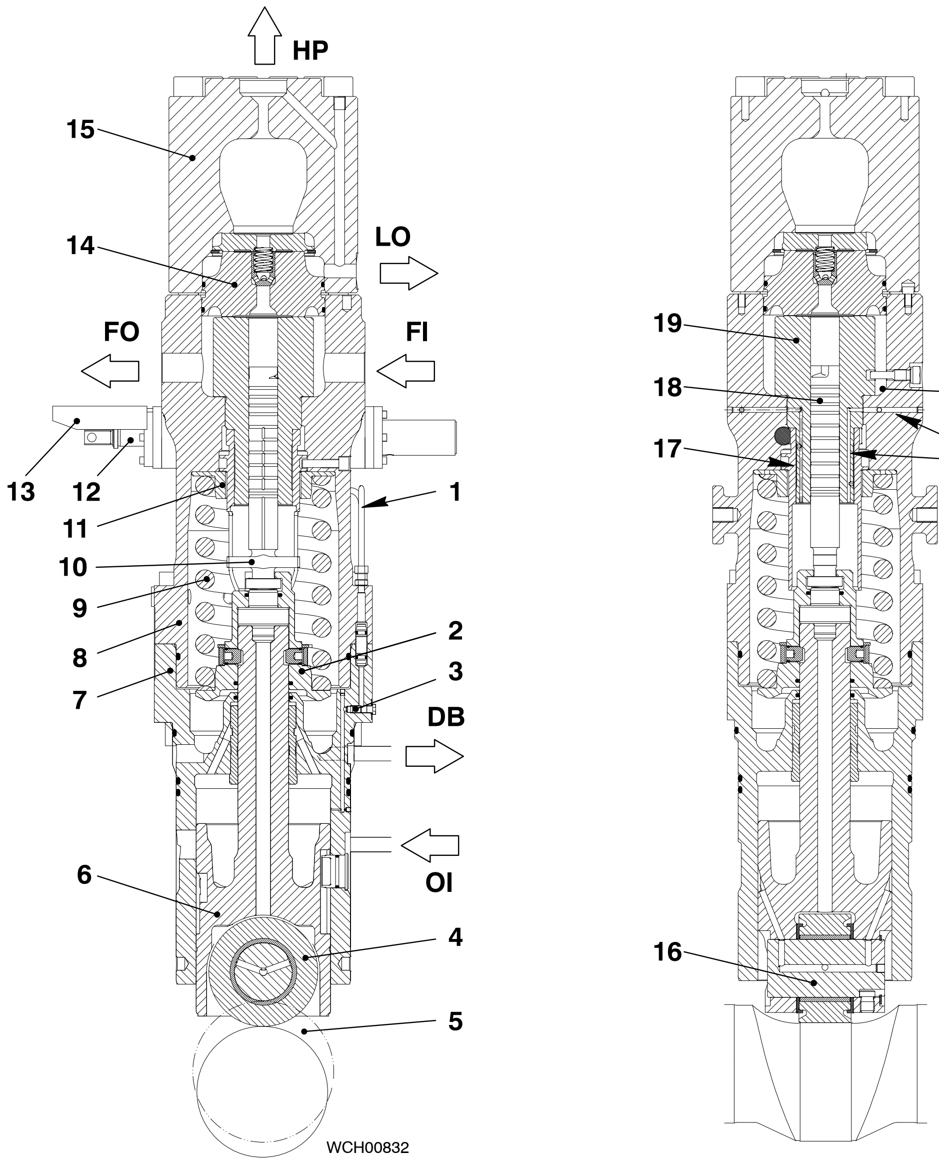


Fig. 2: Fuel Pump

1	Oil pipe	16	Roller pin
2	Bottom spring carrier	17	Regulating sleeve
3	Orifice	18	Pump plunger
4	Roller	19	Pump cylinder
5	Cam		
6	Guide piston		
7	Bottom housing		
8	Top housing	DB	Leakage fuel
9	Compression spring	FI	Fuel inlet
10	Driver (of pump plunger)	FO	Fuel outlet
11	Top spring carrier	HP	HP fuel to fuel rail
12	Toothed rack	LO	Leakage fuel outlet
13	Cover (toothed rack)	OB	Lubricating oil bore
14	Non-return valve	OI	Lubricating oil inlet
15	Pump cover	SC	Suction chamber

When the pump plunger passes BDC, fuel flows through the two inlet bores (5, Fig. 3) and the two control grooves (2) into the plunger chamber (1). The quantity of fuel that enters the plunger chamber (1) is related to the control position (between 0 for zero supply and 10 for maximum supply).

Note: No fuel is supplied in the position 0 (zero).

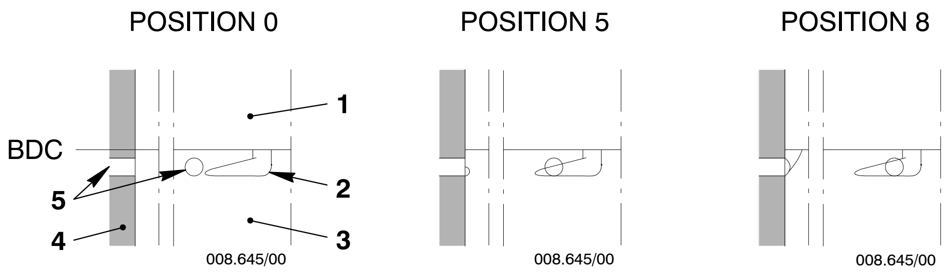


Fig. 3: Control Grooves of Pump Plunger

1 Plunger chamber
2 Control groove
3 Pump plunger
4 Pump cylinder
5 Inlet bore

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Fuel Pump – Cutting Out and Cutting In

1. General

If a fuel pump is unserviceable (e.g. the pump plunger cannot move) or the HP fuel pipe is broken (between the fuel pump and the fuel rail) the fault must be repaired immediately.

If the fault cannot be repaired, because the engine must operate, it is possible to cut out the unserviceable fuel pump.

You must not operate the engine with a fuel pump removed. This will decrease the supply of oil, i.e. there could be a decrease of lubrication to the other fuel pumps.

Note: If one fuel pump is cut out, there is almost no limit in engine operation. If more than one pump is cut out, you can only operate the engine at decreased load. When a fuel pump is cut out, oil in the system will decrease.

2. Cutting Out and Cutting In

2.1 Cutting Out Procedure

1) Stop the engine.
2) Remove the applicable HP fuel pipe from the related fuel pump (see Fig. 1 and the Maintenance Manual 8752–1 Removal).
3) Install the blank flange (3) (tool 94569) to the fuel pump (4).
4) Attach the blank flange (1) tool 94569a) to the intermediate piece (2).
5) Remove the applicable cover (5).
6) Find the position of the related cam.

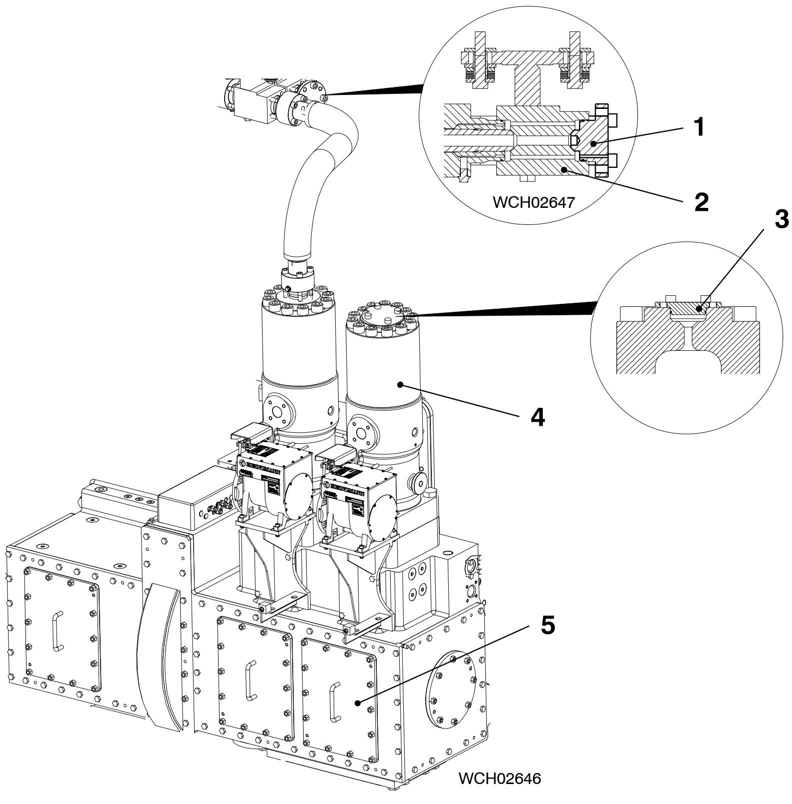

Fig. 1

WARNING

Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel.

7) Use the turning gear to turn the engine until the roller (1, Fig. 2) of the guide piston (2) is at the highest position (cam peak).

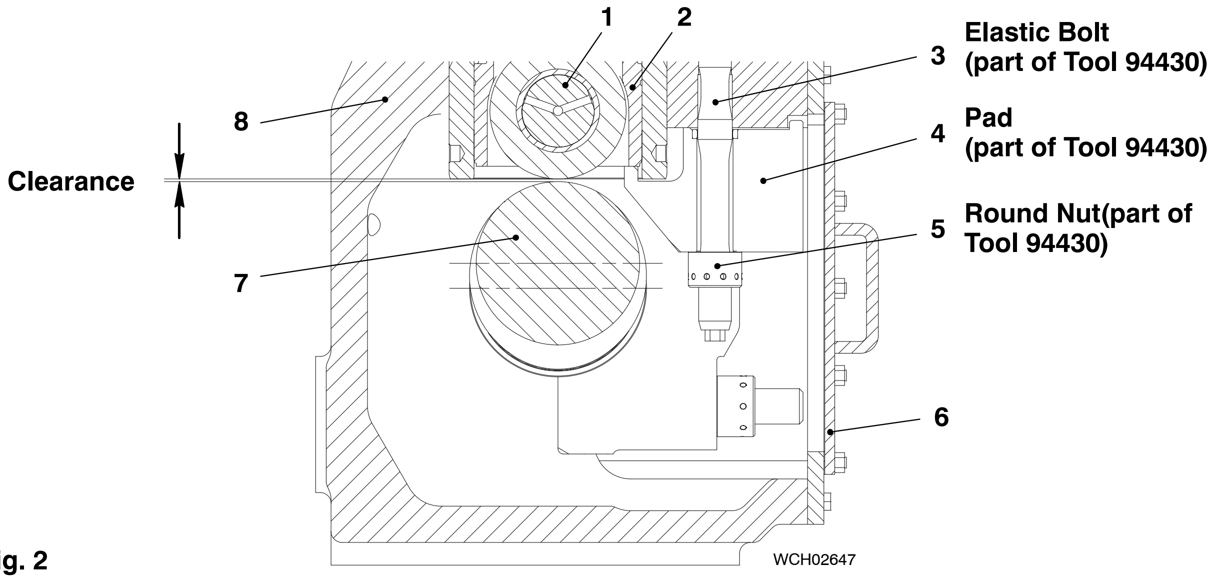

Fig. 2

8) Fully turn the elastic bolt (3) together with the pad (4).
9) Put the tool (94430) in position.
10) Turn the round nut (5) until it touches the pad (4). Make sure that the pad (4) touches the guide piston (2) and the casing (8).
11) Put the pre-tensioner (6, Fig. 3) on to the elastic bolt (3). The pre-tensioner must touch the pad (4).
12) Make sure that the vent screw 8 on the pre-tensioner is open.

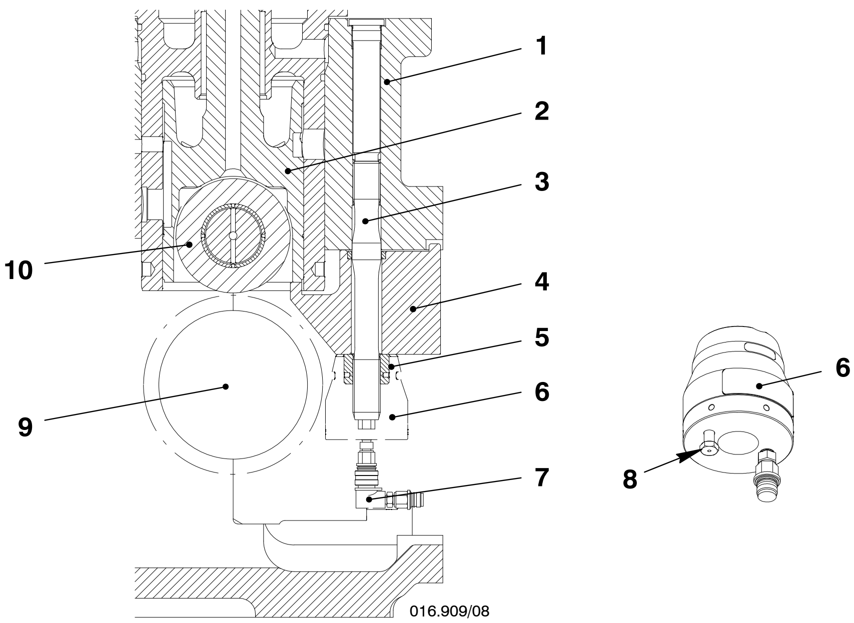

Fig. 3

13) Adjust the tension on the elastic bolt (3, Fig. 3) to 1500 bar (see the procedure in the Maintenance Manual 9403–4).
14) Make sure that the roller (3) has moved up approximately 3.0 mm from the cam (1).
15) Turn the round nut (11) until it touches the pad (10) (the angle must be approximately 84°).
16) Remove the pre-tensioner (6) (see the procedure in the Maintenance Manual 9403–4).
17) Make sure that the roller (10) stays approximately 3.0 mm above the cam (9).
18) Install the cover (6, Fig. 2).

Note: For the torque values and lubrication of the applicable screws, see the Maintenance Manual 0352–1.

2.2 Cutting In

1) Stop the engine.
2) Remove the cover (6).
3) Find the position of the related cam (7).

WARNING

Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel.

4) Use the turning gear to turn the engine until the roller (1) of the guide piston (2) is at the highest position (cam peak).
5) Put the pre-tensioner (6, Fig. 3) on to the elastic bolt (3). The pre-tensioner must touch the pad (4).
6) Make sure that the vent screw (8) on the pre-tensioner is open.
7) Adjust the tension on the elastic bolt 3 to 1530 bar (see the procedure in the Maintenance Manual 9403–4).
8) Remove the round nut (5).
9) Remove the pre-tensioner (6) (see the procedure in the Maintenance Manual 9403–4).
10) Remove the elastic bolt (3) and the pad (4).
11) Attach the round nut (5) to the elastic bolt (3) on the pad (4) with your hand.

2.3 Completion

1) Install the inspection cover (5, Fig. 1).
2) Remove the blank flanges (1) (tool 94569a) and (3) (tool 94569).
3) Install the HP fuel pipe (4) (see the Maintenance Manual 8752–1 paragraph 3).

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Pressure Control Valve

1. General

1.1 Operation

The engine software controls the fuel pressure. The pressure in the fuel rail is always less than that necessary to open the pressure control valve (PCV). The PCV (1, Fig. 1) is usually closed.

The PCV can also operate as a pressure relief valve and will open if the fuel pressure is more than the specified pressure of approximately 1050 bar.

For more data, see 4002−1, paragraph 3.7 Diesel Fuel Pressure Control).

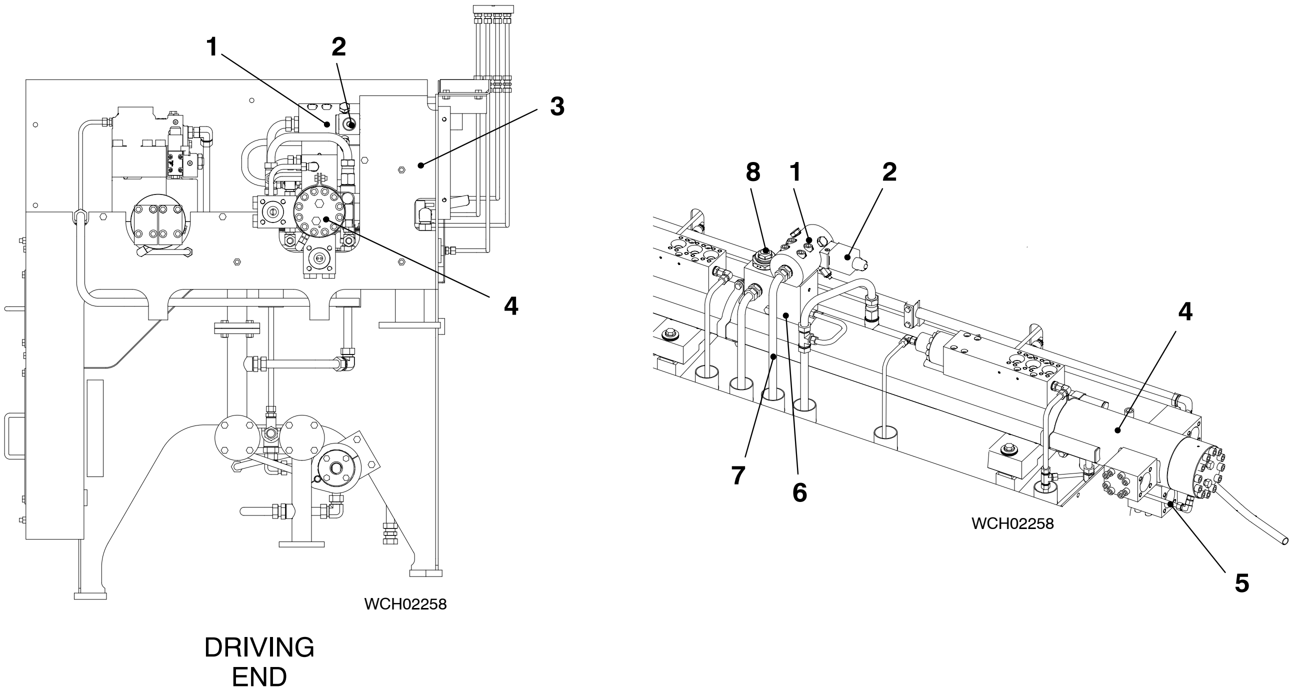

Fig. 1: Location of Pressure Control Valve

1 Pressure control valve 10-5562_E0_5
2 Control valve (ZV7061S)
3 Rail unit
4 Fuel rail
5 Drain pipe
6 Valve block
7 Fuel return pipe
8 Relief valve

1.2 Emergency Stop

The safety system operates the control valve (2), which decreases the fuel pressure to less than 200 bar (usually to 0 bar). Thus, fuel injection is not possible.

The PCV is one of three devices that can shut down the engine. The other devices are:

- Immediate injection stop (engine software)
- Fuel pump supply moved to 0 (engine software).

1.3 Emergency Operation

If the fuel pressure control system becomes defective, the PCV will control the pressure in the system when:

- There are missing or incorrect control signals
- A flow control valve of a fuel pump is unserviceable.

When no control signal is received, the fuel pumps are set to the maximum supply position.

If the fuel pressure is more than the specified pressure (approximately 1050 bar), the PCV will open to gradually drain sufficient fuel to keep the adjusted maximum pressure. If this occurs, longer engine operation time must be prevented.

The PCV must be replaced after a longer operation time during emergency operation.

CAUTION

Damage Hazard: Always do a check of the PCV operation pressure after emergency operation (e.g. no fuel pump control when the PCV is used for pressure control in the fuel rail). Damage can occur if the operation pressure is incorrect.

Note: When the PCV opens, fuel will drain and you can hear a loud noise like a whistle.

2. Functions

2.1 Control Function

The PCV (1, Fig. 1) has a primary piston. A pressure balance between the high pressure side and the control side of the PCV controls this primary piston. When the pressure decreases on the control side through a small orifice in the primary piston (because of the control valve or the pneumatic actuator), the pressure difference causes the primary piston to move. The PCV then releases fuel through the return bore.

2.2 Supply Function

During engine stand-by the PCV (1) will open automatically to supply fuel through the fuel pumps, the HP fuel pipes and fuel rail (4) to keep the fuel warm. Downstream from the PCV, fuel is collected in the fuel return pipe (7) and flows back to the booster circuit at 4.0 bar (see also Fuel System 8019–1).

2.3 Emergency Stop Function

If the control valve (2) is energized, the fuel pressure in the fuel rail is immediately released.

Scavenge Air System — Group 6

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Scavenge Air Receiver

1. General

The scavenge air receiver (4, Fig. 1) is a welded assembly attached to the cylinder block on the exhaust side. The scavenge air receiver has the parts that follow:

- Receiver
- Turbocharger support
- Diffuser
- Scavenge air cooler casing
- Charging unit.

The longitudinal wall (7, Fig. 2) divides the receiver into the receiver space (5) and air space (6). The flaps (8, 9) are attached to the longitudinal wall (7).

2. Function

During operation, the turbocharger blows scavenge air through the scavenge air cooler (SAC) into the charging unit, through the water separator and then into the air space (6, Fig. 2). The air then flows through the flaps (8, 9) into the receiver space (5) and through openings in the cylinder block to the piston underside (10). The scavenge air flows through the scavenge ports when the piston is near BDC. The flaps (8, 9) prevent back-flow into the air space (6).

Two auxiliary blowers (3, Fig. 1) are attached to the scavenge air receiver. During engine start or at low engine load, the auxiliary blowers come on and move scavenge air from the space (6, Fig. 2) through the duct to the receiver space (5). The flaps (8, 9) prevent the back-flow of air when the auxiliary blowers are set to off.

The relief valve (5, Fig. 1), installed on the scavenge air receiver, opens when the air pressure increases to more than the permitted value in the receiver space.

WARNING
Injury Hazard: Do not go into the the receiver space (5, Fig. 2) during engine operation. Access into the receiver space through the covers (9, Fig. 1) is possible only when the engine has stopped.

You can do an inspection of the running surface of the piston, cylinder liner, piston rings and the piston rod gland from the receiver space (5, Fig. 2).

Note: If the turbocharger becomes defective, see 0590–1 Defective Turbocharger).

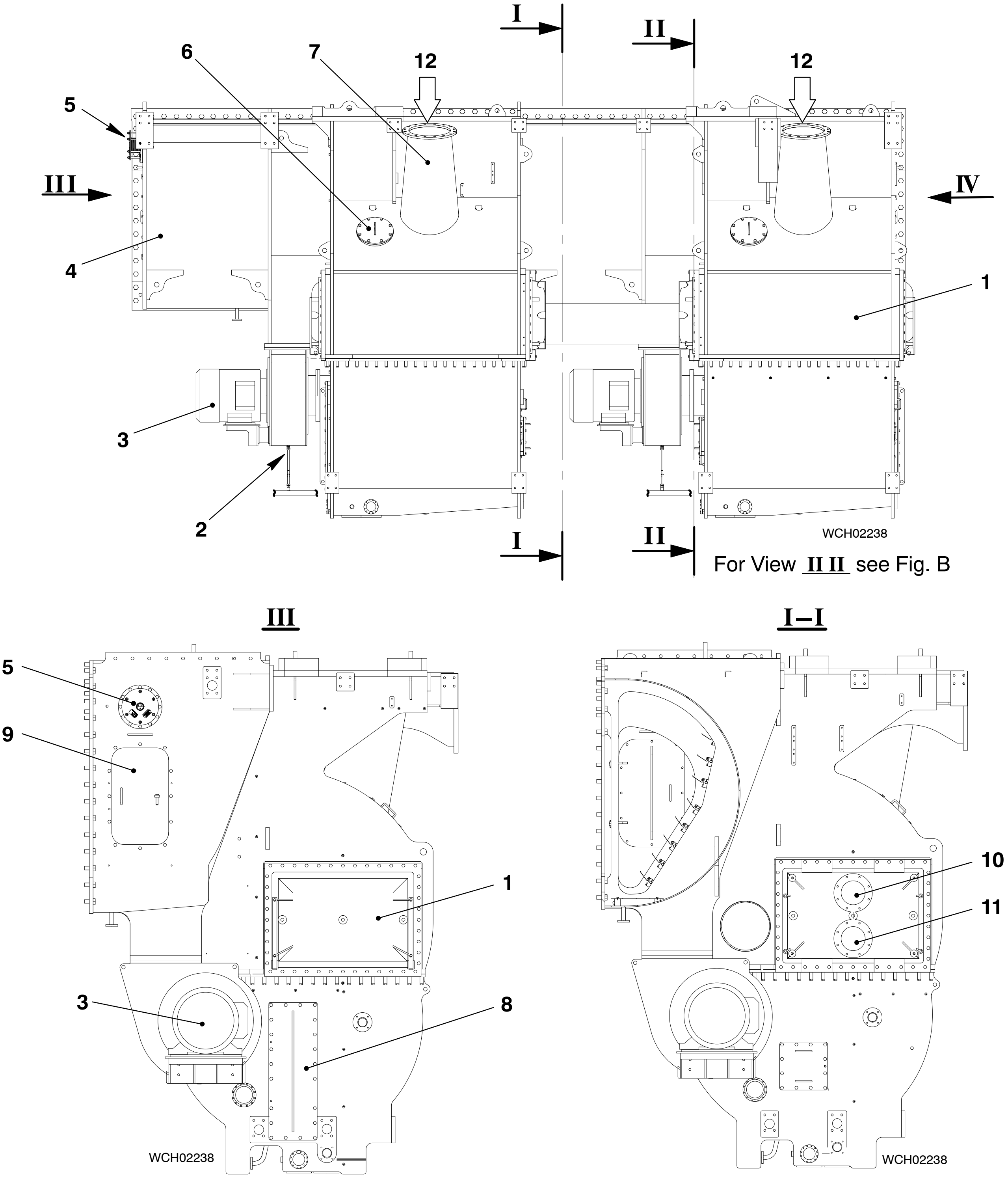

Fig. 1: Scavenge Air Receiver

1 Scavenge air cooler
2 Drain pipe (condensed water)
3 Auxiliary blower
4 Scavenge air receiver
5 Relief valve
6 Cover
7 Diffuser
8 Cover (water separator behind cover)
9 Cover
10 Scavenge air cooler inlet
11 Scavenge air cooler outlet
12 Scavenge air from turbocharger

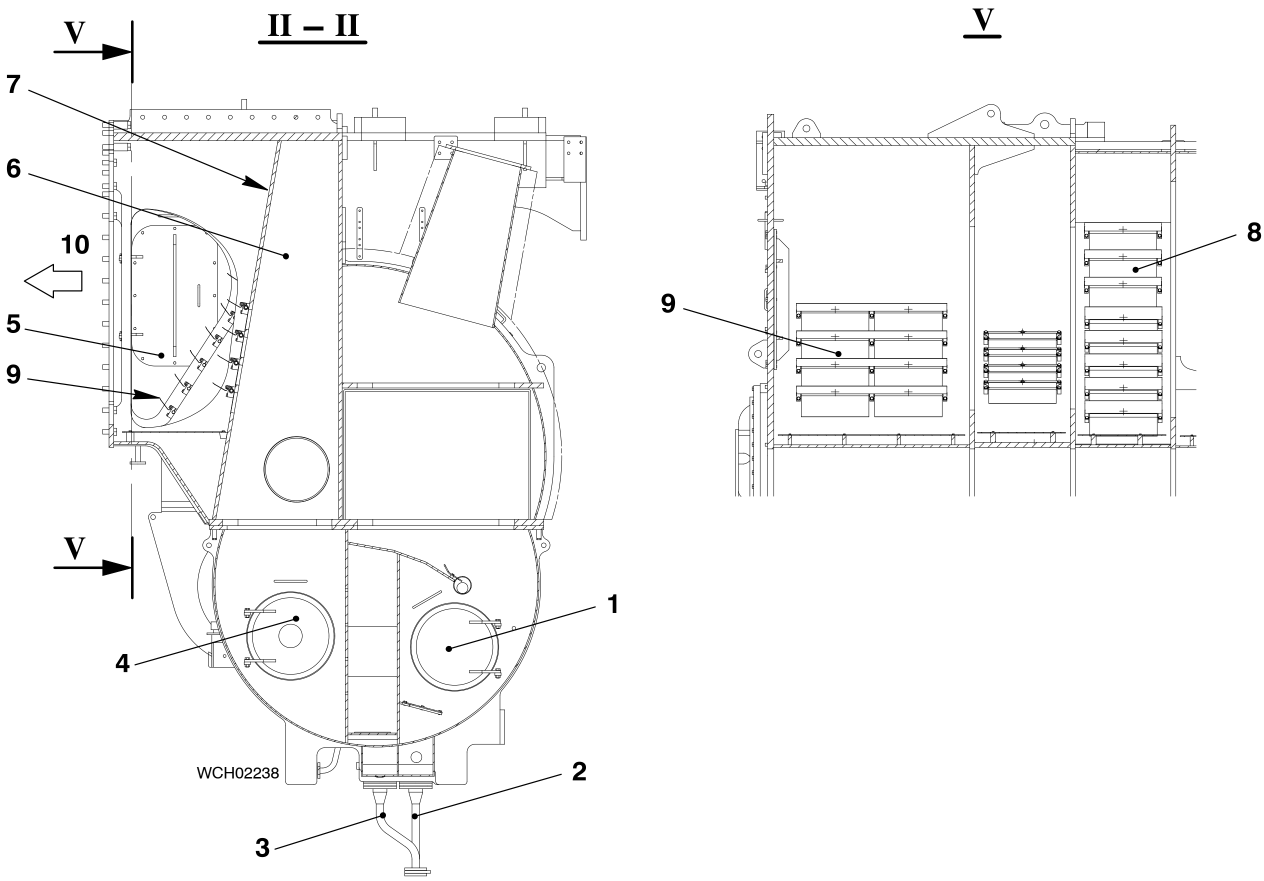

Fig. 2: Scavenge Air Receiver

1	Cover	6	Air space
2	Water drain (from water separator)	7	Longitudinal wall
3	Condensate drain from SAC	8	Flaps
4	Cover	9	Flaps
5	Receiver space	10	Piston underside

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Turbocharging

1. General

The turbocharger is accurately tuned to the engine and related to the number of cylinders, service output, mode of operation etc.

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 (EG, Fig. 1) from the cylinders collects in the manifold (15). The exhaust gas moves the turbine (16), then flows out through the exhaust gas outlet (EO) to the exhaust system of the vessel. The exhaust gas turns the turbine and moves the compressor (2), which is attached to the same shaft. The compressor pulls fresh air (FA) from the engine room through a filter/silencer.

The compressor compresses and heats the scavenge air (SA). This hot compressed air flows into the charging unit (5) through the scavenge air cooler (SAC) (3), which cools the air to a lower temperature range. Because of the high humidity in the air, the SAC produces a large quantity of condensation. The water separator (4) removes the condensation, which flows through the drains (WD and CD).

The scavenge air flows from the air space (AS) through the flaps 18 to the receiver space (RS) and then into the piston underside (PU).

When the piston (9) is near BDC, scavenge air flows through the open inlet ports (10) into the cylinder (12).

After the compression, combustion, and expansion process, the exhaust valve (14) opens and exhaust gas (EG) flows into the manifold (15), which completes the cycle.

During engine start, or low load operation the auxiliary blowers (8) supply air from the air space (AS) to the receiver space (RS). A non-return valve prevents the back-flow of air (see also 6420−1 Scavenge Air Receiver).

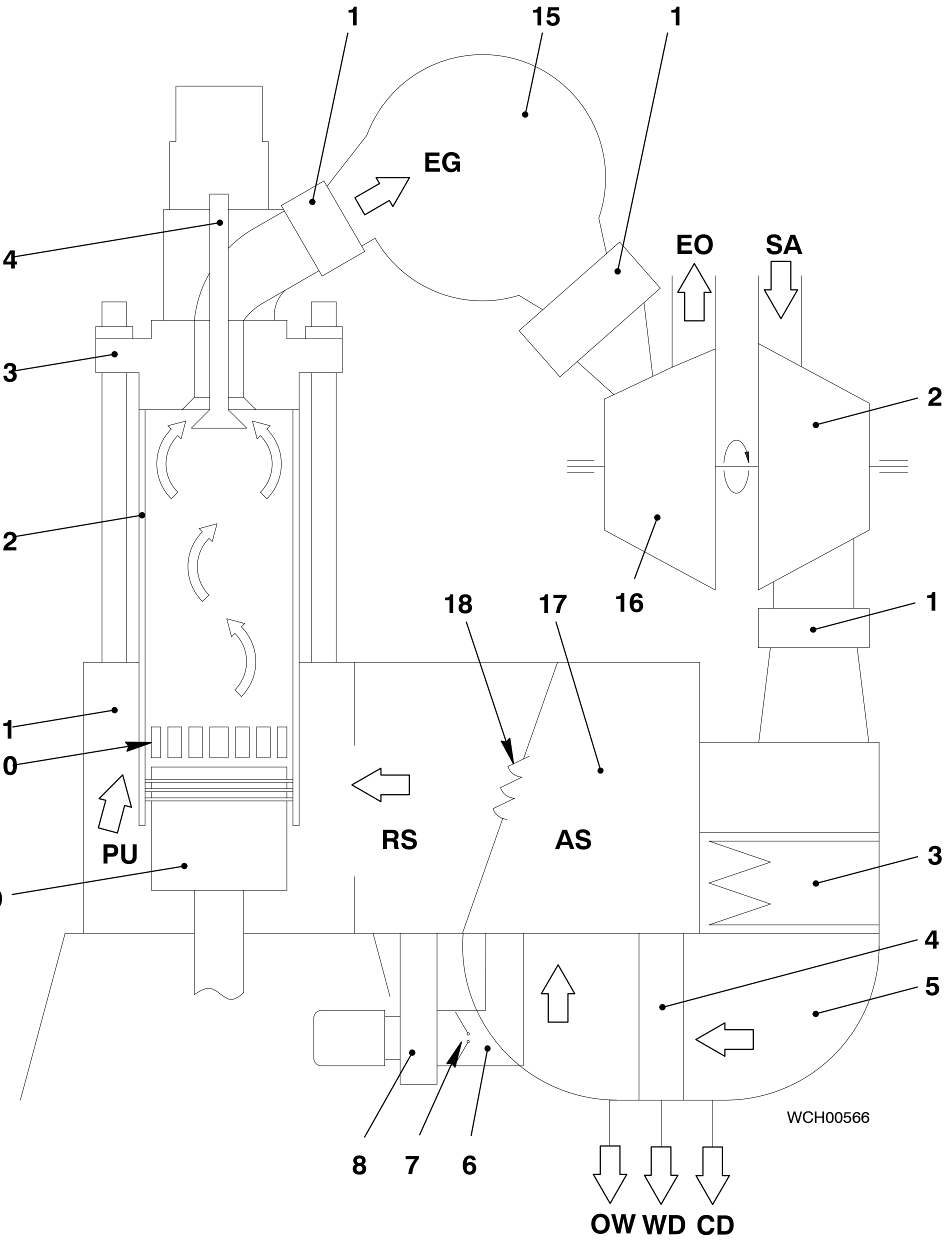

Fig. 1: Schematic Diagram − Turbocharger Operation

1	Expansion piece	15	Manifold
2	Compressor	16	Turbine
3	Scavenge air cooler	17	Receiver
4	Water separator	18	Flaps
5	Charging unit	AS	Air space
6	Air inlet duct	CD	Condensation drain from air cooler
7	Non-return valve	EG	Exhaust gas from cylinder
8	Auxiliary blower	EO	Exhaust gas, outlet
9	Piston	FA	Fresh air
10	Inlet ports	OW	Oily water drain
11	Cylinder block	PU	Piston underside
12	Cylinder liner	RS	Receiver space
13	Cylinder cover	SA	Scavenge air
14	Exhaust valve	WD	Water drain from water separator

Cleaning the Turbocharger during Operation

1. General

The turbochargers have a system to clean the turbine and the compressor. It is possible to clean the turbine and the compressor while the turbocharger operates. Regular procedures to clean the turbine and the compressor prevent or decrease contamination and increase the time between overhauls.

If the quantity of dirt becomes too much (scavenge air pressure decreases and exhaust gas temperature increases), the turbocharger must be disassembled and cleaned in accordance with the instructions given in the turbocharger manual. See 0250−1 Operating Data Sheet for the permitted pressure decrease.

To keep the silencer in a clean and serviceable condition, regular visual checks and procedures are necessary. Clean the silencer and filter only when the engine is stopped and in accordance with the instructions given in the applicable turbocharger manual.

Note: One more filter mat installed on top of the silencer will keep the contamination on the air side to a minimum, but will cause a loss of pressure.

If there is an increase in pressure difference Δp (of 50% compared to the shop test value at the same engine load) or the filter mat is dirty. To clean the filter mat, refer to the instructions given in the turbocharger manual.

2. Turbocharger cleaning

You can use the methods that follow to regularly clean the compressor and turbine:

- Wash the compressor
- Dry-clean the turbine (at full service load).

For data about the procedures to clean the turbocharger and the related intervals between the procedures, see the applicable turbocharger manual.

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Auxiliary Blower and Switch Box

1. Auxiliary blower

1.1 General

The electric motors (4, Fig. 1) operate the two auxiliary blowers (2), which are installed on the scavenge air receiver (3). The auxiliary blowers supply air from the air space through the duct (1) into the receiver space during the engine start and operation at low load. Flaps prevent the back-flow of air to the scavenge air receiver (see 6420-1 Scavenge Air Receiver).

Note: If the auxiliary blower is out of service for a long period, do the procedure given in 0620–1 Prepare the Engine for a Long Shutdown Period, paragraph 2.2 Procedures and Checks.

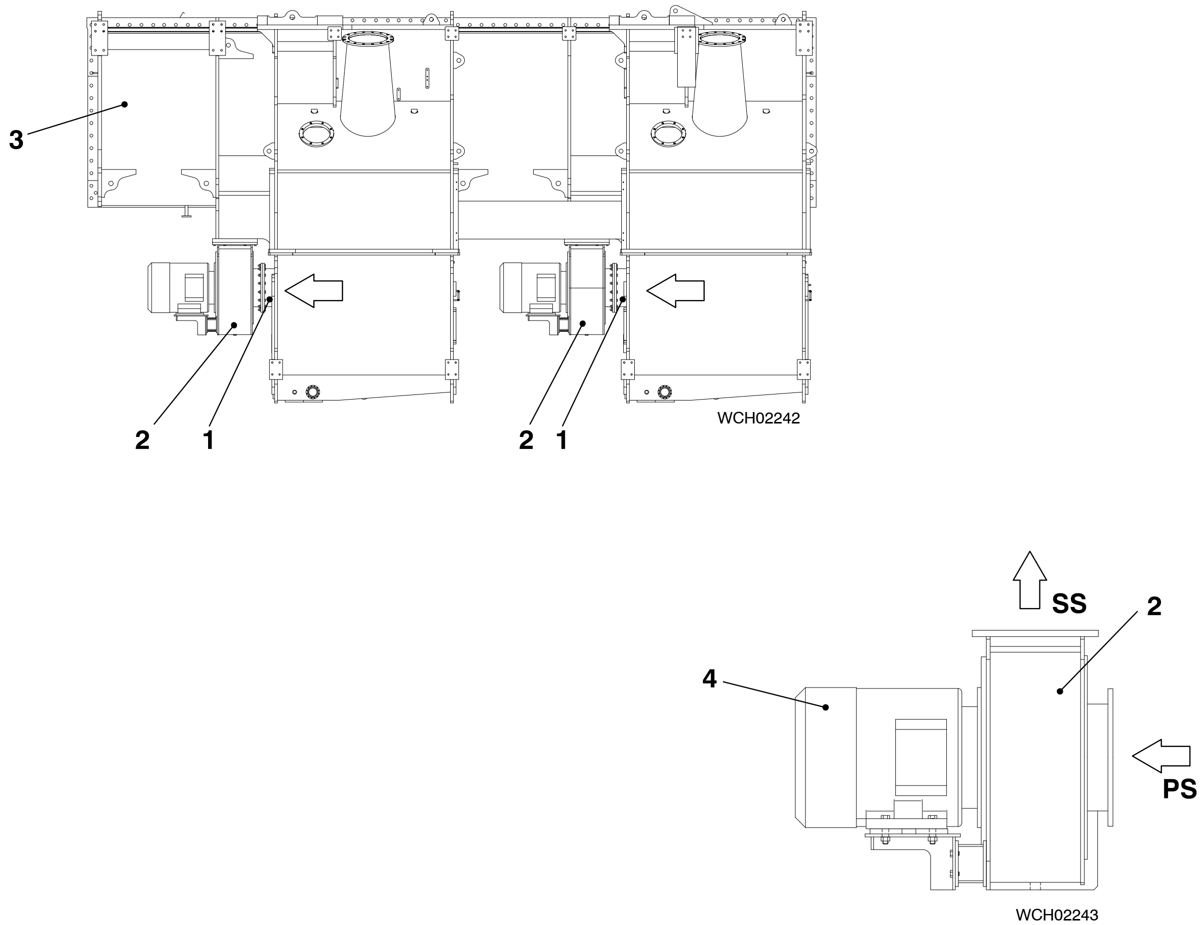

Fig. 1: Location of Auxiliary Blowers

1	Duct	4	Electric motor
2	Auxiliary blower (left hand design)	PS	Pressure side
3	Receiver	SS	Suction side

2. Switch box

2.1 General

The engine builder supplies an electrical switch box (5, Fig. 2) for each auxiliary blower.

2.2 Function

During the engine start procedure, the first auxiliary blower starts immediately. After approximately two to three seconds, the other auxiliary blower starts.

When the turbocharger produces sufficient pressure in the scavenge air receiver, the auxiliary blowers stop.

If the scavenge air pressure decreases below the minimum pressure necessary, the auxiliary blowers operate as given above (for more data, see 4003−1, paragraph 4.5 Auxiliary Blowers).

Note: For emergency operation, if both scavenge air pressure transmitters (PT4043C and PT4044C) become defective, you can control the auxiliary blowers manually.

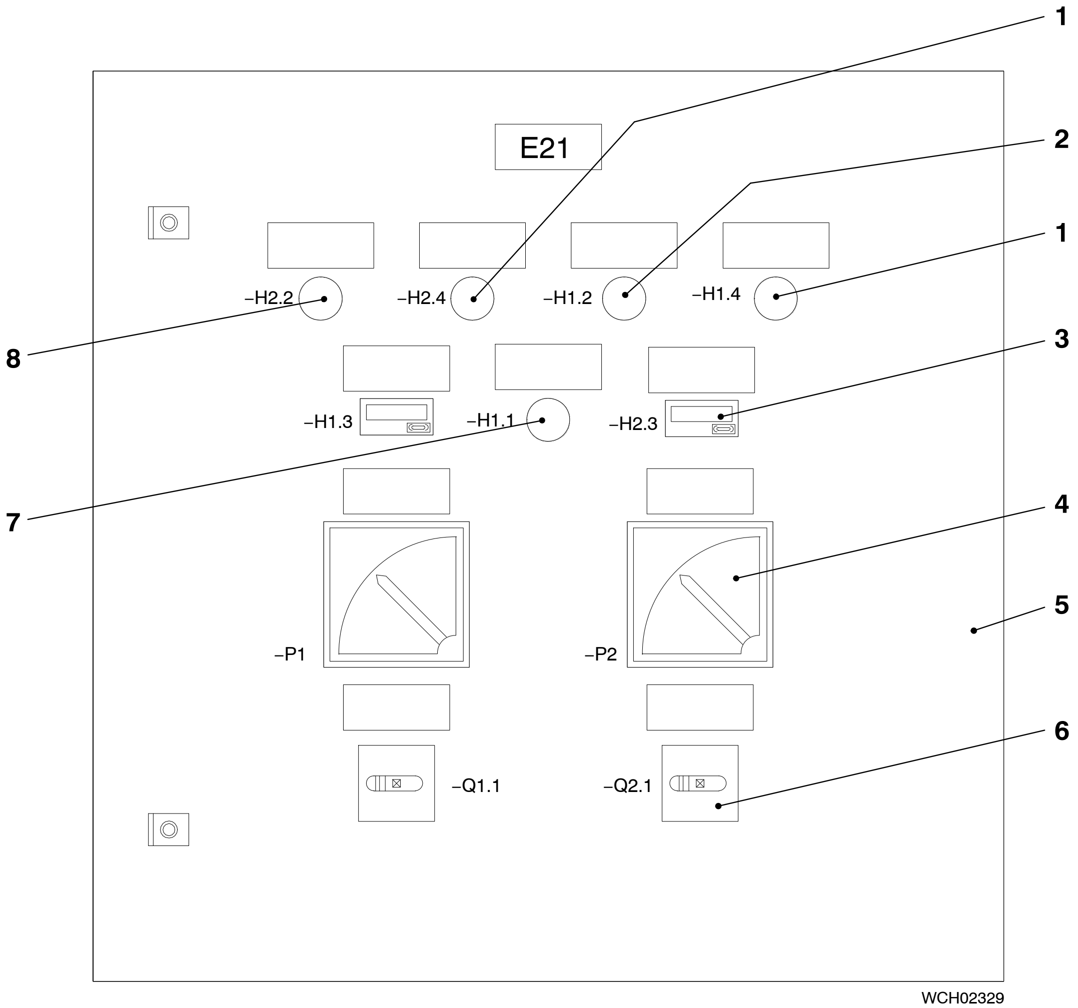

Fig. 2: Switch Box

1 Overload indicator
2 In operation indicator
3 Main switch
4 Ampere meter
5 Switch box
6 Hour counter
7 Control voltage indicator
8 In operation indicator

Scavenge Air Cooler

1. General

A Scavenge Air Cooler (SAC) is installed downstream of the turbocharger. The SAC decreases the temperature of the compressed / heated air that flows from the turbocharger. The standard cooler is a single-stage multi-pass item. The water flows through the cooler in the opposite direction of the air flow more than one time. The temperature difference of the water and scavenge air is thus applied equally along all of the SAC.

2. Operating Instructions

If air collects in the cooling water system of the SAC, problems for the engine and the SAC can occur. Thus, the SAC must operate correctly.

You must do regular checks of the SAC temperature. See the data in 0250-1 Operating Data Sheet.

If the level switch (15, Fig. 1) of the condensate collector (9) activates an alarm during operation, the cause (condensate water or SAC cooling water) must be found. If the cause is SAC cooling water, the SAC must be disassembled and repaired (see the Maintenance Manual 6606−1).

To prevent damage to the SAC, the cooling water must flow correctly during operation. The cooling water flow must not be decreased at part load, or during maneuvering.

CAUTION

Damage Hazard: Do not use the butterfly valves at the cooling water inlet and outlet pipes to control the flow rate. The water separators (which are plastic) could be damaged because the scavenge air temperatures are too high at higher loads.

For data about operation with a defective SAC, see 0550-1 paragraph 1.

During correct operation of the SAC, record the temperature difference between the scavenge air outlet and the cooling water inlet. You use the temperature difference as a guide. You must do regular checks of the two temperature values and compare them with the temperatures you recorded.

If the temperature difference increases and the engine load and cooling water flow do not change, the SAC is dirty.

If the water side of the SAC is dirty, the scavenge air temperature increases.

If the air side of the SAC is dirty, the pressure difference (Δp) of the scavenge air through the SAC increases. This does not show the full effect of the dirt because an increased resistance also causes a decreased air flow from the turbocharger. For more data about the SAC during operation, see 0250-1 Operating Data Sheet.

Higher scavenge air temperature and decreased air flow cause increased thermal load of the engine and higher exhaust gas temperatures.

You can clean the air side of the SAC during engine operation, see paragraph 3.

You can clean the water side of the SAC only when the engine has stopped. For data to clean the water side of the SAC, see the Maintenance Manual 6606-1.

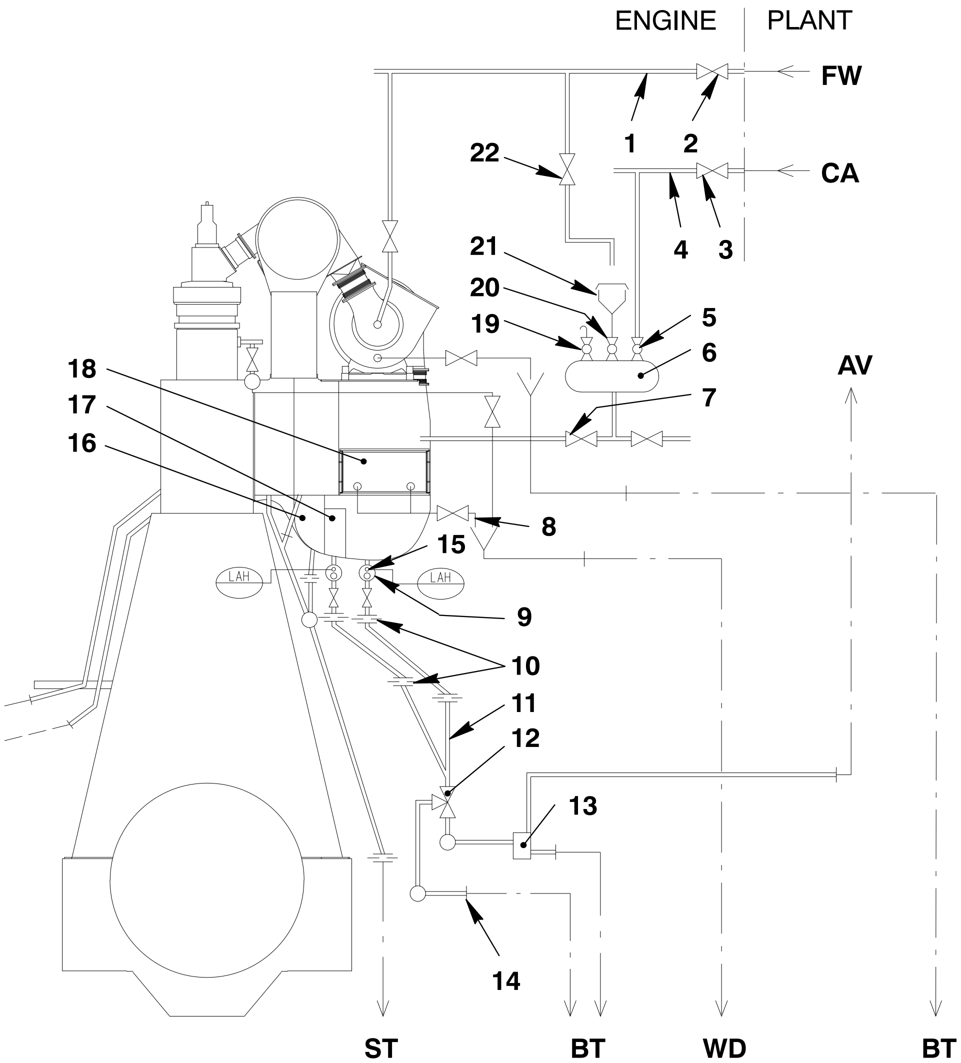

Fig. 1: Location of Wash-water System Parts

1	Fresh water supply pipe	16	Receiver
2	Ball valve	17	Water separator
3	Ball valve	18	Scavenge air cooler (SAC)
4	Compressed air supply pipe	19	Shut-off valve (vent)
5	Shut-off valve	20	Shut-off valve
6	Container	21	Funnel
7	Ball valve	22	Shut-off valve
8	SAC drain		
9	Condensate collector		
10	Throttle disc	AV	Vent
11	Condensate and wash-water drain	BT	Drain to bilge water tank
12	3-way ball valve	CA	Compressed air from board system 7.0 bar to 8.0 bar
13	Vent unit	FW	Fresh water 2.5 bar
14	Cleaning fluid and wash-water drain	ST	Drain to sludge water tank (oleiferous)
15	Level switch	WD	Drain to water drain tank

3. SAC Air Side – Clean during Operation

The equipment necessary to clean the air side of the SAC is installed on the engine.

3.1 Intervals

Initially, it is recommend that you clean the SAC one time each week. If there is no change in the pressure difference (Δp) through the SAC, the interval can be extended (e.g. one time each month).

The pressure difference must not be more than the maximum limit (Δp increase of 50% compared to the shop test value at the same engine load). For more data, see the Maintenance Manual 0380-1).

The quantity of contamination in the SAC is related to the condition of the airflow into the SAC and the maintenance of the air suction filter on the turbocharger.

Note: It is recommended that you do not clean the SAC in tropical conditions because of increased condensation.

3.2 Cleaning Agents

Use cleaning agents only from recommended suppliers. You must follow the instructions in the supplier documentation for the applicable water/cleaning fluid ratios.

For in-service cleaning, use only those fluids that have a sufficiently high flash point.

3.3 Procedure

Clean the SAC while the engine operates at less than 50% load (see also the instruction panel on the engine). The air temperature downstream of the compressor (turbocharger) must not be more than 100°C. This is because heat will change too much of the cleaning agent to a gas.

1) Decrease the engine power to the value given before.
2) Make sure that compressed air and fresh water are available at the shut-off valves (1 and 12, Fig. 2).

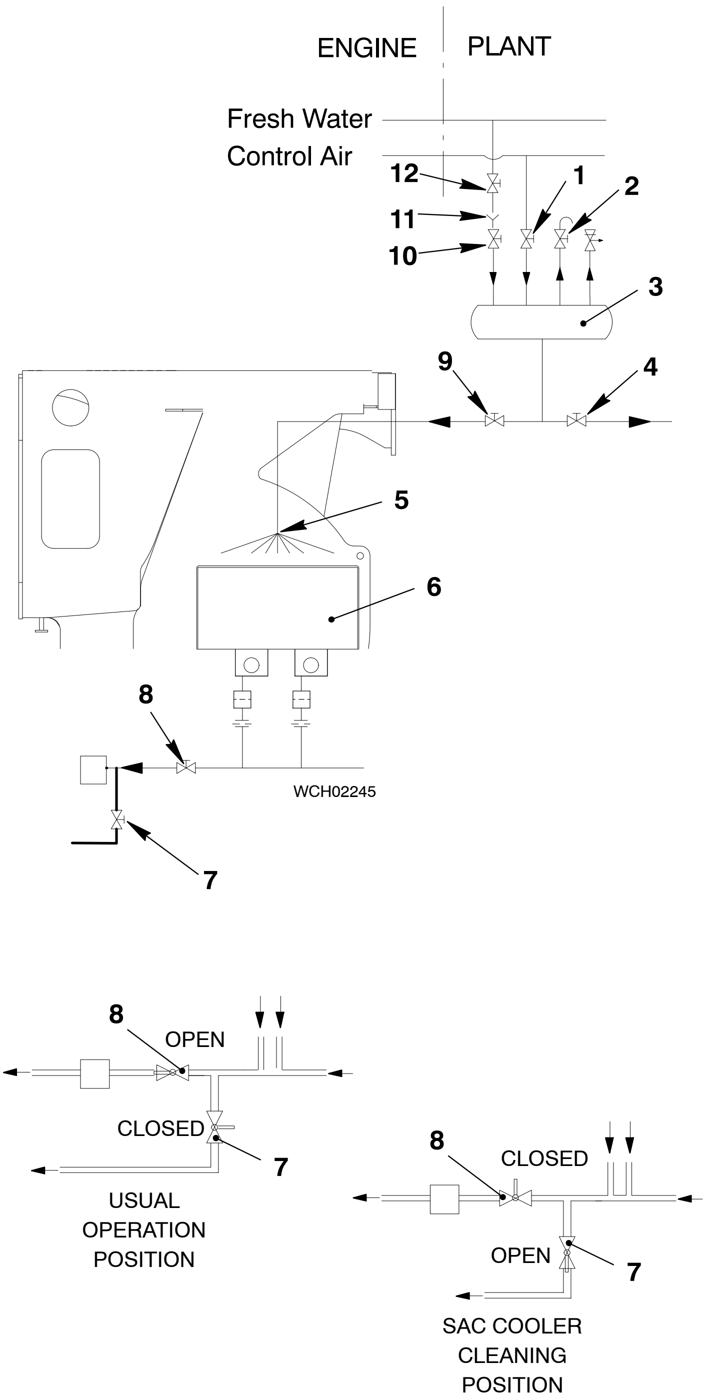

Fig. 2: SAC Air Side – Clean

3) Open the ball valves (2 and 10, Fig. 2).
4) Carefully open the ball valve (12) sufficiently to prevent back-flow of water in the funnel (11).
5) Fill the air tank (3) through the funnel (11) with fresh water and the specified quantity of cleaning fluid (max 20 liters) (see paragraph 3.2).

Note: You can also use a hand-held container filled with cleaning fluid mixed with fresh water to put into the funnel (11). When you use this method, make sure that the shut-off valve (12) stays closed.

6) Close the ball valves (2 and 10).
7) Open the ball valve (1).
8) Open the ball valves (4 and 9). The water/cleaning fluid comes out of the nozzles (5) as a spray into the SAC (6) for approximately one minute.
9) Close the ball valve (8).
10) Open the ball valve (7).
11) Close the ball valve (1).
12) Close the ball valves (4 and 9).
13) Open the ball valve (2) until the air tank has no pressure.
14) After 10 minutes, do the procedure again with only fresh water (do not use cleaning fluid).
15) Open the ball valve (8).
16) Close the ball valve (7)
17) The procedure is completed.

Note: Dirt particles that are loosened from the cooling fins can collect in the water separator or the scavenge air receiver. Do a check of the cooling fins and clean if necessary (see the Maintenance Manual).

3.4 Instruction Leaflets

Data about operation, maintenance and repair of the SAC are given in the Instruction Leaflets from the engine manufacturer or supplier.

You can get these Instruction Leaflets directly from the manufacturers. It is also possible to send an order for Instruction Leaflets from the engine manufacturer or supplier.

When you send an order for Instruction Leaflets, you must give the data that follows:

- The engine type and number
- The engine supplier
- The SAC manufacturer and type
- The applicable language.

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Scavenge Air Waste Gate

1. General

Some engine versions have a scavenge air waste gate, which protects the engine from scavenge air pressure that is too high in arctic conditions (when the outside air temperature is below -5°C). The waste gate operates as a safety valve, i. e. the overpressure is blown off into the engine room.

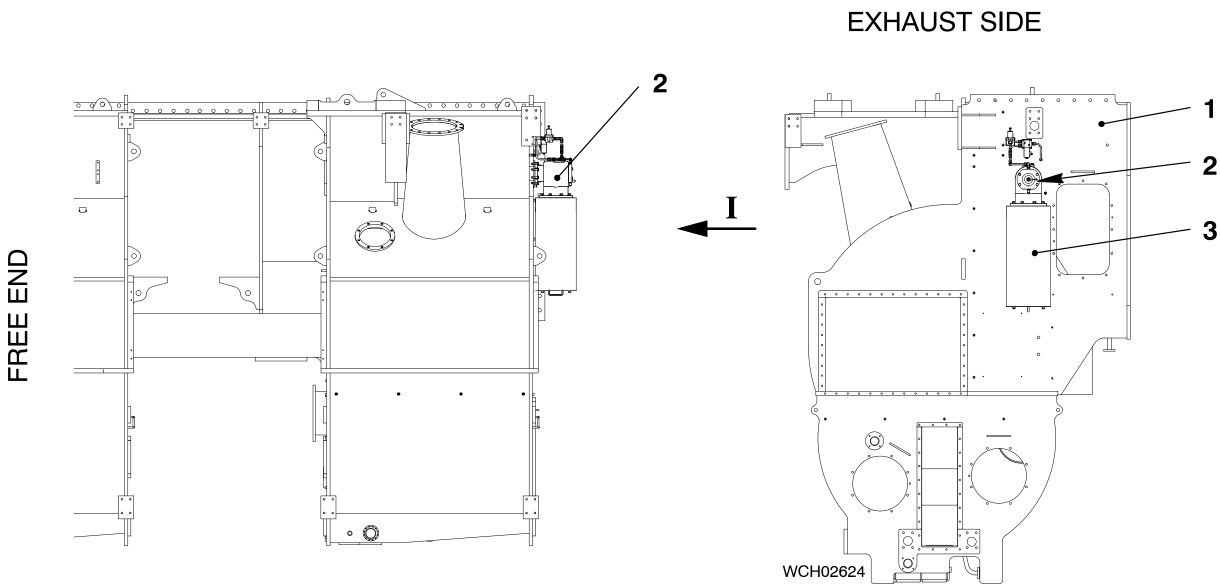

Fig. 1: Location of Scavenge Air Waste Gate

1 Scavenge air receiver
2 Waste gate valve
3 Silencer

2. Operation

During usual operation conditions, scavenge air flows through the non-return valve (4, Fig 2) into the pressure space (13). This pressure, and the pressure from the compression spring (7), keep the piston (6), and thus the waste gate valve, in the closed position.

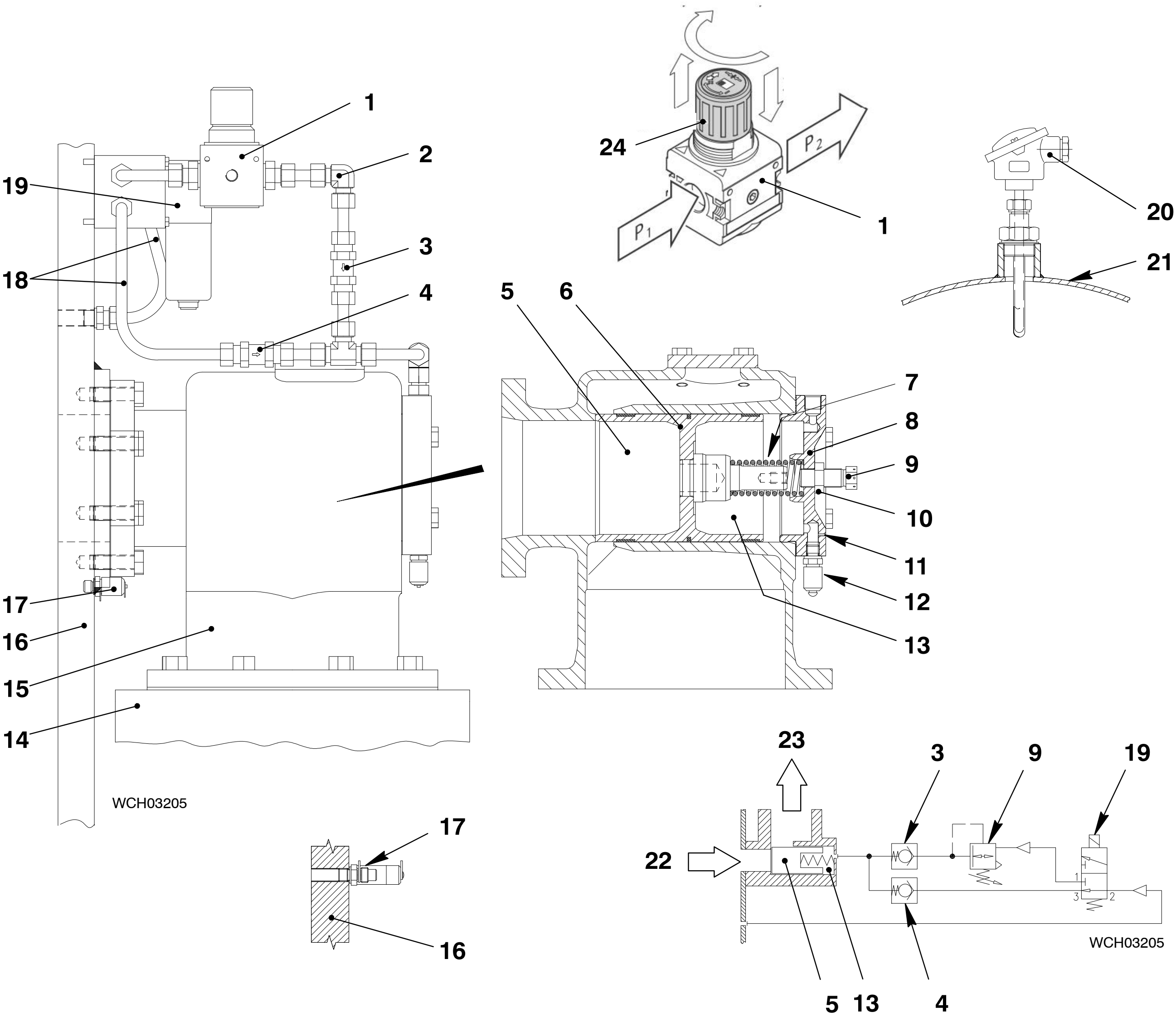

Fig. 2: Waste Gate Valve and Control Diagram

1	Pressure control valve	13	Pressure space
2	Scavenge air pipe	14	Silencer
3	Non-return valve	15	Valve housing
4	Non-return valve	16	Scavenge air receiver
5	Pressure area (scavenge air pressure)	17	Test connection (scavenge air)
6	Piston	18	Scavenge air pipes
7	Compression spring	19	Solenoid valve
8	Cover	20	Temperature sensor (TE3991C)
9	Adjustment screw (piston stroke)	21	Air suction duct to turbocharger
10	Locknut	22	Scavenge air inlet
11	Vent bore	23	Scavenge air outlet
12	Test connection (valve)	24	Adjustment knob

2.1 Open and Close Phases

When the outside air temperature decreases below the values given in Table 1, the solenoid valve (19, Fig. 2) energizes. The scavenge air pressure flows through the pressure control valve (1), then through the non-return valve (3) to the pressure space (13). The pressure in the pressure space (13) decreases.

Table 1: Temperatures and Pressures

Waste Gate Valve Movement	External Temperatures	
	Engine without WHR	Engine with WHR
Opens at	+5° C	–5° C
Opens at	+10° C	0° C
	Pressures	
Opens at	0.75 bar	0.7 bar

Note: WHR (Waste Heat Recovery System)

The decreased pressure in the pressure space (13) is now less than the pressure in the pressure area (5). The pressure in the pressure area (5) moves the piston (6) against the force of the compression spring (7) and the waste gate valve opens. Scavenge air then flows through the silencer into the engine room.

The temperature sensor (20) (TE3991C) measures the outside air temperature to energize/ de-energize the solenoid valve (19).

When the solenoid valve energizes, the waste gate valve opens.

When the solenoid valve de-energizes, the waste gate valve closes.

3. Adjustments

3.1 Valve Stroke Check

This task is only necessary after faults, overhauls or when the waste gate valve was replaced.

Do this check when the engine has stopped, or when the engine operates at a load of 75% or less at the usual suction temperatures (more than +5°C).

1) Remove and discard the lockwire from the adjustment screw (9).
2) Loosen the locknut (10).
3) Turn the adjustment screw (9) fully clockwise to its limit.
4) Adjust the nominal piston stroke with reference to Table 1 (one full turn of the adjustment screw (9) is equal to a piston movement of 1.5 mm).

Table 2: Valve Stroke

Number of Cylinders	Number of Waste Gates	Piston Stroke (mm)	Number of Turns
5	1	4.5	3.0
6	1	5.25	3.5
7	1	6.0	4.0
8	1	6.75	4.5

5) Tighten the locknut (10).
6) Lock the adjustment screw (9) in position with lockwire.

3.2 Pressure Check

You use the pressure control valve to adjust the pressure that opens the waste gate valve.

1) Operate the engine at approximately 50% load (when the scavenge air pressure is more than 1.0 bar).

Note: For the pressure that opens the valve, see Table 1.

2) Connect a pressure gauge to the test connections (12, 22) (scavenge air pressure is more than 1.0 bar).

3) Energize the solenoid valve (20, Fig. 2) (this simulates low temperature in the air intake).

4) If the pressure gauge shows a pressure difference, do as follows:

   a) On the pressure control valve (1), lift up the adjustment knob (24) to unlock.

   b) Turn the adjustment knob (24) to adjust the pressure that opens the waste gate valve.

   c) Push down the adjustment knob (24) to lock.

4. Function Check

You must do the function checks at six-monthly intervals during engine operation. Also, you must do these function checks before voyages in regions of arctic conditions.

1) At an engine load of approximately 50%, energize the solenoid valve (19, Fig.).

2) Make sure that the waste gate valve opens.

Note: When the waste gate opens, scavenge air flows through the silencer.

If a malfunction in the waste gate occurs, you must do an overhaul as soon as possible. Refer to the Maintenance Manual 6735−1.

Cylinder Lubrication Group 7

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Cylinder Lubrication

1. General

The cylinder lubricating system operates independently to lubricate the cylinder liners and pistons. The engine control system (ECS) controls the adjustable load-related supply rate of lubricating oil to each lubrication point.

1.1 Cylinder Lubricating Oil

During usual operation, a high-additive, alkaline cylinder lubricating oil is necessary. The alkalinity of the lubricating oil that is chosen is related to the sulphur content of the fuel (see 0750-1 Operating Media, paragraph 3).

1.2 Running-in

For running-in, approved cylinder lubricating oil is recommended (see 0410-1 Running-in of New Cylinder Liners and Piston Rings).

1.3 Cylinder Lube Oil Tank (Plant Side)

The cylinder lube oil tank (1, Fig. 1) for the cylinder lubricating oil is installed at a specified height above the engine. This lets static pressure move the oil down through the duplex filter (4).

The ECS sends signals to the control valve (2) on each cylinder lubricating pump. This operates the pump and activates an injection. The pressure transmitter (3) monitors the injection pressure.

2. Lubricating Oil System – Overview

The diagram Fig. 1 shows the complete system, which has the components that follow:

- Cylinder lube oil tank (1) for cylinder lubricating oil (plant side)
- Duplex filter (10) with a lever to change filters
- Lubricating quills (2) with a non-return valve and an injection nozzle
- System control from the ECS (see 4002-1, paragraph 3.4 Cylinder Lubricating Control).

The cylinder lubricating pumps 25-7230_C#_1 (one for each cylinder) have the parts that follow:

- Cylinder control module 20 (CCM-20)
- 4/2-way solenoid valve (2)
- Pressure transmitter (3).

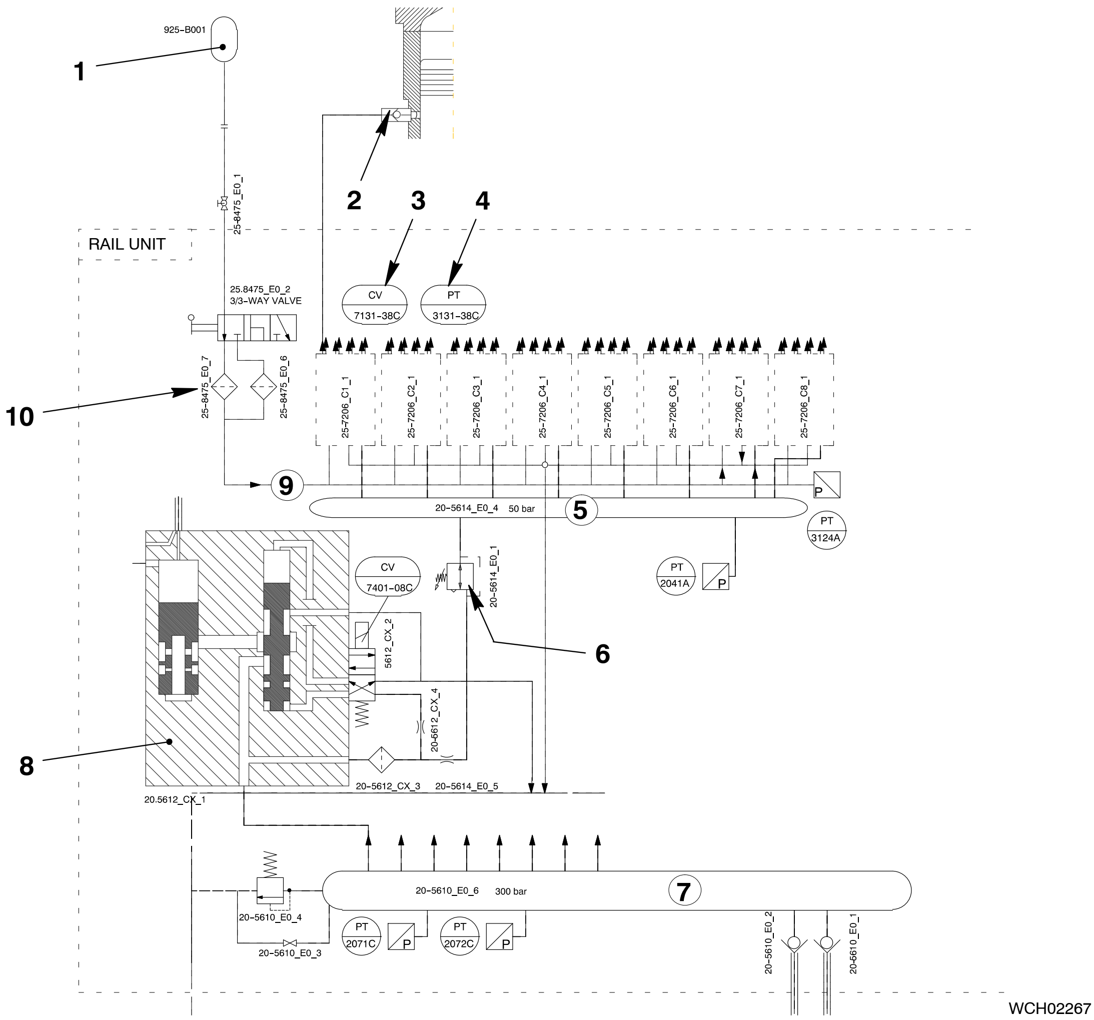


Fig. 1: Schematic Diagram – Cylinder Lubrication System

1	Cylinder lube oil tank	6	Pressure reducing valve
2	Lubricating quills	7	Servo oil rail
3	Control valve CV7131C – CV7138C	8	Exhaust valve control unit
4	Pressure transmitter PT3131C – PT3138C	9	Lubricating oil supply pipe
5	Servo oil supply pipe	10	Duplex filter

3. Cylinder Lubricating Oil Supply

3.1 Supply Pipe − Cylinder Lubricating Oil

Cylinder lubricating oil from the tanks (1, Fig. 1) flows through the lubricating oil inlet pipe (5, see Fig. 3) to the duplex filter (6). The filtered cylinder lubricating oil flows through the lubricating oil inlet pipe (7) into the lubricating oil supply pipe (8) to the cylinder lubricating pumps (1).

In usual operation, the cylinder lubricating pumps (1) supply the necessary oil pressure to the eight lubricating quills on each cylinder. The pressure transmitters PT3131C to PT313#C are connected to the ECS and monitor the pressure.

The pressure transmitter PT3124A (see Fig. 1) monitors the pressure in the lubricating oil supply pipe (8, Fig. 2).

If there is no lubricating oil supply pressure (less than 0.1 bar), the pressure transmitter PT3124A sends an alarm signal to the ECS. For more data see 4002−1 Engine Control System, paragraph 3.4 Cylinder Lubricating Control.

For more data, see 4003−2 Control Diagram and 4003−3 Control and Auxiliary Systems.

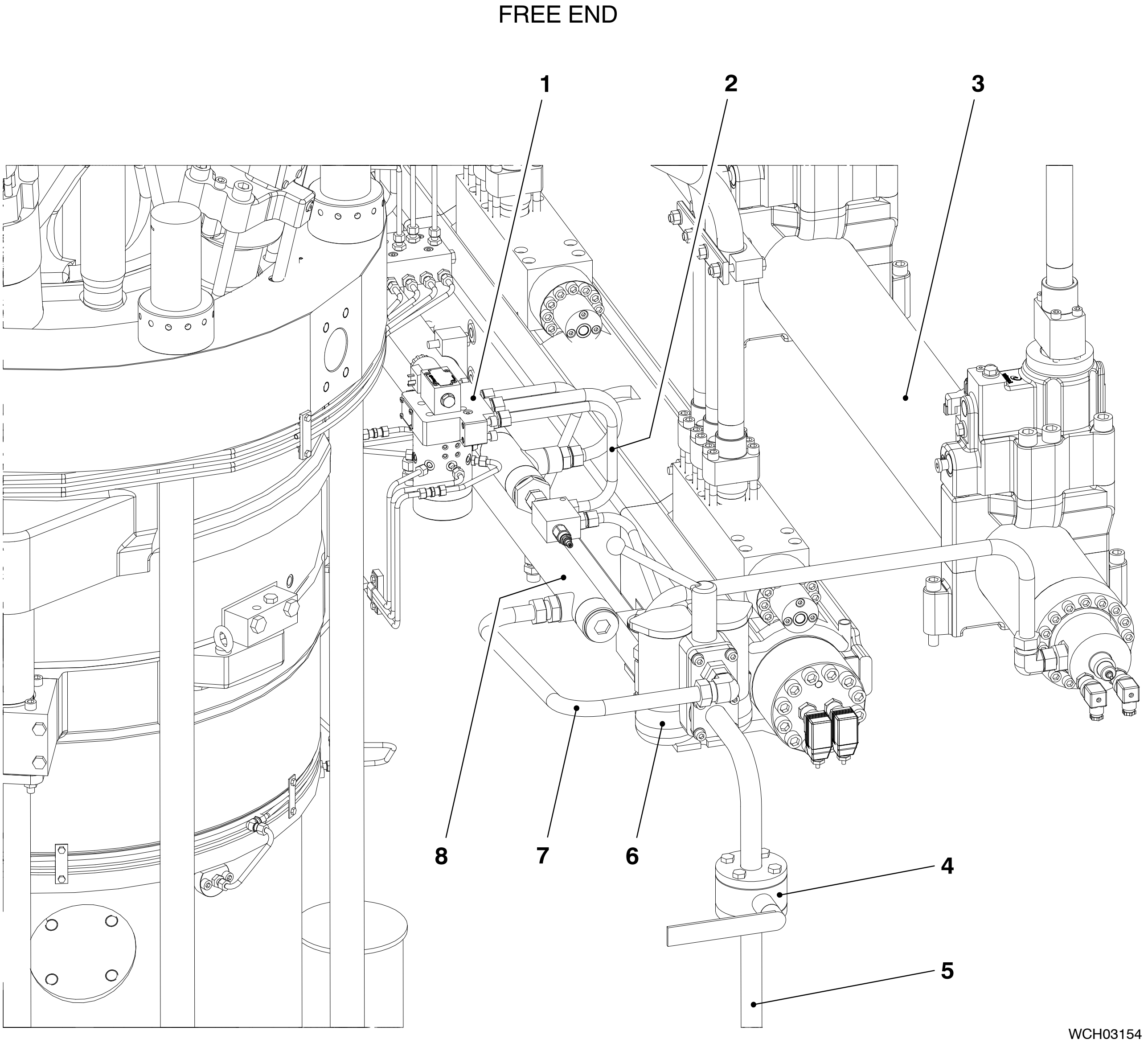


Fig. 2: Cylinder Lubricating Oil Supply

1 Cylinder lubricating pump
2 Lubricating oil inlet
3 Servo oil rail
4 Ball valve
5 Lubricating oil inlet pipe
6 Duplex filter
7 Lubricating oil inlet pipe
8 Lubricating oil supply pipe

4. Servo Oil Supply

Servo oil from the servo oil rail (7, Fig. 3) flows through the exhaust valve control unit (8) to the servo oil inlet pipe (6). Servo oil then flows through the servo oil supply pipe (2) and the servo oil inlet (3) into the cylinder lubricating pumps (5). The servo oil operates the cylinder lubricating pumps (5). For more data see paragraph 5.

The servo oil flows from the cylinder lubricating pumps (5) through the servo oil outlet (4) into the servo oil return pipe and back to the plant.

The pressure transmitter PT2041A (1) monitors the pressure in the servo oil supply pipe (2). If there is no servo oil supply pressure or the supply pressure is less than 40 bar, the pressure transmitter PT2041A (1) sends an alarm signal to the ECS. For the values, see 0250–2 Operating Data Sheet.

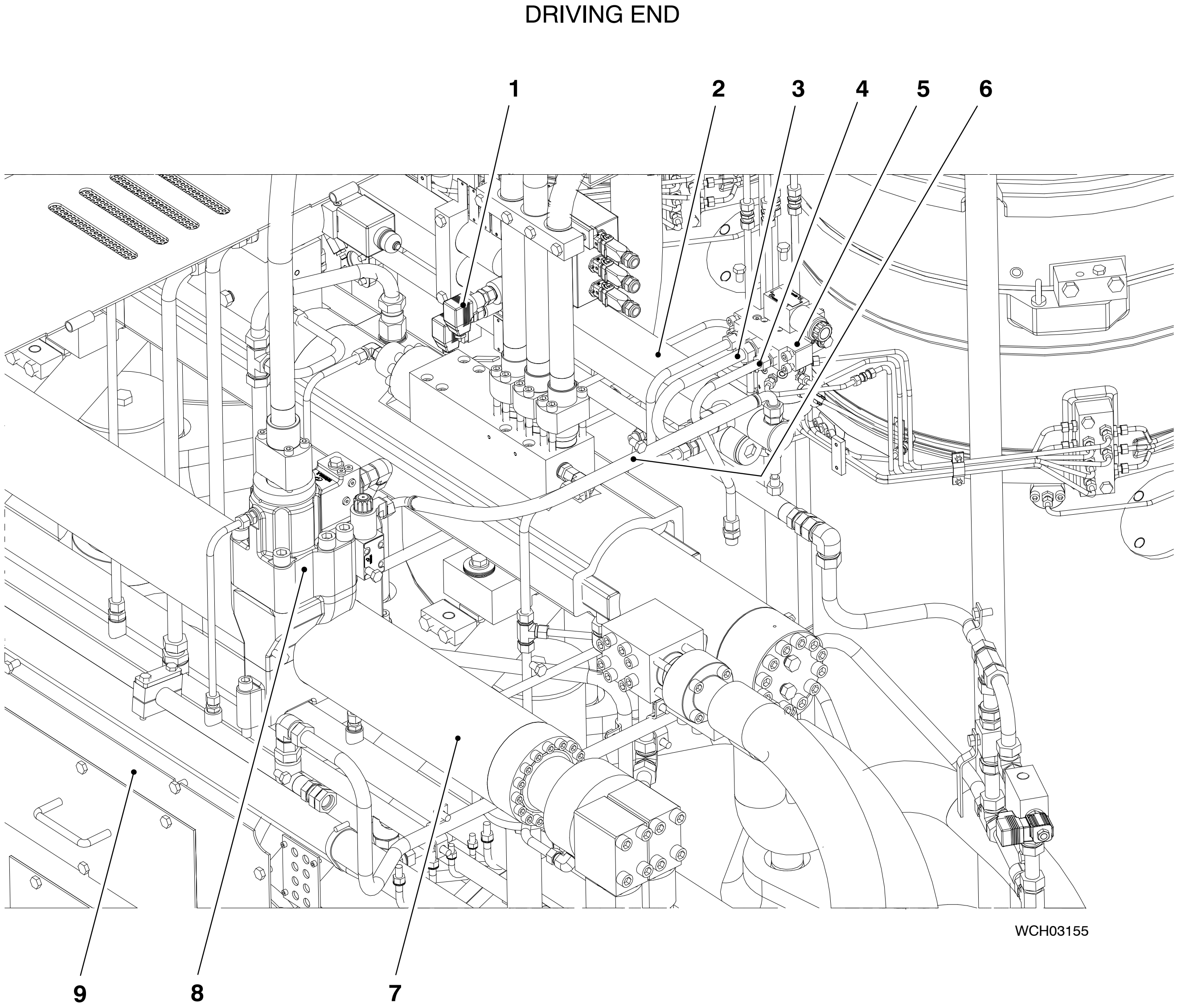


Fig. 3: Cylinder Lubricating System – Servo Oil Supply

1 Pressure Transmitter PT2041A
2 Servo oil supply pipe
3 Servo oil inlet
4 Servo oil outlet
5 Cylinder lubricating pump
6 Servo oil inlet pipe
7 Servo oil rail
8 Exhaust valve control unit
9 Rail unit

5. Cylinder Lubricating Pump

5.1 General

Each cylinder has a self-contained cylinder lubricating pump (5, Fig. 2) installed on a support in the rail unit (2, Fig. 3). All of the cylinder lubricating pumps are connected to supply pipes in the rail unit. Servo oil flows into a collector pipe installed below the rail unit.

Servo oil operates the cylinder lubricating pumps when the related control signals are released from the ECS.

Note: If a cylinder lubricating pump becomes defective and the safety system releases a slow-down signal, the fuel injection of the related cylinder must be cut out (see 0510-1 Operation during Unusual Conditions).

The cylinder lubricating pump has a pump body, 4/2-way solenoid valve (1) and a pressure transmitter (6).

Two bushes are installed in the cylinder lubricating pump. The low feed rate (LFR) bush is installed on the adjustment screw (7). The high feed rate (HFR) bush is installed in the storage position (2). For more data about these bushes and the related change procedure, see 7218–1.

5.2 Function

When the ECS sends a signal to the 4/2-way solenoid valve (1) on one of the cylinder lubricating pumps, the 4/2-solenoid valve operates, which causes an injection.

A specified quantity of high pressure cylinder lubricating oil is injected through the outlet ports (3) of the cylinder lubricating pump. This high pressure lubricating oil flows through the oil pipes (4) to the lubricating quills (5) on the related cylinder.

5.3 Cylinder Lubricating Pump – Bleed

To bleed the cylinder lubricating pump, the cylinder lubricating system must be ready for operation (see 0140-1 Prepare the Cylinder Lubricating System).

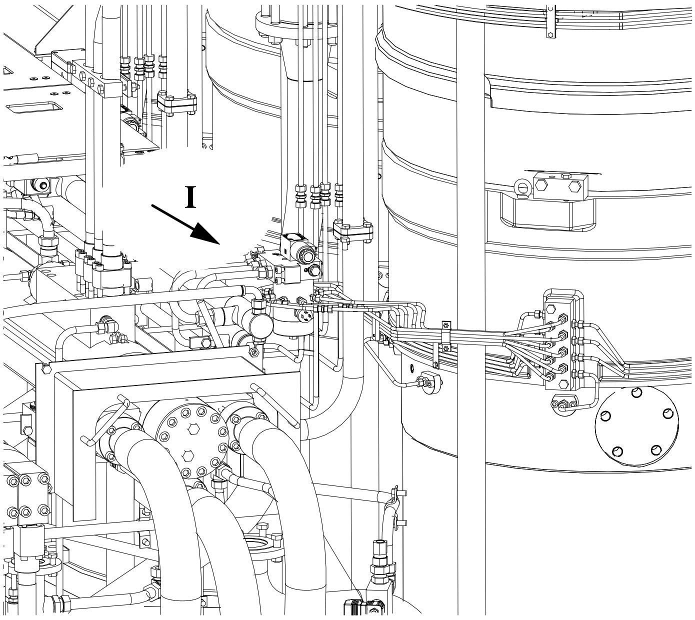
To bleed the cylinder lubrication system, see paragraph 6 and the procedure given in the Maintenance Manual 7218-1.

5.4 Cylinder Lubricating Pump/Components – Maintenance

For an overhaul, or a replacement of the cylinder lubricating pump, send the pump/components to the manufacturer.

For faults, causes and repair procedures, see 0820-1 Operating Problems, paragraph 2 Cylinder Lubrication, and the supplier documentation for the cylinder lubricating pumps.

DRIVING END



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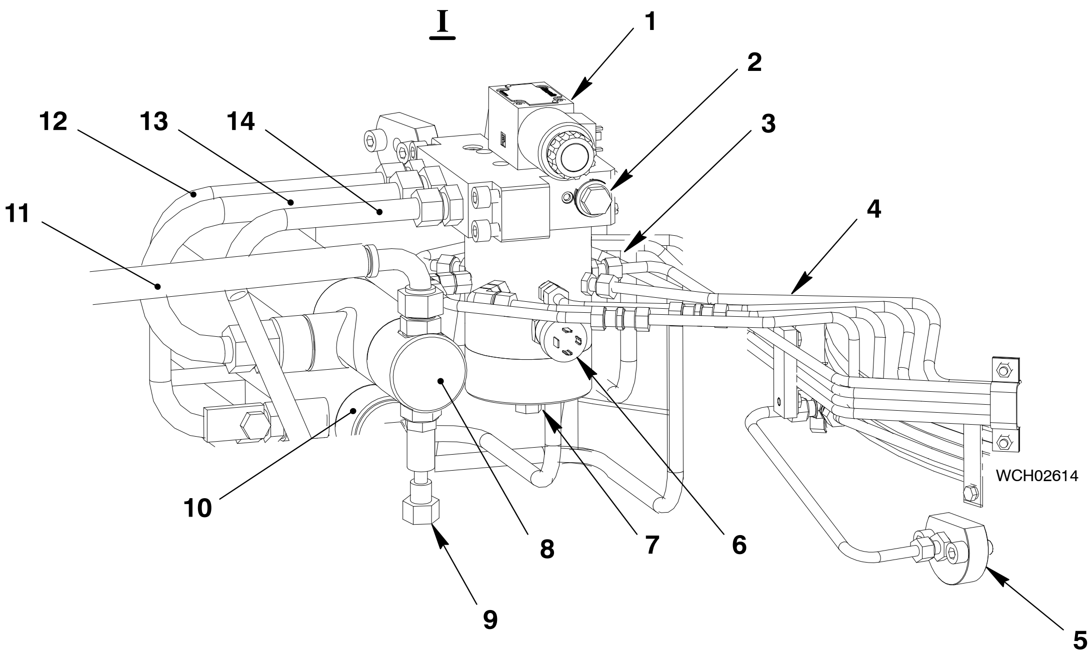

Fig. 4: Cylinder Lubricating Pump

1	4/2-way solenoid valve (CV7131–38C)	8	Servo oil supply pipe
2	Storage position for HFR bush	9	Pressure relief valve
3	Outlet port	10	Lubricating oil supply pipe
4	Oil pipes	11	Servo oil – supply pipe
5	Lubricating quill	12	Lubricating oil inlet
6	Pressure transmitter PT3131C – PT313#C	13	Servo oil inlet
7	LFR bush (for usual engine operation)	14	Servo oil outlet

6. Cylinder Lubricating System – Bleed

To bleed the lubrication oil supply pipe (10, Fig. 4), and the cylinder lubricating pumps, see the procedure given in the Maintenance Manual 7218–1.

After you bleed the lubricating oil supply pipe (10), and the cylinder lubricating pumps (see paragraph 5.3), it is necessary to bleed the oil pipes (4) to the lubricating quills (5) as follows:

1) See 4002-2, LDU-20, paragraph 3.2 User Guide and paragraph 3.9 Cylinder Lubrication.
2) In the LDU-20, get the MAIN page.
3) In the navigation menu, select Cylinder Lubrication.
4) In the CYL. LUBRICATION page, field Manual lub. to Cyl. #, select the applicable cylinder number.

Note: If necessary, it is possible to change the number of lube pulses (in the range 0 to 200) in the field # of Manual Lub. Pulses.
When 100 is entered in the field Manual lub. to Cyl. #, all cylinders will be lubricated in sequence.

5) Do the procedure given in the Maintenance Manual 7218–1.

7. Lubricating Quill

Lubricating oil is injected on to the cylinder liner (3, Fig. 5) wall through the six lubricating quills (2) installed on the circumference of the supporting ring (see also paragraph 8.2).

For the function of the lubricating quill (2), see 2138-1 Lubricating Quills on Cylinder Liner.

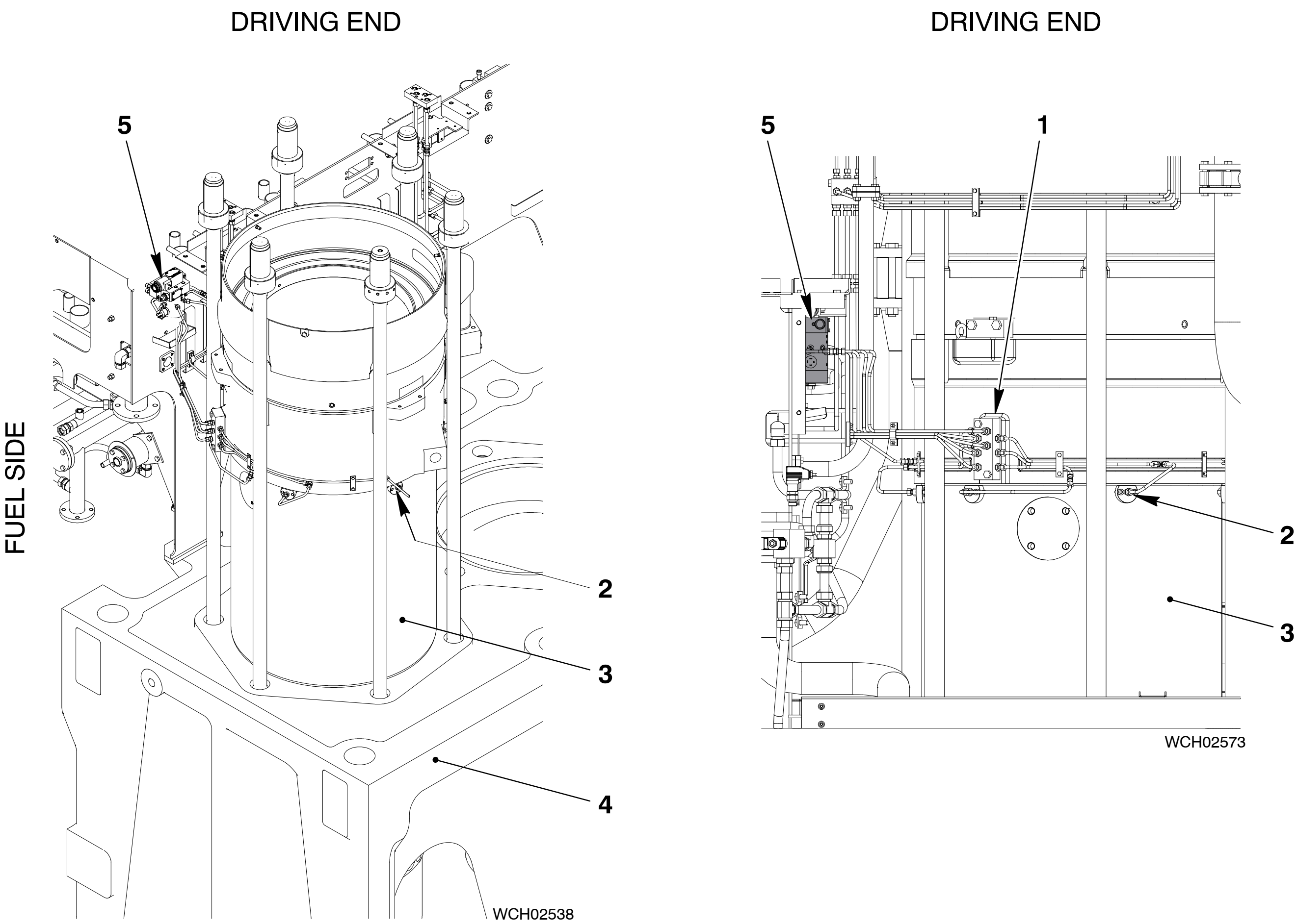

Fig. 5: Lubricating Quills

1 Connector block
2 Lubricating quill 25-2138_CX_Y
3 Cylinder liner
4 Cylinder block
5 Cylinder lubricating pump 25_7230_C#_1

8. Cylinder Lubricating System − Control

8.1 Control System

The cylinder lubricating system (see Fig. 6) is a time−based system, which supplies lubricating oil on to the cylinder liner wall.

For more data about the cylinder lubricating control, see 4002−1 Engine Control System, paragraph 3.4 Cylinder Lubricating Control.

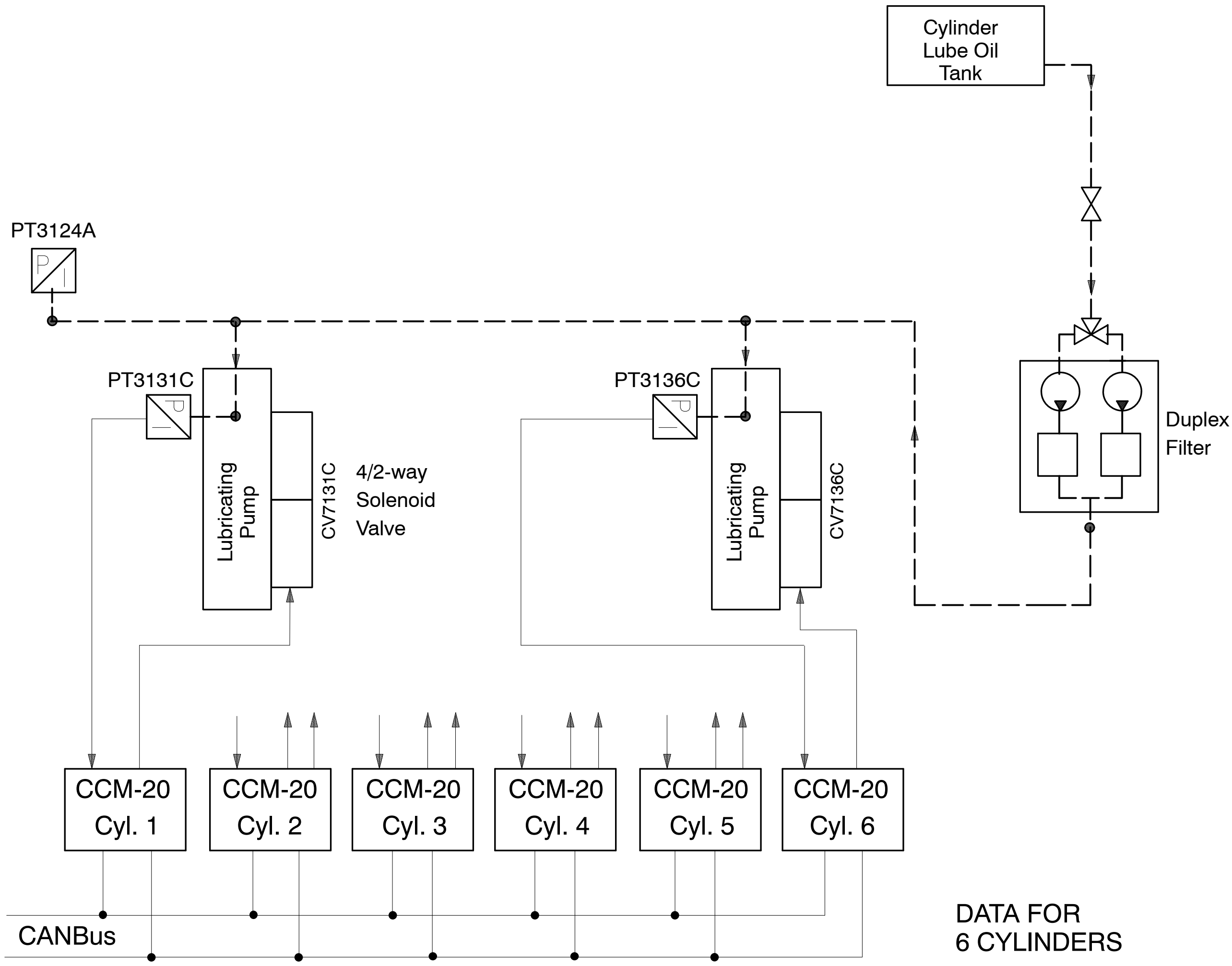

Fig. 6: Control System

8.2 Radial Oil Supply

The nozzle tip in the lubricating quill has holes in specified positions. The lubricating oil flows out of these holes at high pressure. This gives equal lubrication on to the cylinder liner wall (see Fig. 6).

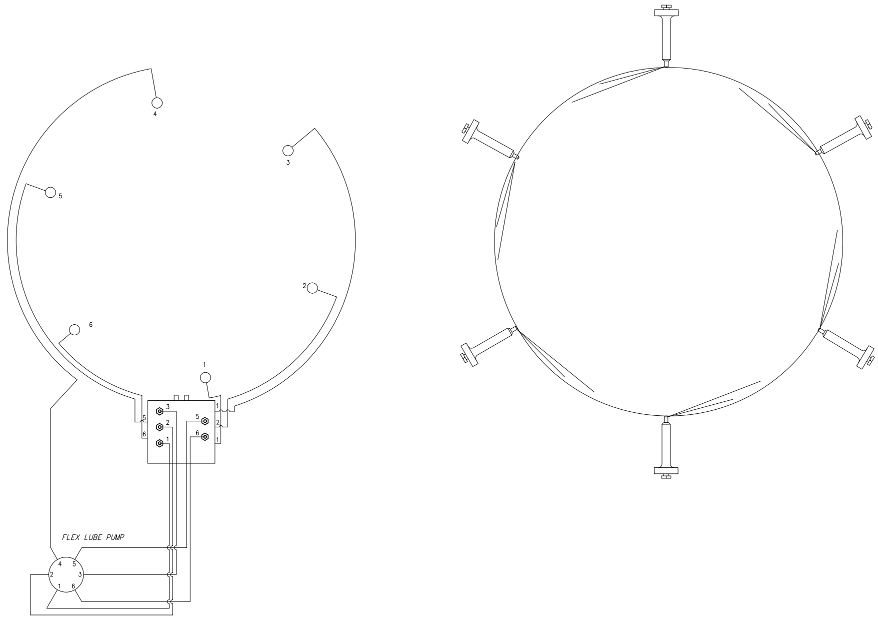

Fig. 7: Radial Oil Supply

8.3 Vertical Oil Supply

The ECS parameters adjust the timing, which gives the position and percentage of cylinder lubrication oil on the cylinder liner wall and between the piston rings (see Fig. 7).

The ECS parameters also adjust the timing (with its percentage supply of the feed rate) during the first commissioning.

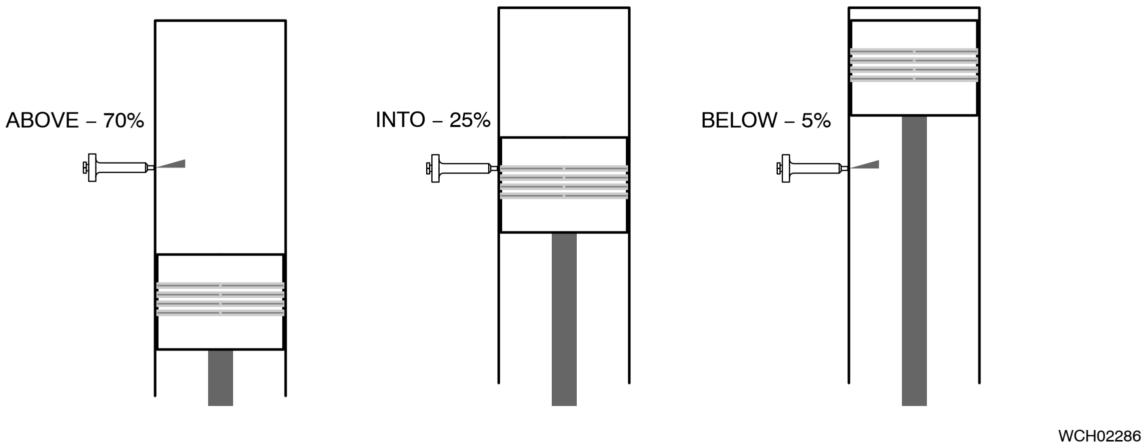

Fig. 8: Vertical Oil Supply

8.4 Lubricating Oil Feed Rate – Adjustment

It is possible to adjust the lubricating oil feed rate in steps of 0.1 g/kWh. Use the parameters in the columns Feed Rate and Adjustment for one cylinder, or for all cylinders (see 4002–2, paragraph 3.9 Cylinder lubrication, CYL. LUBRICATION page).

For more data about the adjustment of the lubricating oil feed rate, see 7218–3 Feed Rate – Adjustment.

For data about the guide feed rates for running-in of new cylinder liners and piston rings, see 0410–1 Running-in New Cylinder Liners and Piston Rings.

Cylinder Lubrication – LFR and HFR Bushes

1. Description

There are two bushes installed on each cylinder lubricating pump (1, Fig. 1).

The low feed rate (LFR) bush (3) is installed on the screw (2) at the bottom of the cylinder lubricating pump. This bush is for usual operation.

Note: For usual operation, it is not necessary to change the bushes in service. The engine control system (ECS) always uses the correct value to calculate the appropriate pump capacity. The correct value in the engine control system is set after the shop test.

Note: When you install the HFR bush, the output of the cylinder lubricating pump increases by 34%, compared to the output when the LFR bush is installed.

The high feed rate (HFR) bush (4), is installed in the storage position. This bush is used when it is necessary to change the output of the cylinder lubricating pump (e.g. for running-in or other unusual operations).

To change the bushes, see the procedure in paragraphs 2.1 and 2.2.

2. Change Procedure

2.1 LFR Bush to HFR Bush

1) Carefully loosen the stroke adjustment screw (2), then remove the LFR bush (3).
2) Loosen the screw (5), then remove the HFR bush (4) from the storage position.
3) Put the HFR bush (4) in position on the screw (2).
4) Torque the stroke adjustment screw (2) to 40 Nm.
5) Put the LFR bush in the storage position on the screw (5).
6) Tighten the screw (5).

2.2 HFR Bush to LFR Bush

1) Carefully loosen the stroke adjustment screw (2), then remove the HFR bush (4).
2) Loosen the screw (5), then remove the LFR bush (3) from the storage position.
3) Put the LFR bush (3) in position on the screw (2).
4) Torque the stroke adjustment screw (2) to 40 Nm.
5) Put the HFR bush in the storage position on the screw (5).
6) Tighten the screw (5).

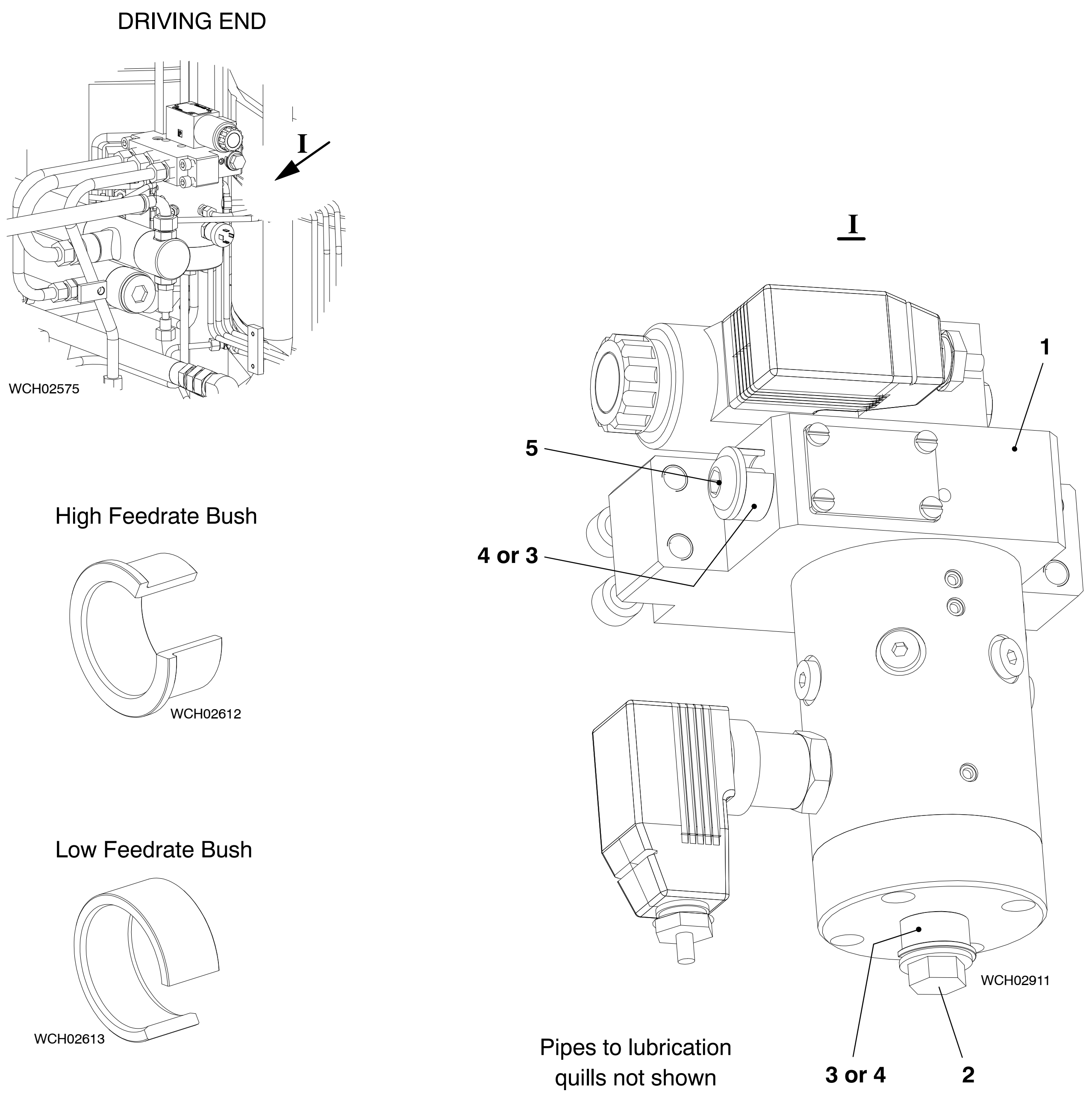

Fig. 1: Cylinder Lubricating Pump

1 Cylinder lubricating pump
2 Stroke adjustment screw
3 Low feed rate bush
4 High feed rate bush
5 Screw

Feed Rate – Adjustment

1. General

To set the applicable cylinder lubricating oil feed rate, it is very important to monitor the piston running performance of the engine. The procedures that follow are necessary:

- Use an on-board monitoring programme to monitor the piston underside (PU) drain oil. Make an analysis of the Fe content, Cr content and the residual base number (BN) from the PU drain oil. For more data, refer to 0750–1 Lubricating Oils, paragraph 3.2.
- At regular intervals, visually examine the PU.
- Make an analysis of the fuel quality. If possible, send a sample of the fuel to a laboratory to make an analysis of the effective sulfur content. Do the analysis before you use the fuel for the first time. For more data, refer to 0710–1 Diesel Engine Fuels.

Note: Engines with the same design can have different piston running performances (because of different operation modes, the properties of the used cylinder lubricating oil, or engine tuning). The most important problem is cold corrosion, which causes the piston running components to become quickly worn.

To find an applicable cylinder lubricating oil, refer to the data given in 0750–1 Lubricating Oils, paragraph 3 and paragraph 8.2.

For more data about cold corrosion, refer to 0750–1 Lubricating Oils, paragraph 3.2 and paragraph 3.3.

2. Feed Rate Adjustment

CAUTION
Equipment Hazard: The results of the bunker analysis and the values given in the Bunker Delivery Note (BDN) can be different. Always use the higher sulfur content value to adjust the feed rate. This makes sure that the engine operates safely.

To prevent damage to the engine, it is necessary to set the feed rate in relation to the used fuel and cylinder lubricating oil.

To set the applicable feed rate, it is necessary to make an analysis of the PU drain oil. Set the feed rate related to the analysis of the residual base number (BN) and the iron content of the PU drain oil. For more data and the procedure to get a sample of PU drain oil, refer to 0750–1 Lubricating Oils, paragraph 3.2.

To adjust the cylinder lubricating oil feed rate, use the data that follows:

- Current feed rate [g/kWh]
- Residual base number (BN) and iron content of the PU drain oil
- The sulfur content [% m/m] of the used heavy fuel oil (HFO)
- The BN [mg KOH/g] of the used cylinder lubricating oil.

2.1 Empirical Data Collection

To adjust the feed rate to an applicable value, it is necessary to collect empirical data for each engine.

Start to collect the empirical data after the first running-in period of the engine. For the procedure, Wärtsilä Services Switzerland Ltd recommends to use lubricating oil with the highest available BN in relation to the used fuel. Use a baseline feed rate of 0.9 g/kWh. For more data, refer to 0750–1 Lubricating Oils.

Collect the data of the PU drain oil samples at different engine loads. For the procedure to get a sample of PU drain oil, refer to 0750–1 Lubricating Oils, paragraph 3.2. Make sure that you always operate the engine in the safe operation area (see Fig. 1, Fig. 2 and Fig. 3). If necessary, adjust the feed rate and/or the lubricating oil base number. For specified recommendations related to the selected feed rate, refer to the Wärtsilä “PU Drain Oil Analysis Tool”.

Fig 1. shows the relation between the residual BN and the total iron content of the PU drain oil. This data is only applicable when fuel with a sulphur content between 0.5% m/m and 3.5% m/m and cylinder lubricating oil with a BN between 40 and 100 is used. For data about cylinder lubricating oils with a base number less than 40, refer to 0750–1 Lubricating Oils.

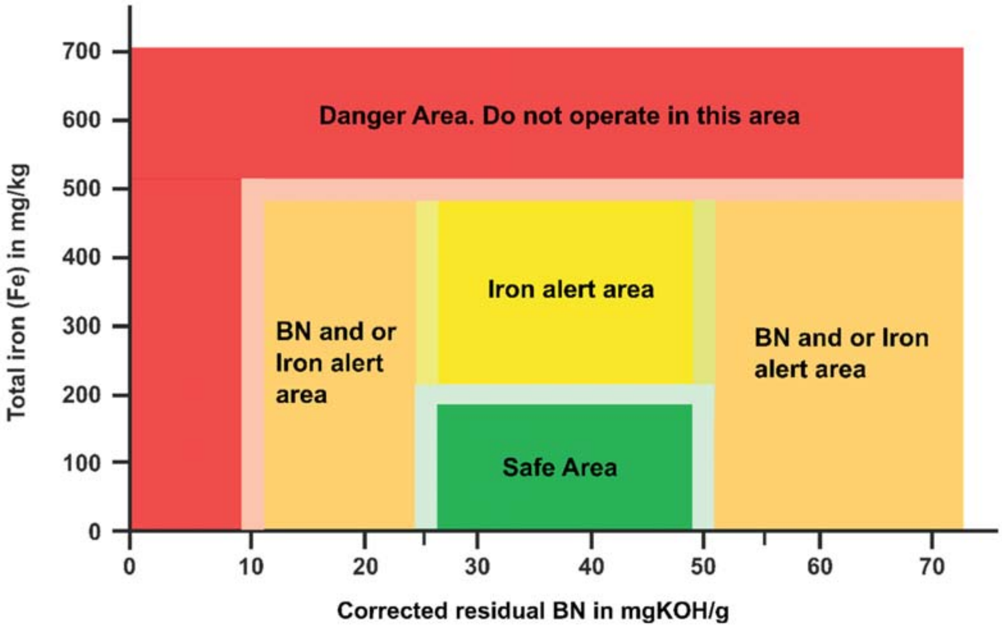

Fig. 1: PU Drain Oil – Relation between Residual BN and Total Iron

The empirical data can be used for future operation with the same cylinder lubricating oil and fuel with the same sulphur content (± 0.125 % m/m). When you use your empirical data, Wärtsilä Services Switzerland Ltd recommends that you do a PU oil sample. This makes sure that the used feed rate is applicable. For more data, refer to Service Bulletin RT-161 Issue 2 Cylinder Lubrication.

CAUTION	
⚠	**Equipment Hazard: The Wärtsilä PU Drain Oil Analysis Tool and its recommendations are only applicable for cylinder lubricating oils with a base number more than or equal to 40 (BN ≥ 40).**

You can use the Wärtsilä PU Drain Oil Analysis Tool to collect your data. You can see examples of its analysis in Fig. 2 and Fig. 3.

The tool is available at http://www.wartsila.com/products/marine-oil-gas/engines-generating-sets/low-speed-rt-flex-engines

For more data, speak to or send a message to Wärtsilä Services Switzerland Ltd.

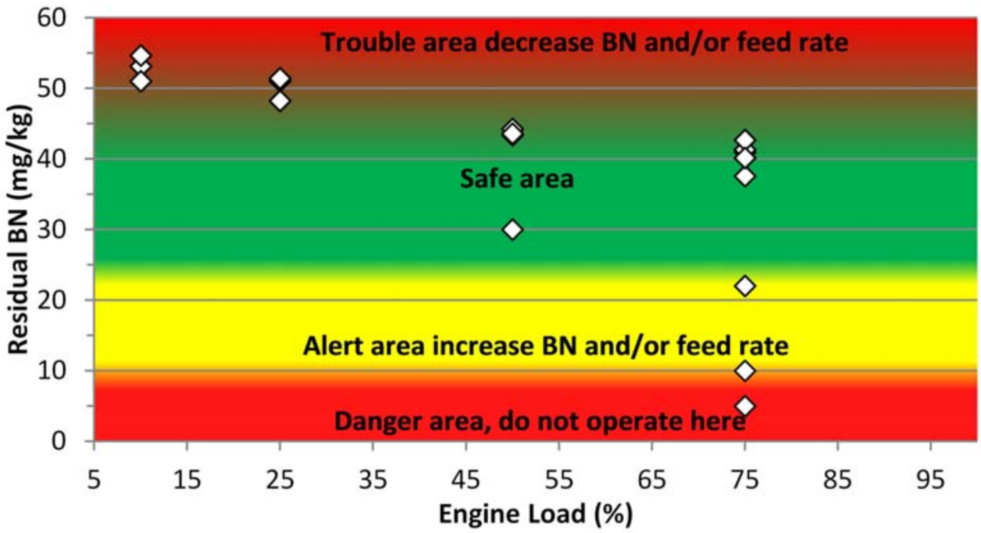

Fig. 2: PU Drain Oil Analysis Tool – Residual BN in Relation to the Engine Load

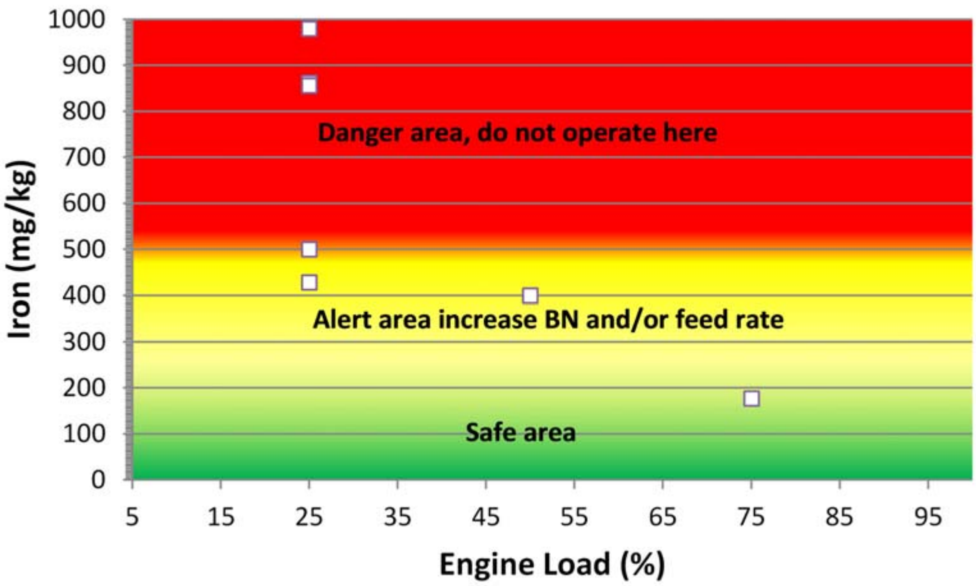

Fig. 3: PU Drain Oil Analysis Tool – Iron Content in Relation to the Engine Load

Note: If the engine operates with fuel that has a sulphur content less than 0.1% m/m (and a cylinder lubricating oil with a base number (BN) between 15 and 25) the minimum value of the residual BN value is 10 mg/kg. For more data, refer to 0750–1 Lubricating Oils.

2.2 How to Set the Best Applicable Feed Rate

Use the empirical data (see paragraph 2.1) from the PU drain oil samples to adjust the feed rate to get the best applicable feed rate.

Note: You must make sure that the feed rate is not less than the minimum permitted value of 0.6 g/kWh.

If the residual BN is in the safe area (Fig. 2), adjust the feed rate in steps of 0.05 g/kWh to get the iron content value to approximately 200 mg/kg. You must get PU drain oil samples regularly to make sure that the feed rate used is applicable.

Wärtsilä Services Switzerland Ltd recommends that you do a check of the coating thickness of the piston rings each 1500 to 2000 running hours.

For more data, refer to Service Bulletin RT-161 Issue 2 Cylinder Lubrication.

3. Running-in New Cylinder Liners and Piston Rings

For data about the running-in procedure for new cylinder liners and piston rings, refer to 0410–1 Running-in New Cylinder Liners and Piston Rings.

4. Blending on Board

You can use the Wärtsilä Blending on Board (BoB) system to adjust the BN of the cylinder lubricating oil.

The system oil is used as a base oil and the correct additive package is added to make an applicable cylinder lubricating oil. The BoB system gives the best results related to the applicable neutralization and detergency properties of the cylinder lubricating oil.

You can make different BN lubricating oils on board. With an applicable cylinder lubricating oil it is not necessary to adjust the feed rate to different operation modes (i.e. the base feed rate is not changed, but the cylinder oil BN is adjusted).

Use the BoB system together with an on-board monitoring system for the PU drain oil (e.g. SEA-Mate© B2000 blender combined with the SEA-Mate© M2000 XRF analyzer) to make a lubricating oil that has the correct BN. The correct BN improves the corrosion protection, and the properties to clean the lubricating oil.

The BoB system is applicable for vessels that operate on a wide range of different fuels (related to the fuel sulfur content) and operation modes.

As a general recommendation, refer to the data given in Table 1, but, adjust the values as a function of the engine performance for each engine. For more data, speak to or send a message to Wärtsilä Services Switzerland Ltd.

Table 1: BN Values Related to Sulfur Content for a Base Feed Rate of 0.8 g/kWh

Sulfur Content [%]	Usual Operation (above 60% CMCR)	Low Load Operation (below 60% CMCR)	Safeguard Operation
1.0	40	40	40
1.1	40	40	40
1.2	40	40	40
1.3	40	40	40
1.4	40	40	40
1.5	40	40	50
1.6	50	50	50
1.7	50	50	50
1.8	50	50	60
1.9	50	50	60
2.0	50	50	60
2.1	50	50	60
2.2	50	70	60
2.3	50	70	70
2.4	50	70	70
2.5	50	70	70
2.6	50	70	70
2.7	50	70	80
2.8	50	70	80
2.9	51	72	80
3.0	53	75	90
3.1	55	77	90
3.2	57	80	90
3.3	59	82	100
3.4	61	85	100
3.5	63	87	100

Integrated Electric Balancer

1. Description

An optional integrated electric balancer (ELBA) can be installed on the engine. The ELBA decreases the free 2nd order moments in 4-cylinder to 6-cylinder engines.

Note: An integrated ELBA can be installed at the driving end and the free end.

Two shafts (6, Fig. 1) that have gear wheels (1, 2) and balance weights (3, 4) are installed at the driving end of the column.

An electric motor (5) is installed on the column at the free end and the driving end. These electric motors operate two shafts and the balancer gear. For more data, refer to paragraph 2.

A frequency converter electronically controls the electric motor (5). This frequency converter, the control system and the safety devices are installed in an electrical cabinet in the control room. These items can also be installed in the engine room. For more data about the control system, refer to paragraph 2.2.

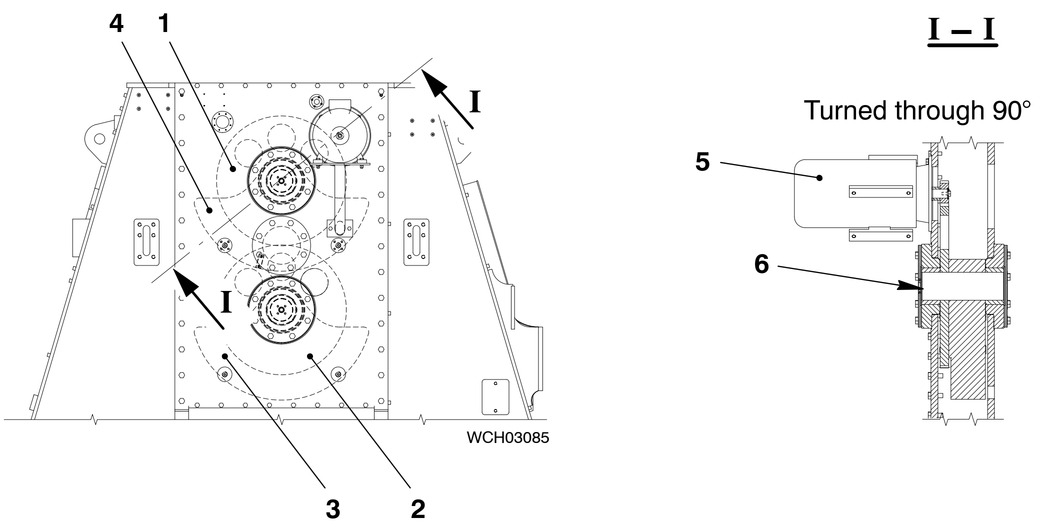

Fig. 1: Location of ELBA

1 Gear wheel
2 Gear wheel
3 Balance weight
4 Balance weight
5 Electric motor
6 Shaft

2. Operation

2.1 Integrated Electrical Balancer

The two shafts (6 and 7, Fig 2) are installed in the housing (5). These shafts turn in opposite directions at two times the engine speed. When the gear wheels (1, 4) turn, the two balance weights (2, 3) cancel each effect of the horizontal centrifugal forces. A vertical force moves up and down two times for each revolution of the engine.

Each of the two shafts transmit the balance forces through the bearings (8, 9).

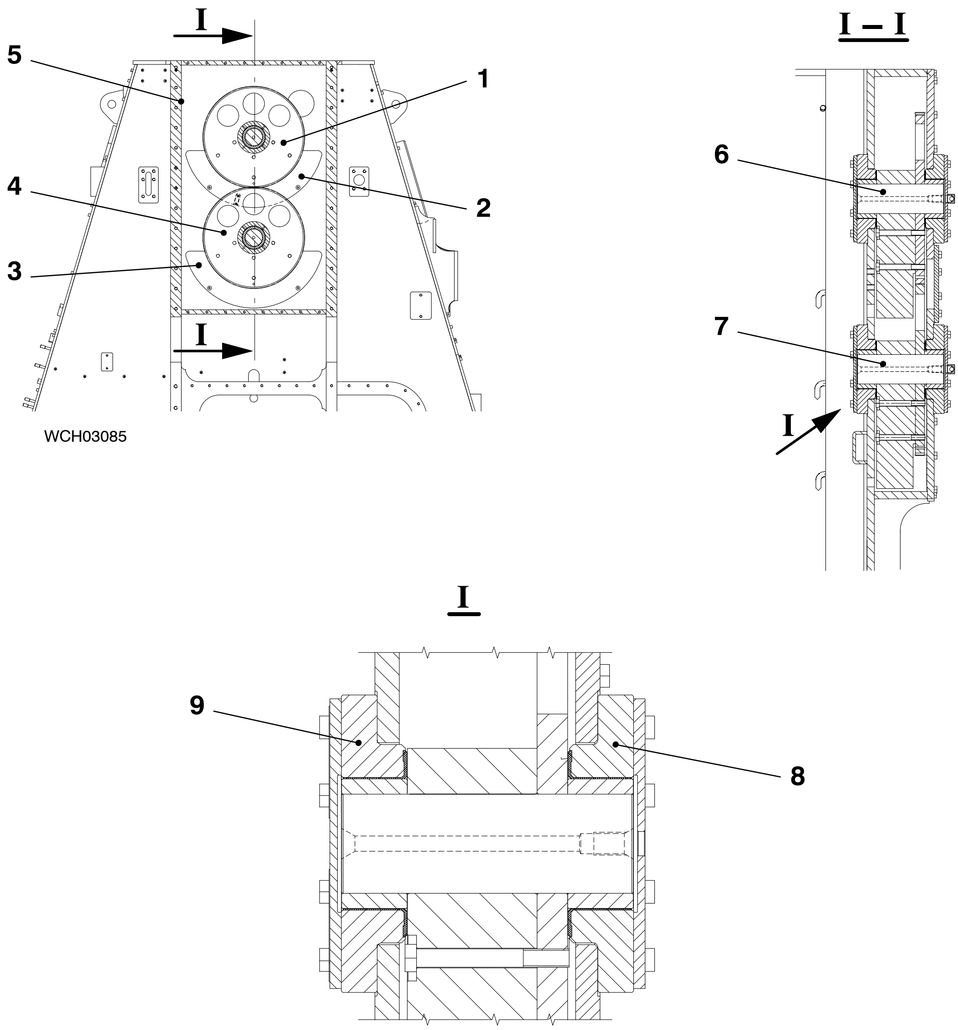

Fig. 2: Electrical Balancer and Shafts

1 Gear wheel
2 Balance weight
3 Balance weight
4 Gear wheel
5 Housing
6 Shaft
7 Shaft
8 Bearing
9 Bearing

2.2 Control System

The control system has the functions that follow:

- At the driving end, the proximity sensor ZS5401C senses the tooth movement of the balance weight. The signals are then transmitted through the terminal box 38.1 (2, Fig. 3) to the control unit.
- At the free end, the proximity sensor ZS5405C senses the tooth movement of the balance weight. The signals are then transmitted through the terminal box 38.1 (2) to the control unit.
- The proximity sensors (ZS5141C and ZS5142C) transmit the speed of the flywheel (1) and the TDC position along the cables (3) to the terminal box 38.1 (2) at the driving end. These signals then go to the control unit. Attached to the electric motor is a resolver, which sends the motor speed to the control system.

Control of the ELBA is automatic. The ELBA activates when the engine speed is more than 60 rpm. When the engine speed decreases to less than 50 rpm, the ELBA de-activates.

A manual operation mode can also be selected. On the door of the electrical cabinet, a mode switch has the label Heavy Sea Mode. When selected, the ELBA operates at different higher engine speeds. Also, the engine RPM is not in the given limits.

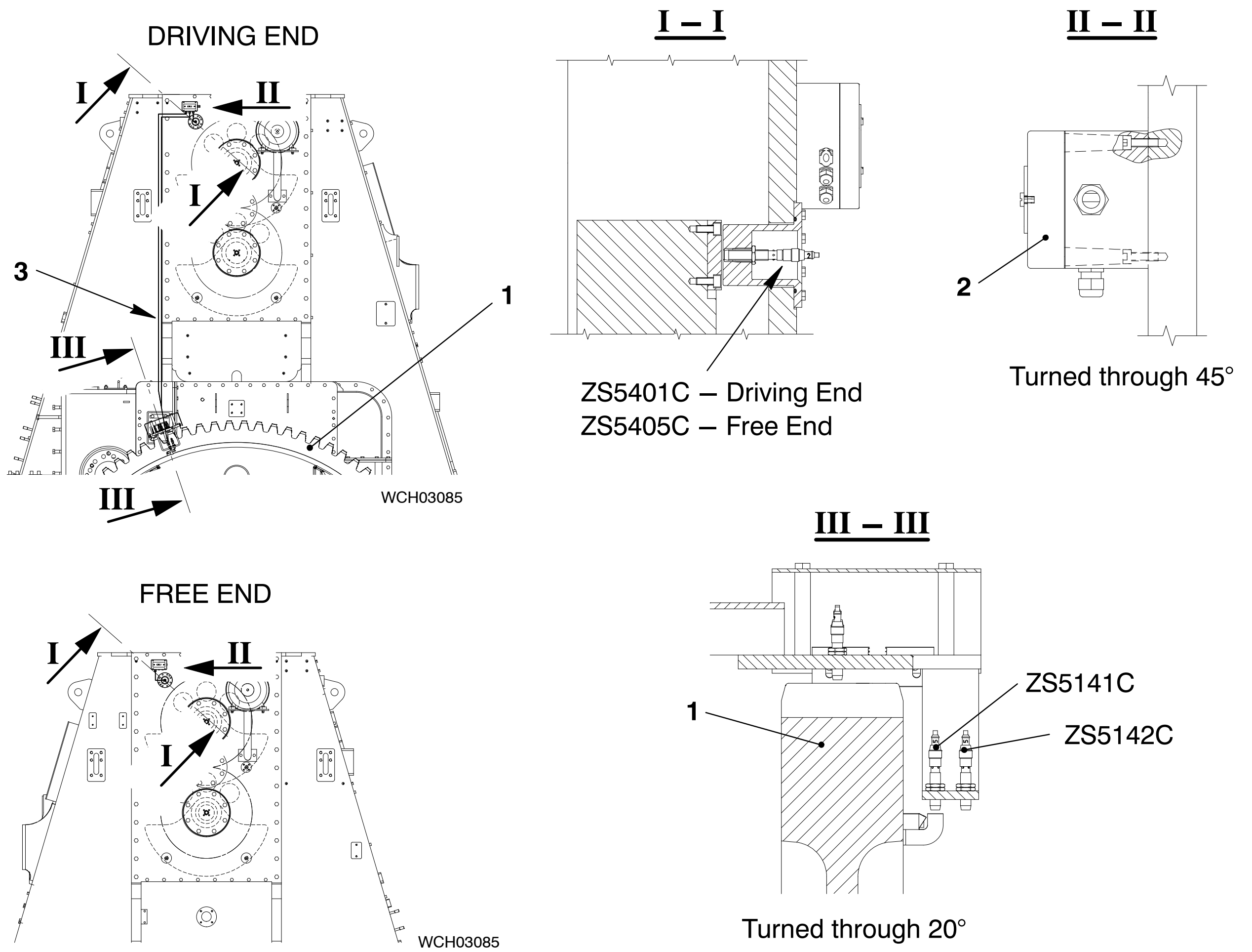

Fig. 3: Control System

1 Flywheel
2 Terminal box 38.1
3 Cable

2.3 Lubrication

The lubrication system of the ELBA is connected to the low-pressure oil system of the engine. In the housing (1, Fig. 4) lubricating oil (3) flows through the pipes (2) to the shafts to lubricate the gear wheels. Oil that is not used flows through the oil return to the crankcase.

Note: Damage to the gear wheels can occur if the oil supply to the ELBA system stops.

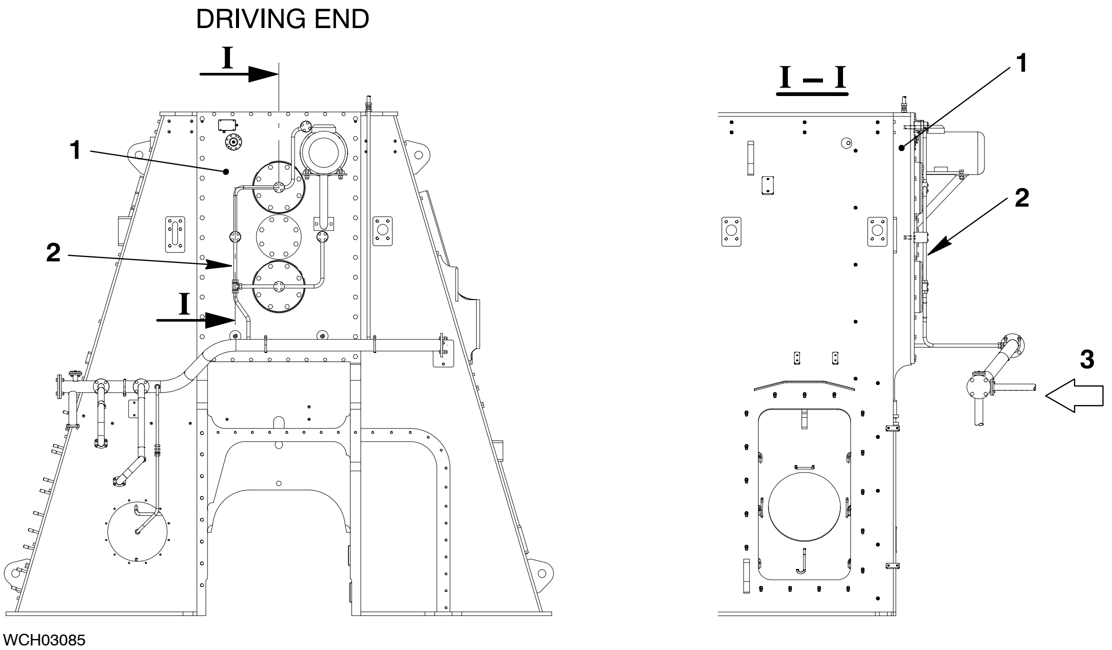

Fig. 4: ELBA Lubrication System

1 Housing
2 Pipe
3 Oil inlet

2.4 ELBA Failure

If the ELBA becomes defective, the engine can continue to operate, but there could be an increase of 2nd order vibration at some engine speeds. Table 1 shows the error modes and descriptions.

2.4.1 Procedure

If there is damage to, or problems with the electric motor, control system or gear wheels do the procedure that follows:

Note: Do not set to OFF the main switch in the terminal box.

1) In the terminal box in the control room, set to OFF the monitor switch.
2) Refer to the documentation of the manufacturer and send a report to Wärtsilä Services, Switzerland.

Refer to the Maintenance Manual 7722–1 for the procedures that follow:

- Removal and Installation of the bearings
- Checks
- Permitted limits of clearances.

Table 2: Error Modes and Descriptions

	Error Mode	Error Description
1	DC-bus under-voltage	No voltage available for the drive in X100 (power input).
2	Engine maximum speed exceeded	Diesel engine speed is more than permitted.
3	Balancer maximum speed exceeded	Electric motor speed is more than permitted.
4	Balancer BDC missing	Balancer BDC not found. Sensor is defective, or has become disconnected. Replace the defective sensor, refer to the Maintenance Manual 7762–1.
5	Engine BDC missing	Engine BDC not found. Sensor is defective, or has become disconnected. Replace the defective sensor, refer to the Maintenance Manual 7762–1.
6	Engine TDC missing	Engine TDC not found. Sensor is defective, or has become disconnected. Replace the defective sensor, refer to the Maintenance Manual 7762–1.
7	Servo drive over-temperature	Servo drive internal temperature too high
8	Emotor over-temperature	Electric motor internal temperature too high
9	Brake resistor over-temperature	Brake resistor internal temperature too high
10	Communication broken	CAN communication between cabinets broken
11	No synchronisation with engine	The synchronisation with the engine is not done in the specified time
12	No synchronisation between the balancers	The synchronisation between the balancers is not done in the specified time
13	Starting exceeding maximum times	The running state takes too long

You can read the errors (3, Fig. 5) from the small display (2) in the control cabinet. The red drive error indicator (1) flashes when there is an error.

Fig. 5: Lenze Drive – Error Messages

1 Drive error indicator
2 Display
3 Error messages

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Piping Systems Group 8

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Lubricating Oil System

1. General

The oil pump supplies the necessary pressure to control and lubricate the engine (this does not include cylinder lubrication). For data about the pressure values, see Operating Data Sheet 0250–1.

The oil supply to the different lubricating points is shown in the schematic diagrams Fig. 2 and Fig. 3.

The locations of the pumps, filters, heat exchangers, etc is shown on the plant diagram which is supplied separately from the engine documentation.

For data about the cylinder lubrication, see 7218–1 Cylinder Lubrication.

2. Lubricating Oil System

The oil flows from the inlet pipe (5, Fig. 2) on the driving end to the supply pipes (7) and (8), through bores in the bearing girders to lubricate the main bearings (20).

Oil flows through the supply pipe (25), through the toggle levers (11) to lubricate the crosshead pins (14) and bottom end bearings (26). From the crosshead pins (14), the oil flows up the piston rods to keep the pistons cool (for more data about the piston, see Piston 3403–1).

The oil also lubricates and keeps cool the axial damper (19) and the vibration damper (18).

Oil from the supply pipe (9) flows to the nozzles (13) in the thrust bearing (21).

Oil flows from the inlet pipe (5) through the supply pipe (2) to the turbochargers. The oil returns through the outlet pipe (1) to the oil system (plant).

You use the ball valves (15) and (16) to get dirty oil samples from the piston underside (see also 0750–1, paragraph 3.2).

Note: During operation, the ball valves (16) are open and the ball valves (15) are closed.

2.1 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, Fig. 1) for approximately 30 minutes to 60 minutes.

Note: Some parts can look different.

Ball Valve Positions

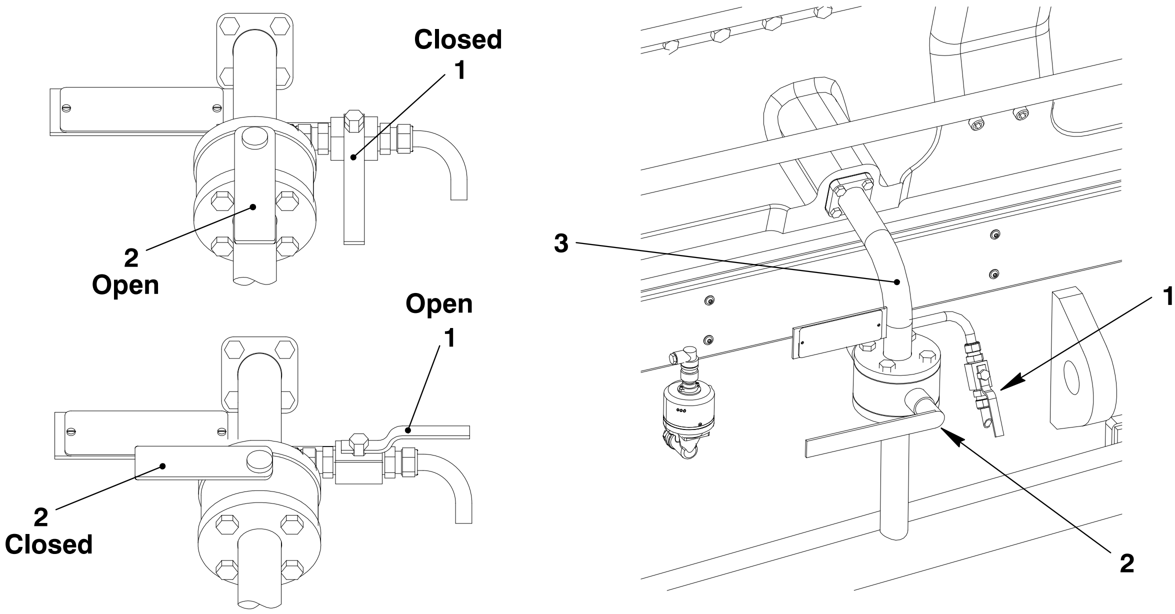


Fig. 1: Location of Ball Valves for Dirty Oil Samples

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.

Note: Winterthur Gas & Diesel Ltd. 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.

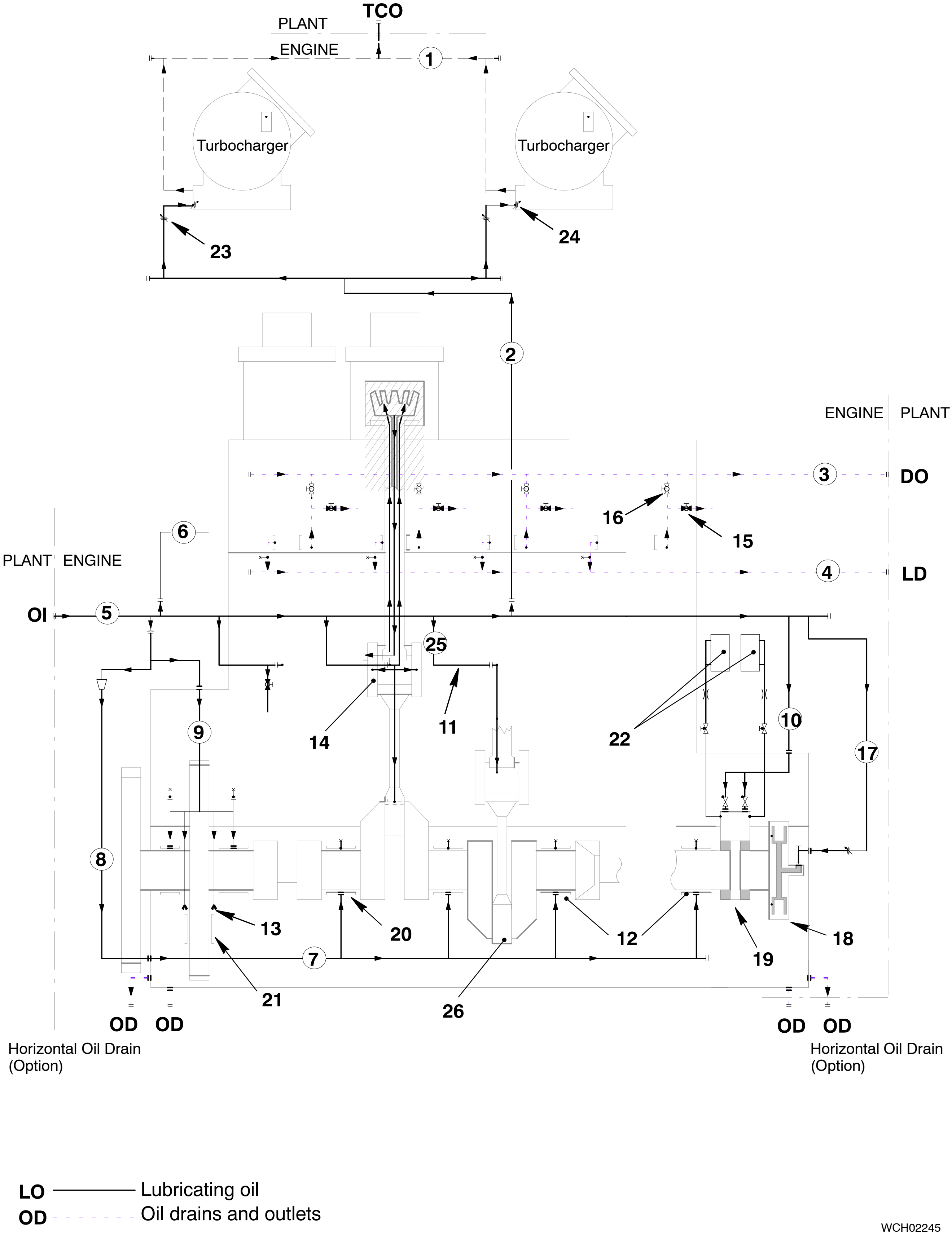


Fig. 2: Lubricating Oil System

Key to Fig. 2

1	Oil pipe – TC outlet	17	Supply pipe – vibration damper
2	Oil pipe – TC inlet	18	Vibration damper – crankshaft
3	Main collector (dirty oil, piston underside)	19	Axial damper
4	Main collector (leak oil – gland box)	20	Main bearing
5	Oil inlet pipe	21	Thrust bearing
6	Oil pipe (bearing drive, supply unit, servo oil)	22	Axial damper monitor
7	Oil pipe (main bearing)	23	Adjustable orifice (MHI turbochargers)
8	Supply pipe (main bearing)	24	Adjustable built-in orifice (ABB turbochargers)
9	Supply pipe (thrust bearing)	25	Supply pipe (piston cooling, crosshead bearing)
10	Supply pipe (axial damper)	26	Bottom end bearing
11	Toggle lever		
12	Bottom end bearing		
13	Nozzle	DO	Dirty oil – piston underside
14	Crosshead pin	LD	Leakage oil outlet – gland box
15	Ball valve (oil samples piston underside)	OD	Oil drain
		OI	Inlet from main oil supply
16	Ball valve (piston underside)	TCO	Oil pipe – TC outlet

3. Servo Oil System

The servo oil system controls the exhaust valve movement. Oil from the lubricating oil system is used in the servo oil system.

3.1 Servo Oil

Oil flows through the oil pipe (1, Fig. 3) (bearing drive) and the supply pipe (14) to the servo oil pumps (17).

Note: Do not operate the engine if the oil does not flow to the servo oil pumps.

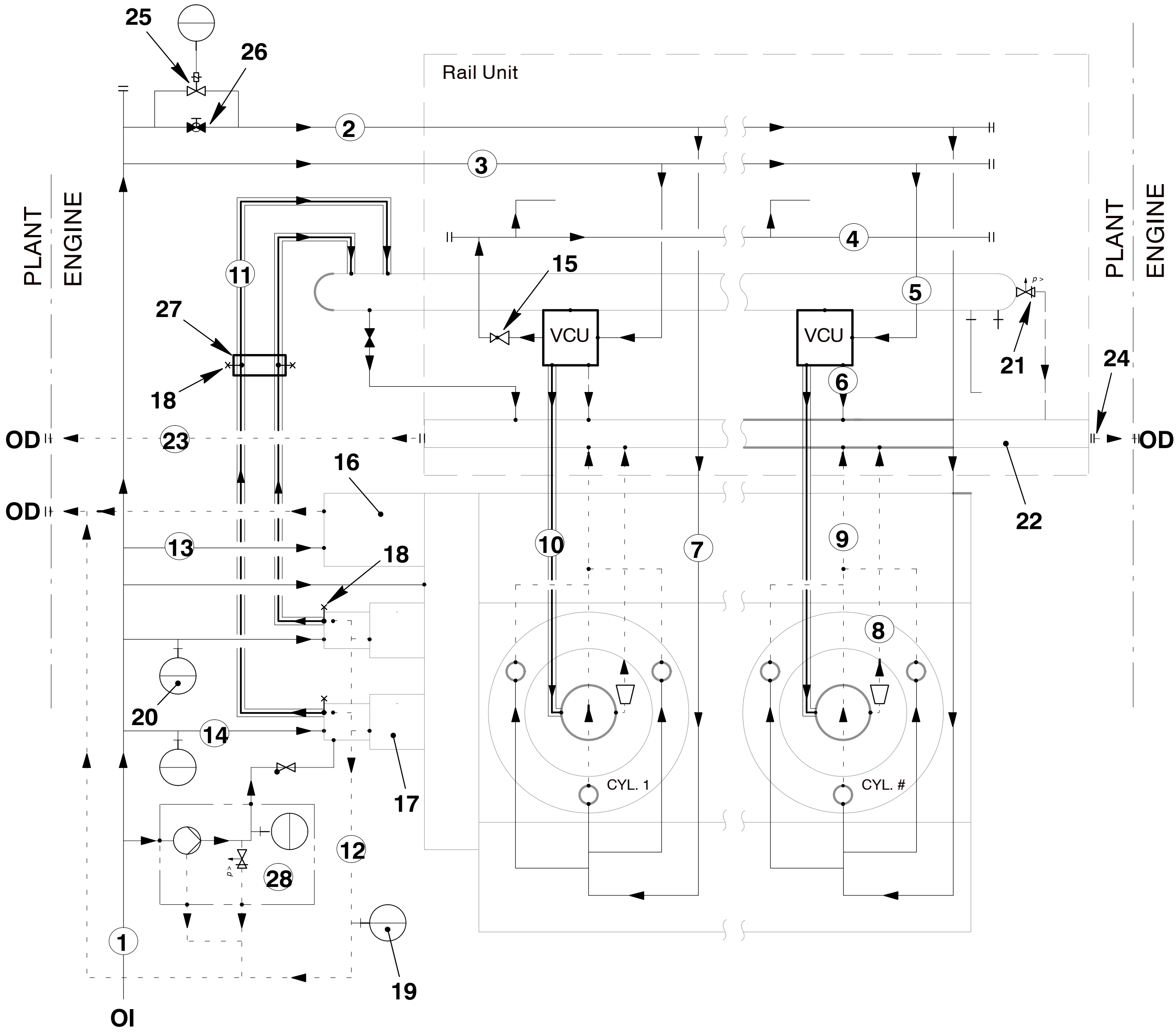
The servo oil pumps supply oil at sufficient pressure through the HP servo oil pipes (11) to the servo oil rail. The necessary oil pressure is related to the engine load.

The leakage oil pipe (12) is located at a connecting block near the servo oil pumps.

The flow sensors (20) (installed upstream of each servo oil pump) monitor the oil supply to the servo oil pumps.

Note: If a servo oil pump becomes defective, an alarm is activated through the alarm and monitoring system (see 5551–1 Servo Oil Pump).

Servo oil flows from the servo oil rail to the Valve Control Units (VCU) and their 4/2-way control valves.



VCU – Valve Control Unit

OD – – – – – – – Oil drains and outlets

OI ———————— Oil inlet

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Fig. 3: Servo Oil System

Key to Fig. 3

1	Oil pipe – bearing drive, supply unit, servo oil	16	Supply unit
2	Supply pipe – cooling oil, injectors	17	Servo oil pump
3	Supply pipe	18	Leakage inspection points – servo oil pipes
4	Cylinder lubrication drive	19	Level switch LS2055A
5	Supply pipe – VCU	20	Flow sensors FS2061–62A
6	Leakage pipe – VCU	21	Pressure safety valve
7	Cooling oil supply – fuel injection valve	22	Main oil collector
8	Drain from exhaust valve	23	Leakage oil outlet DE
9	Cooling oil return – fuel injection valve	24	Leakage oil outlet FE
10	Hydraulic pipe – exhaust valve	25	Control valve CV2003C (injection valve cooling)
11	HP servo oil pipes	26	Ball valve
12	Leakage oil pipe	27	Intermediate piece
13	Supply pipe – supply unit	28	Servo oil service pump
14	Supply pipe – servo oil pump	OI	Inlet from main oil supply
15	Pressure reducing valve		

4. Servo Oil Leakage

4.1 Leakage and Oil Drains

Some of the oil flows from the oil drains OD through the servo oil return in the plant and back to the main oil supply (see Fig. 2).

Leakage oil from the HP servo oil pipes (11, Fig. 3) drains through the leakage oil pipe (12).

Leakage oil from the exhaust valves flows through the leakage oil pipe (8) to the main collector (22) then through the leakage oil outlets (23) and (24). This leakage oil then flows back to the plant.

The level switch LS2055A monitors leakages from the HP servo oil pipes.

Leakage oil from inside the rail unit, flows through a drain to the sludge tank.

If there is a large quantity of leakage oil, the related alarm is activated. See the table below:

Level switch	Monitored components
LS3444A	Monitors fuel and oil leakage from the rail unit (see 8019-1 Fuel System, Fig. 1). The leakage flows to the sludge tank.
LS2055A	Leakages from HP servo oil pipes.

4.2 Leakage Inspection Points

4.2.1 HP Servo Oil Pipes

If there is a leak in the HP servo oil pipes, the leakage inspection points (18, Fig. 3) are used to find the pipe that has the leakage.

4.2.2 Exhaust Valve Control Unit

If oil flows from the leakage inspection point (3, Fig. 4) in the VCU, the related hydraulic pipe (1) has a leak (see also 0520−1 Operation with Exhaust Valve Control Unit Cut Out).

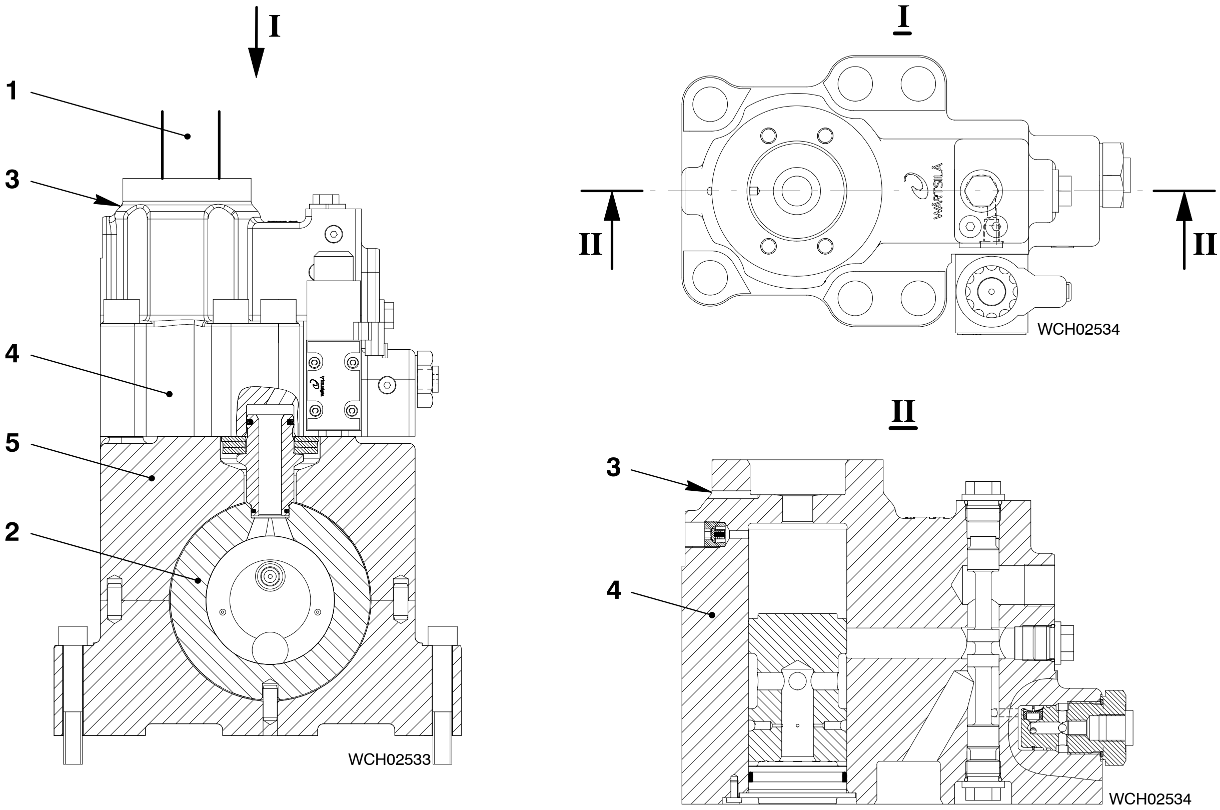

Fig. 4: Leakage Inspection Point – VCU

1 Hydraulic pipe
2 Servo oil rail
3 Leakage inspection point
4 Valve control unit (VCU)
5 Holder

Note: If one of the two HP servo oil pipes has a leak (and thus is unserviceable), the engine can operate fully until the defective pipe is replaced.

4.2.3 Procedure

If the level switch (LS2055A) activates an alarm, do the procedure that follows:

Note: Each of the two HP servo oil pipes (2, Fig. 4) has a screw plug (5, Fig. 5) at the leakage inspection points.

WARNING

Injury Hazard: Always put on gloves and safety goggles when you do work on hot components. When you loosen the screw plugs, high pressure oil can come out as a spray and cause injury.

1) Carefully loosen the screw plug (5, Fig. 5), a maximum of one turn and look for oil.

2) If there is no oil, tighten the screw plug (5).

Note: If oil flows from the screw plug (5), the related HP servo oil pipe (2) has a leak.

3) If necessary, replace the defective HP servo oil pipe (2) (see the Maintenance Manual 8447-1).

4) Do the steps above for the other screw plugs (5).

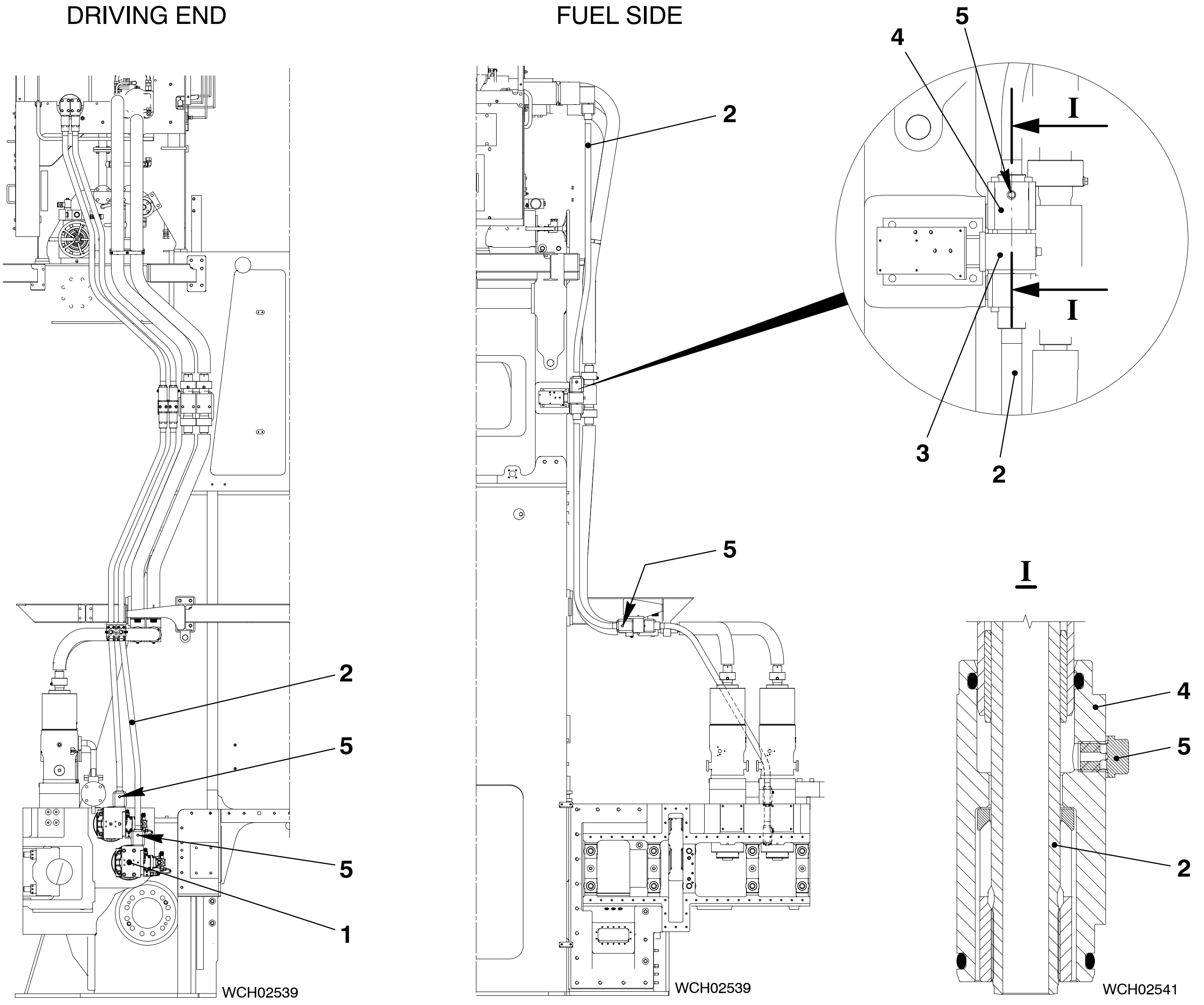

Fig. 5: Leakage Inspection Points – HP Servo Oil Pipes

1 Servo oil pump
2 HP servo oil pipe
3 Intermediate piece
4 Flange
5 Screw plug

5. Servo Oil Rail

5.1 Pressurization

The servo oil pumps (17, Fig. 3) supply high pressure oil to the HP servo oil pipes (11). The oil pressure opens the non-return valves and oil flows into the servo oil rail. The oil then flows into the VCU and hydraulic pipes (10) (see also 2751–1 Exhaust Valve).

1) Make sure that the stop valve downstream of automatic filter is open.
2) Start the bearing oil pump.
3) Set to on the servo oil service pump (28).
4) Do a function check of the exhaust valve movement.
5) Do a leak test of the servo oil system.

5.2 Pressure Release

To release the pressure in the servo oil rail, do the procedure that follows:

WARNING

Injury Hazard: Always put on gloves and safety goggles when you do work on hot components. When you loosen the screw plugs, high pressure oil can come out as a spray and cause injury.

1) Carefully loosen the screw plug (1, Fig. 6) a maximum of two turns.

WARNING

Injury Hazard: If the screw plug (1) stays open after the servo oil pumps start, pressure in the oil rail cannot increase and high pressure oil can come out.

2) When the pressure in the servo oil rail is released, tighten the screw plug (1).

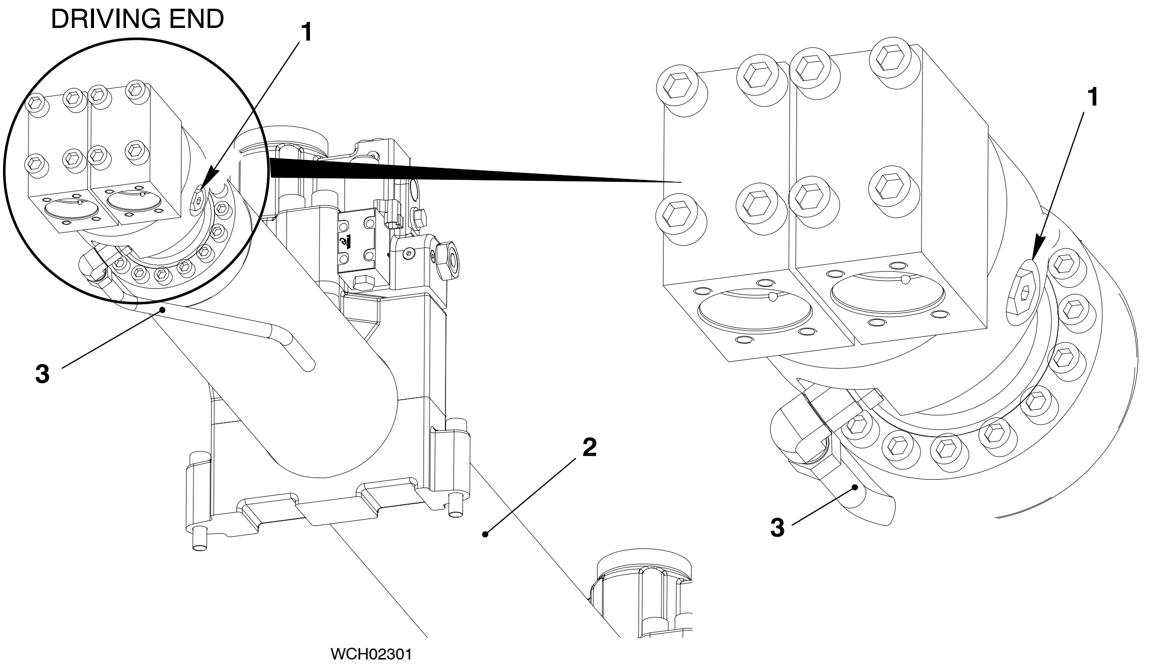

Fig. 6: Servo Oil Rail

1 Screw plug
2 Servo oil rail
3 Drain pipe (to square collector)

Cooling Water System

1. General

The schematic diagram (see Fig.1) shows the cylinder cooling water system on the engine.

The location 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 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 connected to an expansion tank in the plant. The cooling water, keeps cool the cylinder liners, cylinder covers and exhaust valve cages.

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).

A heater installed in the plant, heats the water to the correct temperature before engine operation.

CAUTION
Damage Hazard: If the engine is out of operation for a long period in cold/frosty conditions, you must drain the cooling water system. The water is chemically treated and you must decontaminate the water in accordance with local environmental regulations.

For data about antifreeze, see Cooling Water / Cooling Water Treatment 0760–1.

1.1 Automatic Temperature Control – Cooling Water

The temperature of the cooling water outlet is kept as stable as possible during all load conditions. This prevents too much expansion and contraction of the combustion chamber components e.g. cylinder liners and cylinder covers.

The maximum permitted temperature tolerances are:

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

For data about pressures, temperature ranges, alarm and safety setting points, see the Operating Data Sheets 0250–1 and 0250–2.

2. Function

The cooling water pump supplies cooling water, through the supply pipe (18) on the exhaust side, to the cylinders. The cooling water flows through the cylinder liner (9), water guide jacket (10), cylinder cover (11) and exhaust valve cage (12). When the vent unit (1) and ball valve (2) are open, the system continuously vents.

Note: If problems occur, see the instruction plate on the vent unit (1).

The water flows from the outlet pipe (17) to the cooler and back to the pump. A throttle (13) is installed in the outlet pipe of each cylinder. The throttle controls the flow rate of cooling water through the cylinder. The adjustable throttle (6), installed in the inlet pipe (19), controls the pressure in the system.

The butterfly valve (7) and ball valve (8) are used to isolate the cylinders from the cooling water system. The ball valve (8) is used to drain the water from isolated cylinders and the system.

If it is necessary to remove only the cylinder cover, the ball valve (8) must stay closed. You open the ball valve (5), to let the cooling water flow out through the drain pipe (21).

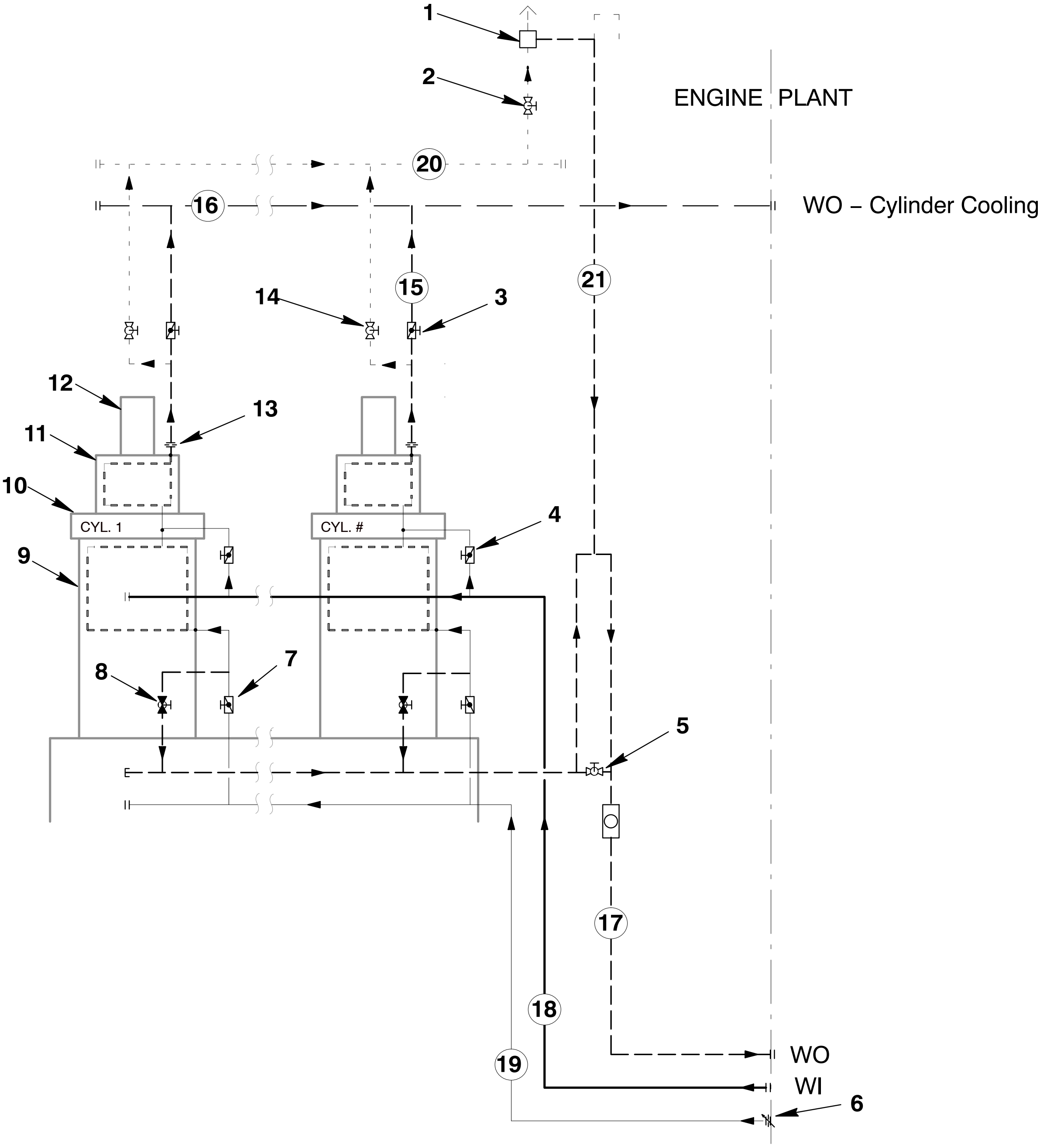

Fig. 1: Lubricating Oil System

1	Vent unit	13	Throttle (cylinder outlet)
2	Ball valve	14	Ball valve
3	Butterfly valve (cylinder outlet)	15	Cylinder outlet
4	Butterfly valve (cylinder inlet)	16	Outlet pipe (cylinder cooling water)
5	Ball valve (to drain the system)	17	Outlet pipe (cooling water)
6	Adjustable throttle (water inlet)	18	Supply pipe
7	Butterfly valve (cylinder liner inlet)	19	Inlet pipe (to cylinder liner inlet)
8	Ball valve (to drain the cylinder)	20	Vent pipe
9	Cylinder liner	21	Drain pipe
10	Water guide jacket		
11	Cylinder cover	WI	Cooling water inlet
12	Exhaust valve cage	WO	Cooling water outlet

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Starting Air Diagram

1. General

The starting air system is shown in the schematic diagram below.

The control air supply unit and air bottle 6 supply the necessary control air for the engine.

For more data, see the Pipe Diagram − Air System 4003-9.

You must make sure that the compressed air is clean and dry.

You must open the drain valves regularly to remove condensation from the starting air system.

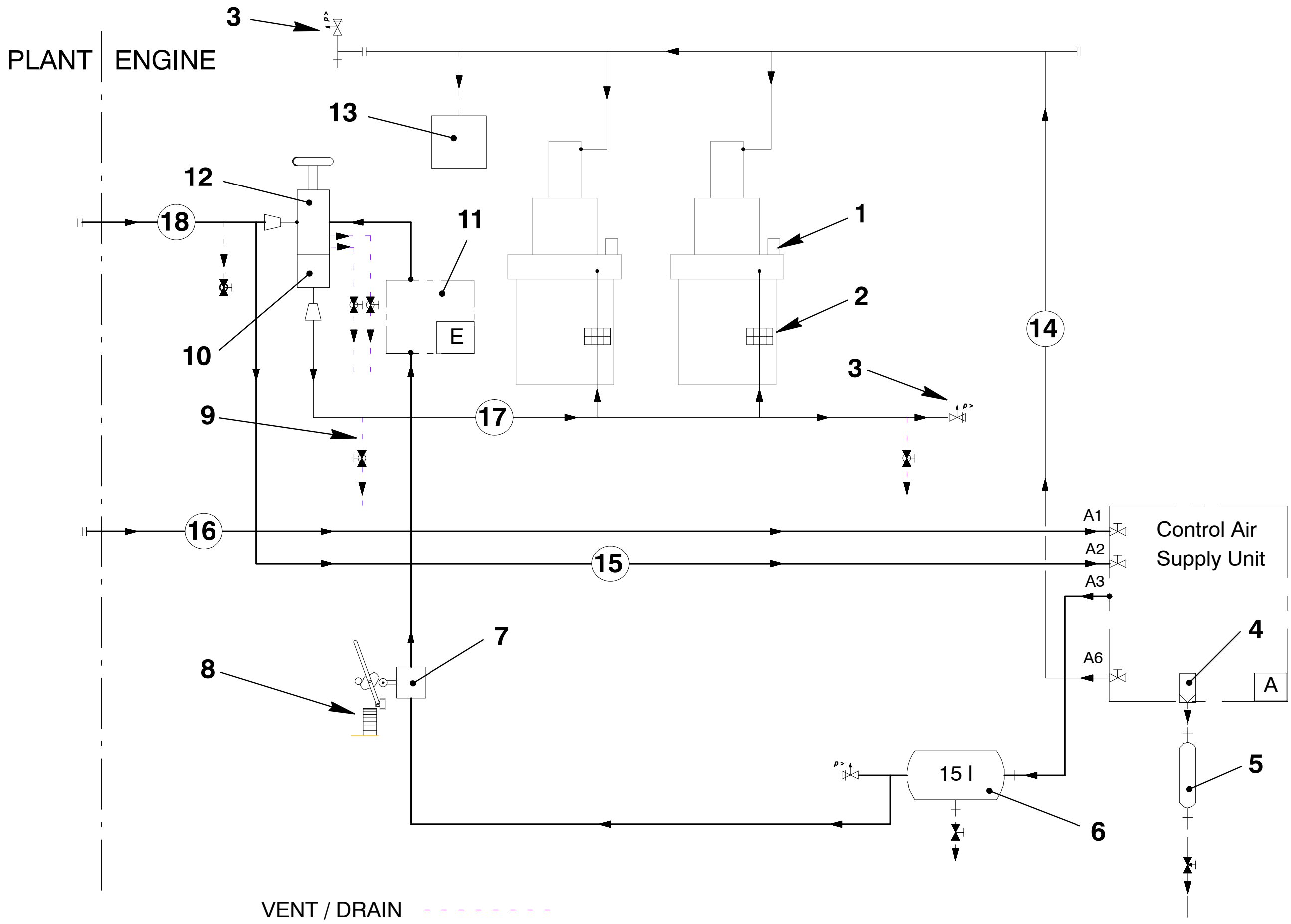

Fig. 1: Schematic diagram − starting and control air

1	Starting valve	10	Non-return valve
2	Flame arrestor	11	Control valve and valve unit for start
3	Pressure safety valve	12	Starting air shut-off valve
4	Air filter	13	Oil leakage return (from air spring)
5	Water bottle	14	Air spring air supply
6	Air bottle (control air supply)	15	Starting air
7	3/2-way valve (turning gear)	16	Control air (board supply)
8	Turning gear	17	Starting air pipe
9	Vent / drain	18	Starting air inlet

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Fuel System

1. General

For heavy fuel oil operation, all pipes to the fuel rail have adjacent insulated heating pipes to heat the fuel (see Fig. 1). These heating pipes also keep the fuel warm during short periods when the engine has stopped.

For safety, the fuel rail is installed in the rail unit (28). All pipes in the high pressure circuit that are out of the rail unit have double walls.

2. Low Pressure Circuit

A booster pump (installed in the plant) supplies the fuel through the fuel inlet pipe (1) to the fuel pumps (3). The fuel quantity that the fuel pumps supply is more than necessary for the engine. The adjustable pressure retaining valve (12) controls the pressure difference upstream and downstream of the supply pumps. The unwanted fuel flows back to the system through the fuel outlet pipe (5).

2.1 Adjustable Pressure Retaining Valve – Setting

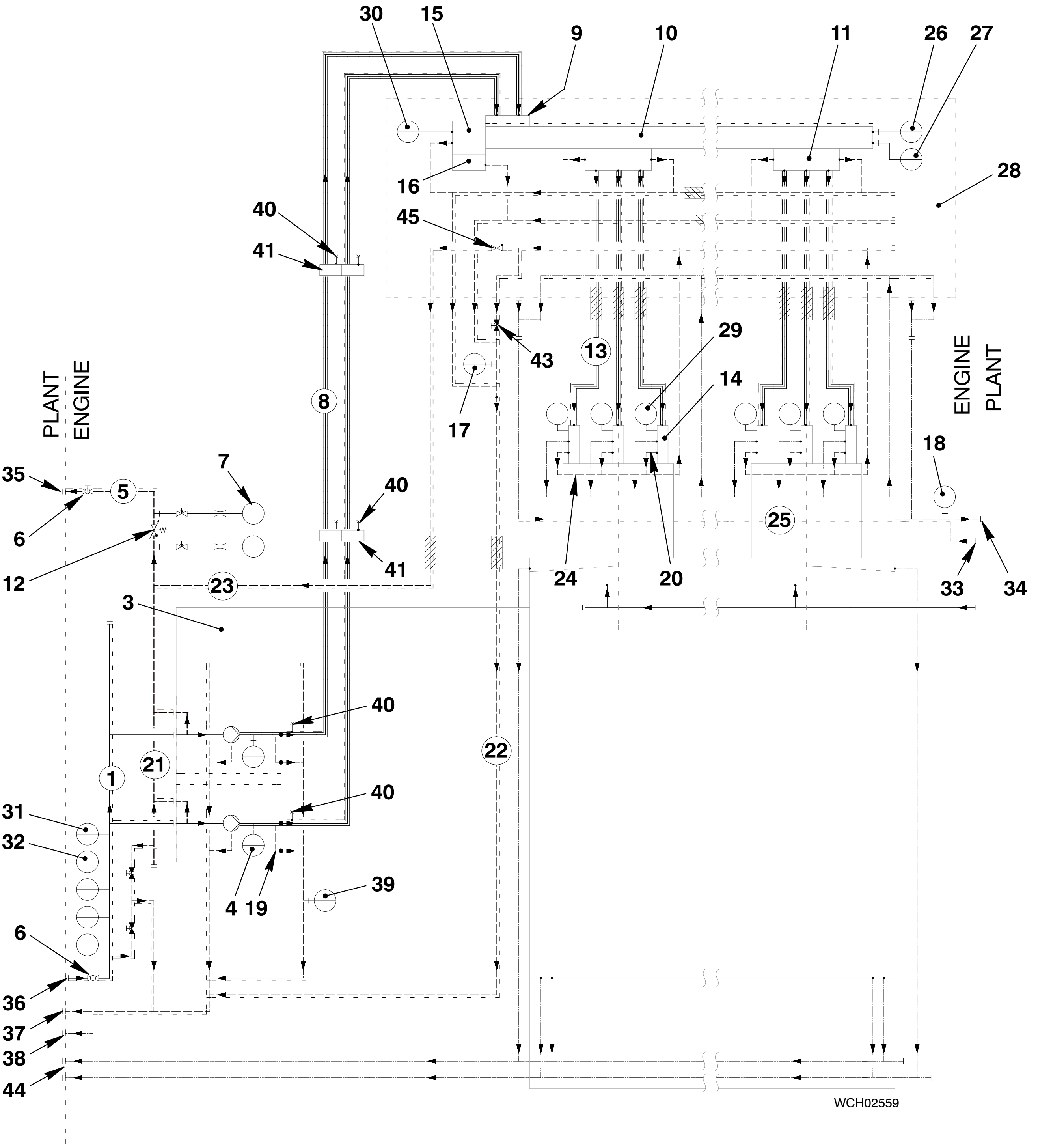
For the values of the adjustable pressure retaining valve, see the indications given in 0250–1, Operating Data Sheet, Fuel Inlet (fuel pump) and Return (fuel pump return).

3. High Pressure Circuit

The fuel pumps (3) supply high pressure fuel through the high pressure (HP) fuel pipes (8) into the fuel rail (10). The fuel pumps supply fuel as necessary to keep the pressure in the fuel rail constant (see 5556–1 Fuel Pump).

If an HP fuel pipe (8) has a leak or is broken, the non-return valves (9) close to prevent a pressure decrease.

The pressure control valve (15) controls the fuel pressure. The pressure control valve also lets fuel flow through the fuel pumps, HP fuel pipes and fuel rail during engine stand-by. This keeps the fuel warm (see also 5562–1 Pressure control valve).



Waste Pipes (Dirty Drain Pipes)
Trace Heating
Fuel Leakage
Fuel Return
Fuel Supply

Fig. 1: Fuel System

Key to Fig. 1

1 Fuel inlet pipe
2 Shut-off valve (plant)
3 Fuel pump
4 Flow control valve
5 Fuel outlet pipe
6 Shut-off valve (plant)
7 Pressure gages
8 HP fuel pipe
9 Non-return valve
10 Fuel rail
11 Flow limiting valve
12 Adjustable pressure retaining valve
13 HP fuel pipe (to injection valve)
14 Injection valve
15 Pressure control valve
16 Pressure relief valve
17 Level switch LS3446A
18 Level switch LS3444A
19 Fuel leakage pipe (from HP fuel pipes)
20 Control fuel outlet pipe
21 Fuel return pipe
22 Fuel leakage pipe
23 Drain pipe to fuel return
24 Fuel leakage pipe (injection valves)
25 Fuel leakage outlet pipe (rail unit)
26 Pressure transmitter PT3461C
27 Pressure transmitter PT3462C
28 Rail unit
29 Control valve (on injection valve)
30 Solenoid valve ZV7061S
31 Pressure transmitter PT3421A
32 Pressure transmitter PT3422A
33 Trace heating inlet
34 Fuel leakage outlet (rail unit)
35 Fuel return outlet
36 Fuel inlet
37 Fuel leakage outlet
38 Trace heating outlet
39 Level switch LS3426A
40 Leakage inspection point
41 Intermediate piece
42 Non-return valve
43 Ball valve (fuel drain for service)
44 Fuel leakage outlet to sludge tank
45 Non-return valve

4. Fuel Leakage System

The level switches (LS) monitor all important leakages in the fuel system.

If there is too much leakage, the related alarm is activated.

Level switch	Monitored components
LS3444A	Leakages (fuel and servo oil) from the rail unit
LS3446A	HP fuel pipes to injection valves (13, Fig. 1)
LS3426A	HP fuel pipes (8) and fuel leakage pipes (19)

4.1 Leakage Inspection Points

You use the leakage inspection points (40) to help you find possible leakages from the HP fuel pipes (8).

4.2 HP Fuel Pipes – Leakage

If the level switch (39) (LS3426A) has activated an alarm, do the procedure that follows:

WARNING

Injury Hazard: Always put on gloves and safety goggles when you do work on hot components. When you open the screw plugs, fuel can come out as a spray and cause injury.

1) Carefully loosen each of the screw plugs (8, Fig. 2) on the flange (5) of the HP fuel pipe (1), a maximum of two turns.
2) Do a check to see if fuel flows out or not as follows:
   a) If fuel flows out, the related HP fuel pipe (1) is defective.
   b) If fuel does not flow out, tighten the screw plugs (8).
3) Carefully loosen each of the screw plugs (9) on the flange (6) of the HP fuel pipes (2), a maximum of two turns.
4) Do a check to see if fuel flows out or not as follows:
   a) If fuel flows out, the related HP fuel pipe (2) is defective.
   b) If fuel does not flow out, tighten the screw plugs (9).
5) Carefully loosen each of the screw plugs (10) on the flange (7) of the HP fuel pipes (3), a maximum of two turns.
6) Do a check to see if fuel flows out or not as follows:
   a) If fuel flows out, the related HP fuel pipe (3) is defective.
   b) If fuel does not flow out, tighten the screw plugs (10).

WARNING

Injury Hazard: The fuel system has high pressure. Replace a defective HP fuel pipe only when the engine has stopped.

Note: If the HP fuel pipe cannot be replaced immediately (or the engine must continue to operate), then the fuel supply of the related fuel pump must be set to 0% (see 4002-2, paragraph 3.7 Fuel injection).

7) If necessary, replace the defective HP fuel pipe (see the Maintenance Manual 8752-1).

Note: When a fuel pump is cut out, operate the engine only at decreased load (see 5556-1 Fuel Pump).

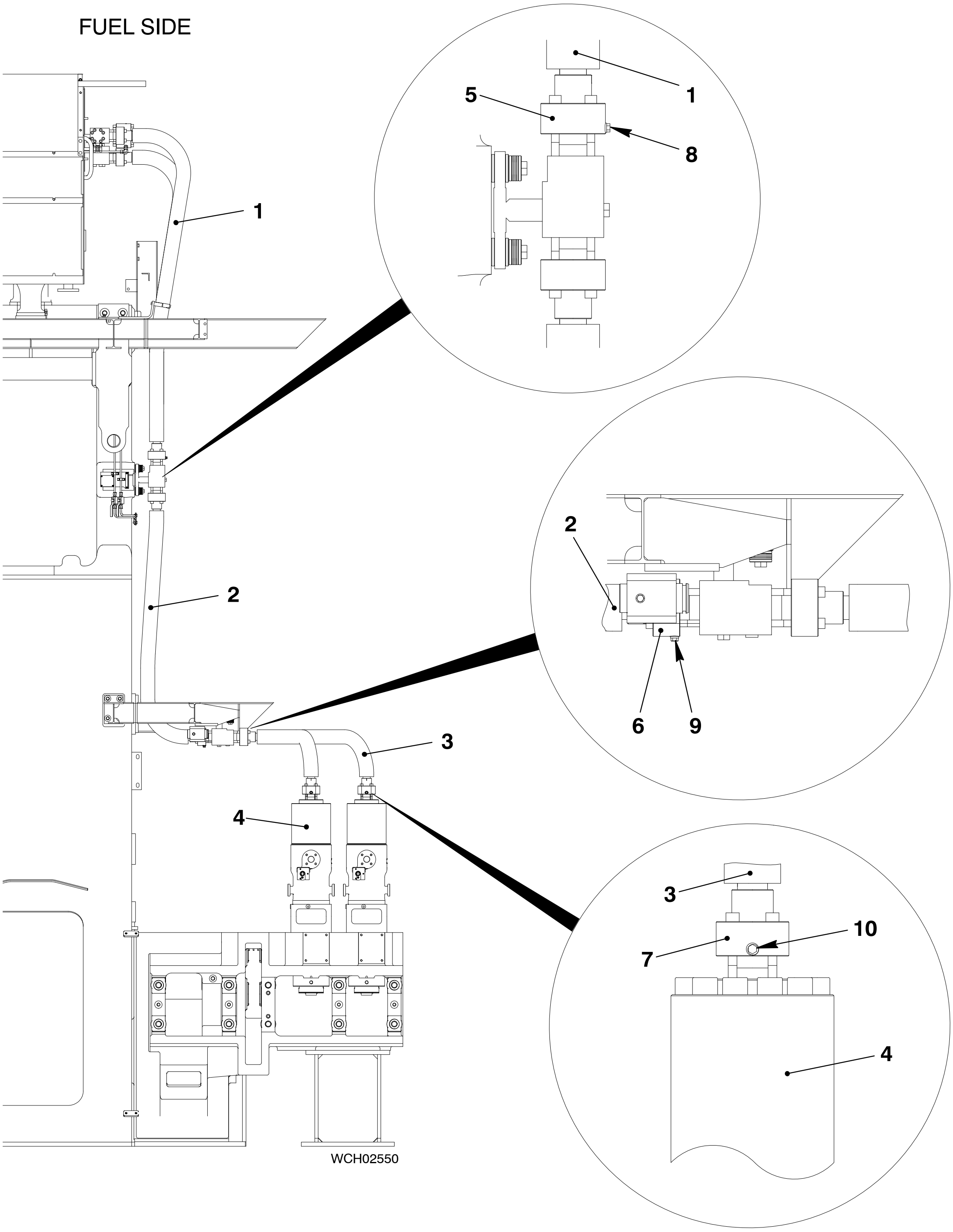


Fig. 2: Leakage Inspection Points

1 HP fuel pipes (top section)
2 HP fuel pipes (middle section)
3 HP fuel pipes (bottom section)
4 Fuel pumps
5 Flange
6 Flange
7 Flange
8 Screw plug
9 Screw plug
10 Screw plug

4.3 HP Fuel Pipes to Injection Valves – Leakage

WARNING

Injury Hazard: Always put on gloves and safety goggles when you do work on hot components. When drain screws and plugs are opened, fuel can come out as a spray and cause injury.

If the level switch (17, Fig. 1) (LS3446A) activates an alarm, you must find the related cylinder. Start at cylinder No.1 (driving end) and do the steps that follow on each cylinder until you find the leakage:

1) On the fuel leakage pipe (6, Fig. 3), carefully loosen the screw-in union (5) approximately two turns.

2) Do a check for fuel flow. If there is no fuel flow from the screw-in union (5) do the procedure given in paragraph 4.4.

3) If fuel flows from the screw-in union (5), do step 4).

4) Make sure that the screws (4) are tightened correctly to 60 Nm as follows:

   a) Symmetrically tighten the screws to 30 Nm.

   b) Symmetrically tighten the screws to 60 Nm.

5) Do a check for fuel. If fuel continues to flow, an HP fuel pipe (1) is defective.

WARNING

Injury Hazard: The fuel system has high pressure. Replace a defective HP fuel pipe only when the engine has stopped.

Note: If the HP pipe (1) cannot be replaced immediately, the injection of the related cylinder must be cut out (see 0510-1 Operation with Injection Cut Out).

6) Remove each of the three HP fuel pipes (1) until you find the defective HP fuel pipe (see the Maintenance Manual 8733–1, paragraph 1).

7) Do a check for damage on the sealing face (7) of the defective HP fuel pipe (1). If you find damage, you must grind the sealing face (see the Maintenance Manual 8733–1, paragraph 3).

8) If it is necessary to replace the defective HP fuel pipe (1), see the Maintenance Manual 8733–1 and 0510–1, paragraph 2.2).

The related flow limiter valve will stay closed until the engine is stopped and the pressure in the fuel rail (3) is released completely.

Note: When the injection is cut out (Inj. CUT OFF), you can operate the engine only at decreased load.

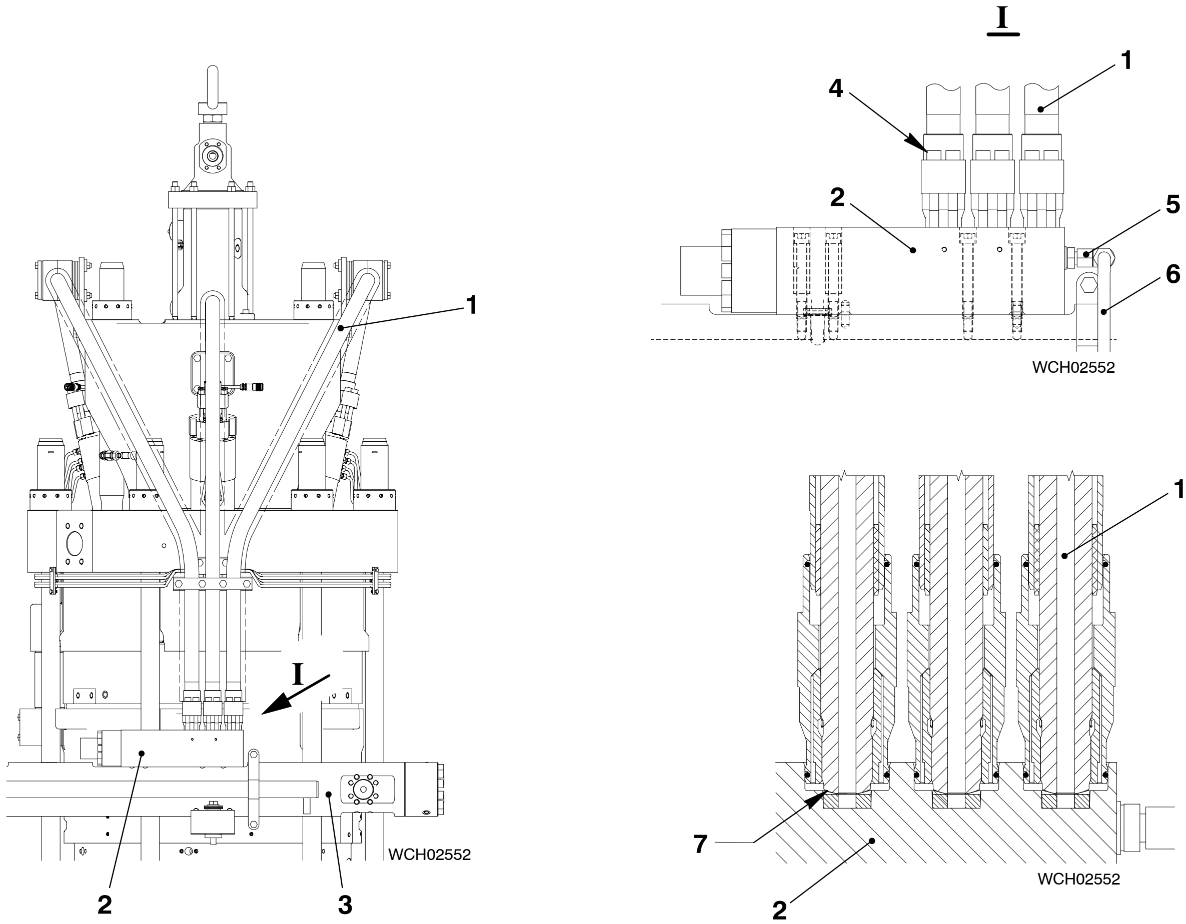


Fig. 3: Leakage Inspection Point − HP Fuel Pipes to Injection Valves

1 HP fuel pipe to injection valve
2 Flow limiter valve
3 Fuel rail
4 Screw
5 Screw-in union
6 Fuel leakage pipe
7 Sealing face

4.4 Leakage Check of Pressure Control Valve

Do the following procedures after emergency operation or maintenance on the fuel oil system only.

WARNING

Injury Hazard: Always put on gloves and safety goggles when you do work on hot components. Fuel can come out as a spray and cause injury.

WARNING

Injury Hazard: The fuel system has high pressure. Replace the defective pressure control valve only when the engine has stopped.

Make sure that the engine is ready for operation (see 0110–1, paragraph 2 Prepare for Operation).

1) In the LDU-20, get the USER PARAMETERS page, then select the button AIR RUN to turn the engine with air (see 4002-2, paragraph 3.10 User parameters).

2) If pressure decrease is unusually high during the air run, do a check of the pressure control valve (1) (see the procedure given in the Maintenance Manual 5562-1).

3) Start the engine (see 0230-1 Operation during Usual Conditions, Engine Start).

4) Open the cover (11) on the rail unit (12) (see Fig. 4)

5) Do a check for unusual noise from the pressure control valve (1).

    a) If you hear an unusual noise (a continuous sound like a whistle whistle), stop the engine and do a check of the pressure control valve (1) (see the Maintenance Manual 5562-1).

    b) If necessary, replace the pressure control valve (1) immediately (see the Maintenance Manual 5562-1 Fuel Pressure Control Valve).

6) Do a check of the temperature of the fuel return pipe (6).

    a) If the fuel return pipe (6) is hot, stop the engine and do a check of the pressure control valve (1) (see the Maintenance Manual 5562-1).

    b) If necessary, replace the pressure control valve (1) immediately (see the Maintenance Manual 5562-1).

7) Close the cover (11) on the rail unit (12).

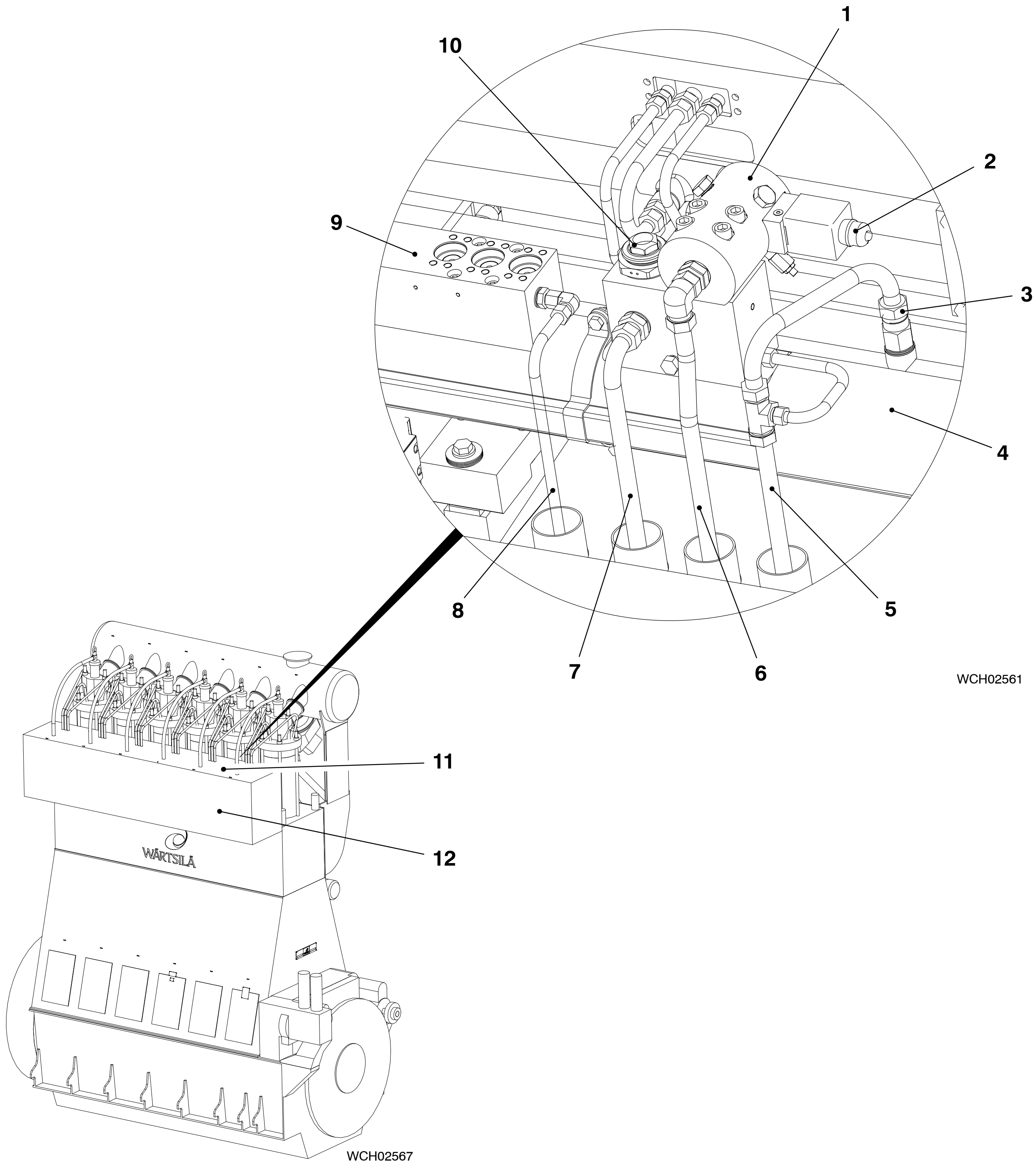


Fig. 4: Pressure Control Valve

1 Pressure control valve
2 Button (for pressure release)
3 Non-return valve
4 Fuel rail
5 Fuel return pipe (10 bar)
6 Fuel return pipe (0 bar)
7 Fuel return pipe (0 bar and monitored)
8 Fuel leakage pipe
9 Flow limiter valve
10 Pressure relief valve
11 Cover
12 Rail unit

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Exhaust Waste Gate (Low-load Tuning)

1. General

The Low-load Tuning (LLT) gives the lowest possible Brake Specific Fuel Consumption (BSFC) in the range of 40% to 70% engine load (see Fig. 1 for the schematic diagram of the LLT function).

With LLT, engines can operate continuously at all loads in the range of 30% to 100%.

The LLT uses a specially designed turbocharger system and specified engine parameters. These parameters are related to fuel injection and exhaust valve control and get the best decreased part-load BSFC in LLT.

Engines with LLT have an exhaust waste gate installed (i.e. a pneumatically operated valve on the exhaust gas manifold upstream of the turbocharger turbine). Exhaust gas blown through the waste gate flows to the exhaust uptake.

The LLT uses a turbocharger for part-load operation. The combustion pressure is increased at less than 75% load through an increased scavenge air pressure (waste gate closed). The waste gate opens at engine loads of more than 85% to prevent damage to the turbocharger and the engine from overload.

The higher scavenge air pressure at part-load causes a decrease in the thermal load and thus, better combustion for the full part-load range.

The engine parameters that control the fuel injection and exhaust valve operation are selected to make sure that the applicable NOx limit is obeyed.

The specified parameters make sure that the waste gate opens and closes smoothly throughout the full range. But, higher scavenge air pressure increases NOx emissions. Thus, to get the correct value for the test cycle, it is necessary to adjust the parameters for the scavenger air pressure increase.

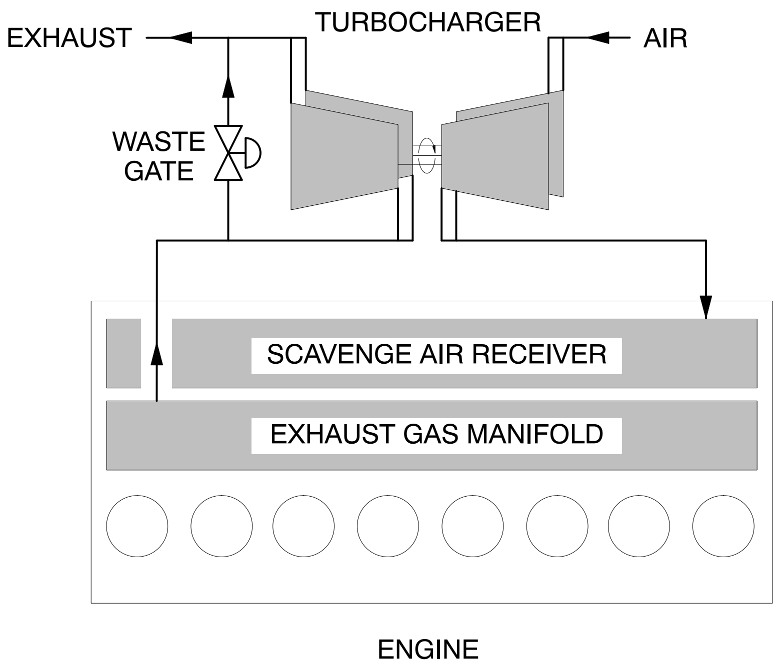


Fig. 1: Schematic Diagram Exhaust Waste Gate

2. Function

When the load is less than 85% (referred to in the ISO conditions), the force of the spring in the actuator (6, Fig. 2) keeps the butterfly valve (3) in the closed position.

2.1 Open

When the engine load is more than 85%, the charge air pressure increases to more than the set limit. The engine control system (ECS) energizes the 3/2-way solenoid valve (7), air spring air is released through the control air pipe (13) to the actuator (6) and the butterfly valve (3) opens (see Fig. 2, Fig. 3 and Fig. 4).

2.2 Close

When the engine load decreases to less than 85% and the charge air pressure decreases to less than the set limit, the ECS de-energizes the 3/2-way solenoid valve (7). This stops the air spring air supply. The pressure in the system is released and the spring in the actuator (6) closes the butterfly valve (3).

If a part becomes defective, alarm messages are activated in the ECS and shown in the alarm and monitoring system (see 0820-1 Operating Problems, paragraph 6).

3. Function check

A function check is necessary when the engine operates for long periods at low engine load with the exhaust waste gate closed. Do the function check that follows one time each week.

You can do this function check:

- When the engine has stopped, or
- When the engine operates at less than 70% load.

You can do Procedure One, or Procedure Two.

3.1 Procedure One

1) On the 3/2-way solenoid valve (7, Fig. 2), turn the screw (11) inwards until the butterfly valve (3) opens.
2) Turn the screw (11) back to its initial position (see Fig. 3).

3.2 Procedure Two

1) In the LDU-20, get the USER PARAMETERS page (see 4002-2, paragraph 3.10, User parameters).
2) In the row Exhaust waste gate, select the button OPEN. The waste gate opens.

Note: After 20 seconds the waste gate will close automatically.

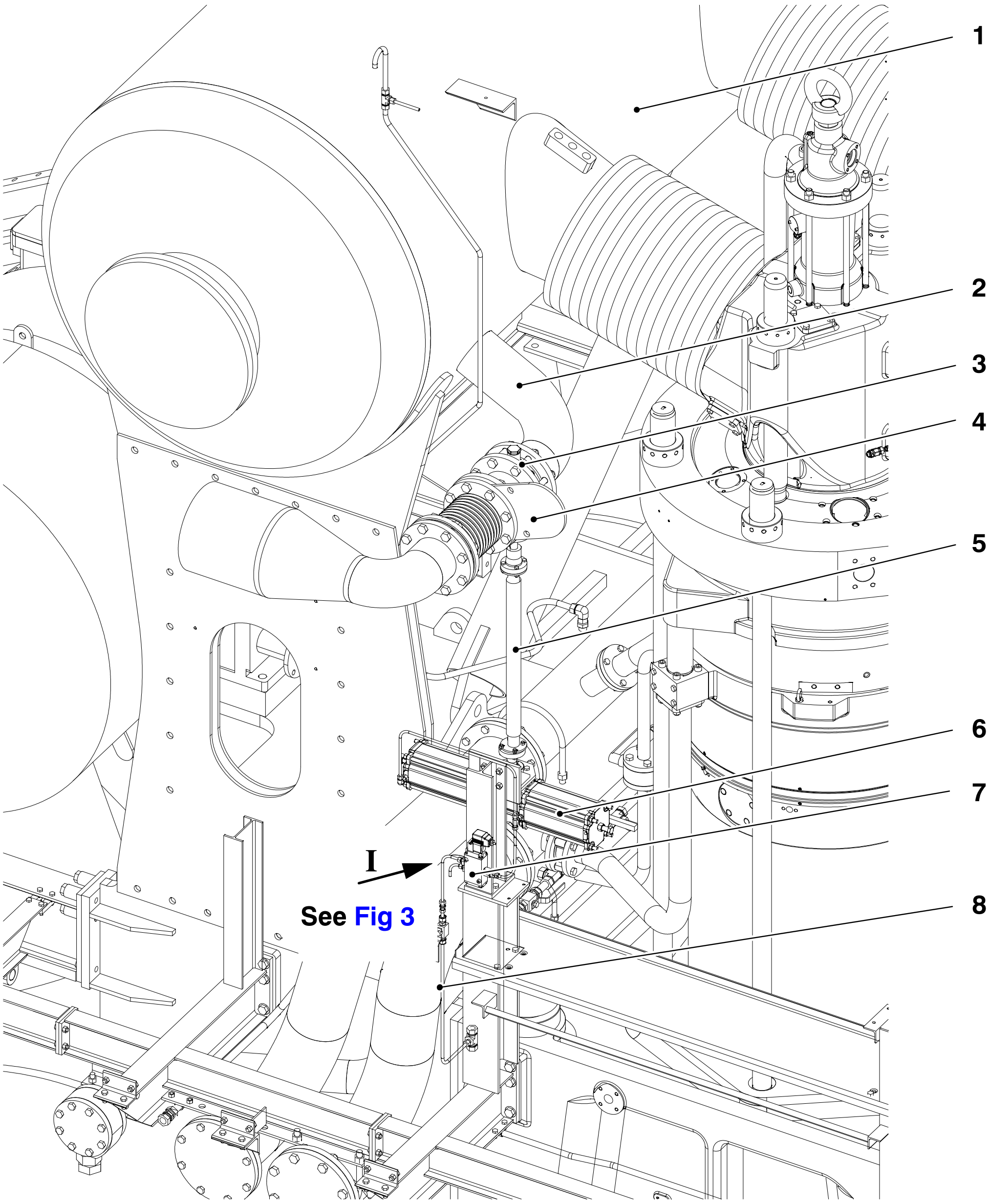


Fig. 2: Exhaust Waste Gate

1 Exhaust gas manifold
2 Exhaust bypass line
3 Butterfly valve
4 Orifice
5 Cardan rod
6 Actuator (ZS5372C)
7 3/2-way solenoid valve (CV7076C)
8 Air spring air pipe

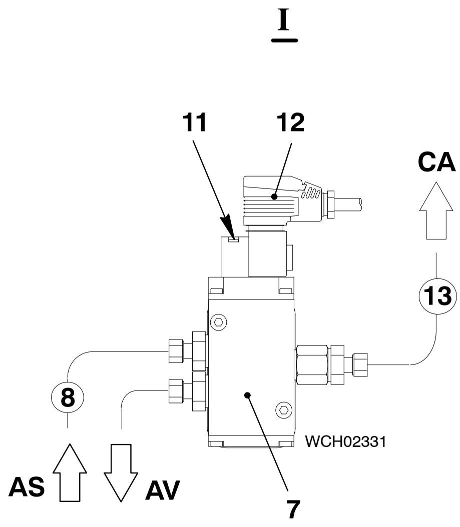


Fig. 3: 3/2-way solenoid valve (CV7076C)

6	Actuator (ZS5372C)	12	Electrical connection
7	3/2-way solenoid valve (CV7076C)	13	Control air pipe
8	Air spring air pipe		
9	Control air supply unit	AS	Air spring air
10	Ball valve	AV	Air Vent
11	Screw	CA	Control air to actuator

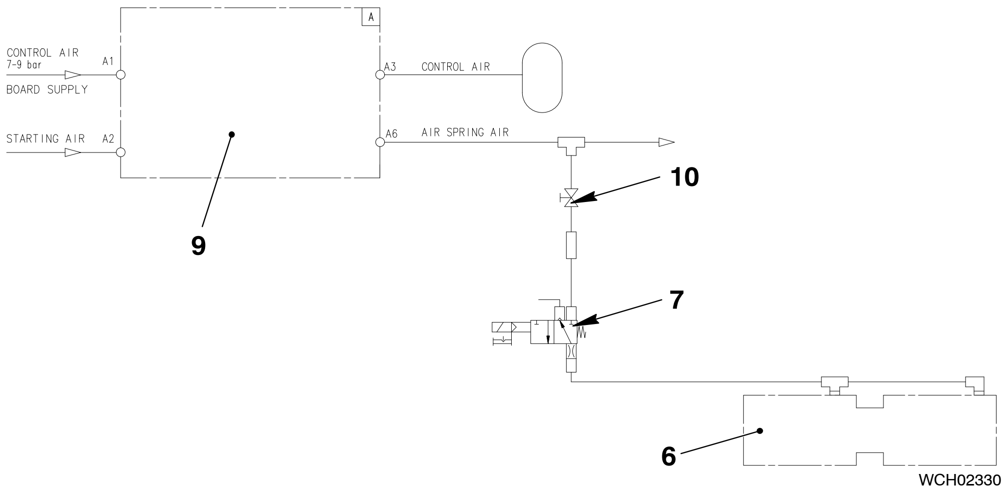


Fig. 4: Schematic diagram air supply

6	Actuator (ZS5372C)	9	Control air supply unit
7	3/2-way solenoid valve (CV7076C)	10	Ball valve

Drainage System and Wash-water Pipe System

1. General

You must do checks at regular intervals to make sure that all drain pipes are not blocked. The checks on the drain pipes from the piston rod gland box (20) and the piston underside (9) are important (see Fig. 1).

The ambient temperature and humidity can cause condensate to flow out upstream and downstream of the scavenge air cooler (14). Very high ambient conditions can make up to 0.16 kg/kWh of condensate.

2. Condensate Drain

Note: Blocked drains let too much condensate collect in the scavenge air receiver. The water / water vapor has an unwanted effect on piston operation and increases wear on the piston rings and cylinder liners.

The condensate drain must operate correctly as follows (see also 0240-1 Checks and Precautions, paragraph 2):

1) Make sure that all valves in the condensate drain pipe are fully open.

2) Make sure that the ball valves (18) and (19) are in the position USUAL OPERATION (see Fig. 1).

Note: The condensate collectors (12) collect dirt particles.

3) At regular intervals, remove dirt particles from the condensate collector (12) when the engine has stopped (see the Maintenance Manual 0380-1 Maintenance Schedule).

4) At regular intervals, look at the sight glasses of the condensate collector (12) to make sure that water flows (see the Maintenance Manual 0380-1 Maintenance Schedule).

Note: For engines with two turbochargers there are two more level switches (LS4072A and LS4076A) installed. For more data see, 4003-4 Pipe Diagram – Water Systems (Scavenge Air Receiver and Turbocharger).

If one, or the two level switches LS4071A (10), LS4075A (13) activates an alarm (condensate level too high), you must find the cause immediately and correct the defect. The possible causes of the alarm are:

- The ball valves (18) and (19) are in the position CLOSED (see Fig. 1).
- The scavenge air cooler (14) is defective (see 0550–1).
- If the orifices (11) are blocked and / or there is too much contamination in the condensate collector (12) (the filter is blocked).

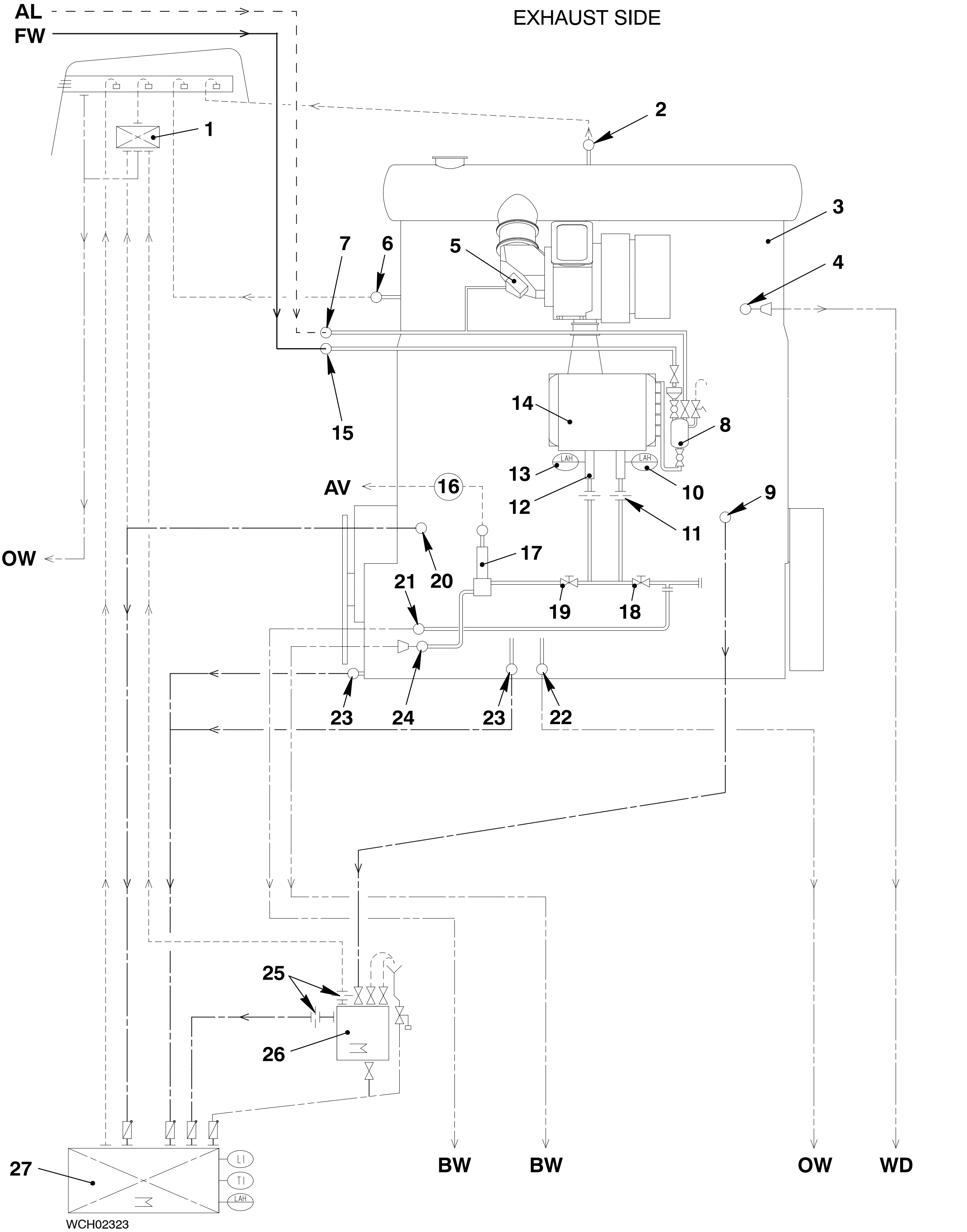
5) To clean the condensate collector (12) and the orifice (11) do step a) to step c).

    a) Stop the engine.

    b) Clean the condensate collector (12).

    c) Clean the orifice (11).

Note: You must clean the filters in the condensate collector (12) and the orifices (11) as soon as possible.



DATA FOR ENGINES WITH ONE TURBOCHARGER

Fig. 1: Schematic diagram

Key to Fig. 1

1	Air vent manifold	18	Ball valve
2	Vent – turbocharger outlet	19	Ball valve
3	Main engine	20	Leak gland box – outlet
4	Cylinder cooling water drain – outlet	21	SAC wash water – outlet
5	Dry cleaning device (TC)	22	Oily water from SAC – outlet
6	Vent crankcase – outlet	23	Leak outlets (main engine)
7	Air for wash plant TC and SAC – inlet	24	SAC condensate water – outlet
8	SAC wash plant	25	Orifice
9	Dirty oil piston underside – outlet	26	Sludge oil trap
10	Level switch (LS 4071A)	27	Sludge tank
11	Orifice		
12	Condensate collector	AL	Air line from board system
13	Level switch (LS 4075A)	AV	Air vent
14	Scavenge air cooler	BW	Drain to bilge water tank
15	Water for wash plant SAC – inlet	FW	from fresh−water system
16	SAC Vent	OW	Drain to oil / water drain tank
17	Vent unit	WD	Drain to water drain tank

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Electrical Trace Heating System

1. General

The main and emergency switchboards supply 230 VAC single phase (230 VAC) to the control box E88 (see Fig. 1 and Fig. 2). The control box E88 is installed in the engine room near the engine.

The control box E88 also supplies 24 VDC to the XS3411C HFO supply and to the temperature element TE3411C.

2. Electrical Trace Heating

The control box E88 supplies electrical power to the terminal box E89. The terminal box E89 supplies power to each connection box E89.01 to E89.0X (see Fig. 1).

The connection boxes E89.01 to E89.0X supply power to the trace heating cables for each fuel injection pipe (see Fig. 2 and Fig. 3).

The electrical trace heating system heats the fuel injection pipes to the target temperature of 130°C ± 10% and keeps this temperature stable.

The electrical heating cables are the self-control type i.e. the electrical current absorbed decreases in relation to an increase in temperature until a stable condition occurs. The power consumption is related to the temperature of the electrical heating cables.

When the heating cable is at the target temperature, the heating cable stays on, but at the lowest power consumption.

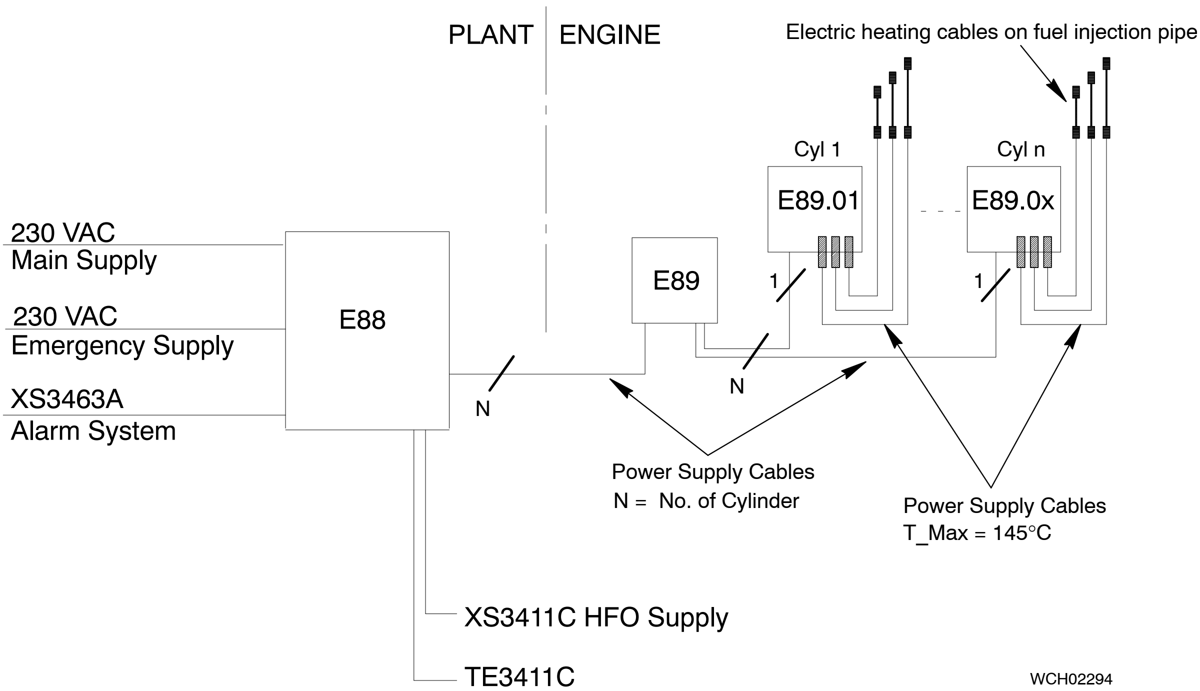


Fig. 1: Schematic diagram – Electrical heating system

2.1 Power Consumption Values

The table below gives an estimate for the power consumption values for the heating cables installed on the engine:

Number of Cylinders	**4**	**5**	**6**	**7**	**8**
Power Consumption (W) Worst Case T_Amb = 0°C	2100	2600	3100	3600	4100
Power Consumption (W) Stable Operation Conditions	1200	1500	1800	2100	2400

A resistance insulation test must be done at regular intervals (a minimum of four each year) for each electrical trace heating circuit. The results must be monitored and recorded (see the Maintenance Manual 8825-1).

2.2 Usual Operation

When the engine operates with:

- Marine Diesel Oil (MDO): The heating cables must be set to off.
- Heavy Fuel Oil (HFO): It is recommended that the heating cables are set to on. This keeps the HFO at the correct temperature.

When the engine has stopped after operation with:

- MDO – The heating cables must be set to off.
- HFO – The heating cables must be set to on.

2.3 Operation Modes

The electrical heating system can operate in Manual mode or automatic mode.

In the control box E88, you set the switch to the applicable position as follows:

- On
- Off
- Auto.

In Auto mode, the temperature measured on the fuel inlet pipe, sets the electrical trace heating system to on or off.

If available, you can also use the MDO/HFO switch in the plant to set the electrical heating system to on and off (MDO – open contact, HFO – closed contact).

2.4 MDO / HFO Supply Status (E88 to ECS)

The temperature element TE3411C (10) measures the fuel temperature in the fuel inlet pipe (9) (see Fig. 2).

The control box E88 gives the status signal XS3411C HFO Supply to the engine control system (ECS) in relation to the measured temperature if:

- The temperature is less than 60°C, then the contact is open (when the engine operates with MDO)
- The temperature is equal to or more than 60°C, then the contact is closed (when the engine operates with HFO).

The status is shown on the LDU-20 on the related page (see 4002-2, paragraph 3.10 User Parameters).

2.5 Alarms from E88 to the Alarm and Monitoring System

The control box E88 gives a digital output signal XS3463A to the alarm and monitoring system (AMS) as follows:

- No alarm: The contact is closed.
- Alarm on: The contact is open.

The control box E88 activates an alarm when there is a minimum of one of the conditions that follow:

- Manual ON mode when the engines is supplied with MDO
- Manual OFF mode when the engine is supplied with HFO
- There is an internal 24 VDC power supply failure in the control box E88.
- The temperature sensor TE3411C is disconnected, broken or out of range.
- In the control box E88, a minimum of one residual current protection device finds a leakage current, which is equal to, or more than 300 mA (power supply output for the heating cables)
- The control box E88 is not connected to the emergency switchboard
- The control box E88 is not connected to the main switchboard.

2.6 230 VAC Emergency Switchboard Supply to E88

The control box E88 is connected to the main and emergency switchboards. The default 230 VAC supply is from the main switchboard.

If the main switchboard becomes defective, the emergency switchboard will supply 230 VAC to the control box E88. When the main switchboard becomes serviceable again, the emergency switchboard will continue to supply 230 VAC. The control box E88 sets to on the related yellow indication (see Fig. 4).

It is recommended that you set to off then on, the main switch in the control box E88. This will make sure that the main switchboard supplies 230 VAC to E88.

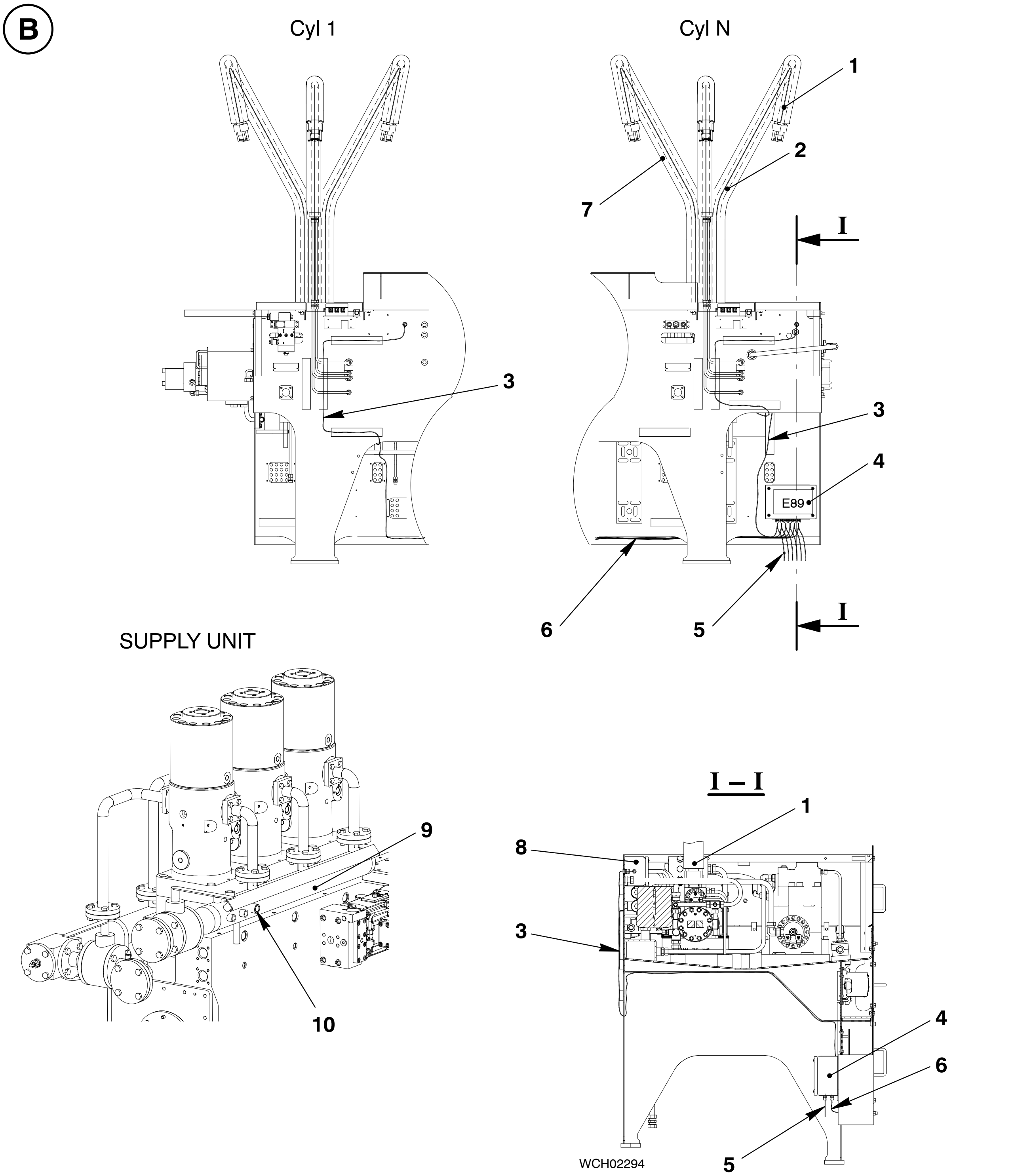
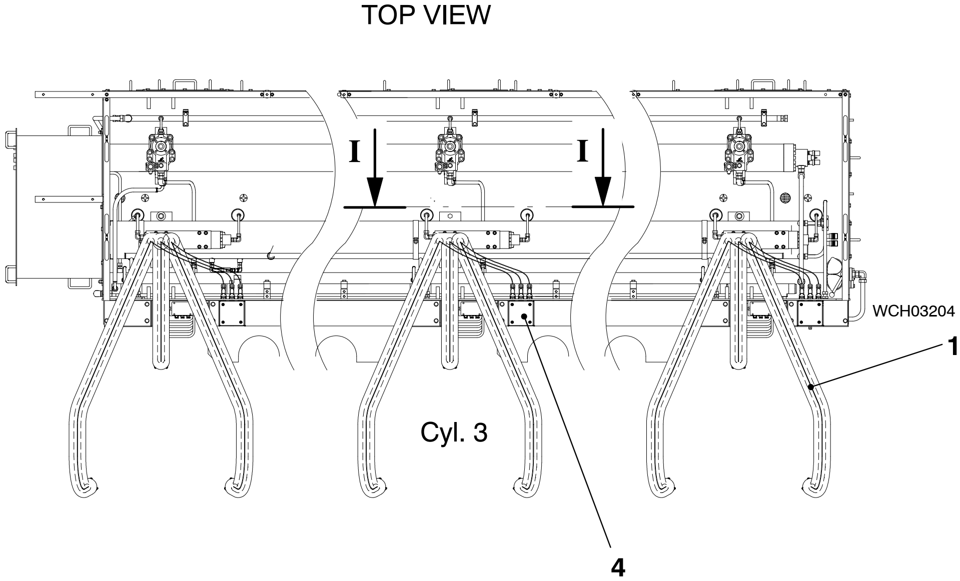


Fig. 2: Electrical trace heating

1 Fuel injection pipes
2 Heating cables
3 Power supply cable (to connection box E89.0X)
4 Terminal box E89
5 Power supply cables (from E88)
6 Power supply cables (to next E89.0X)
7 Insulation
8 Connection box E89.0X
9 Fuel inlet pipe
10 Temperature element TE3411C



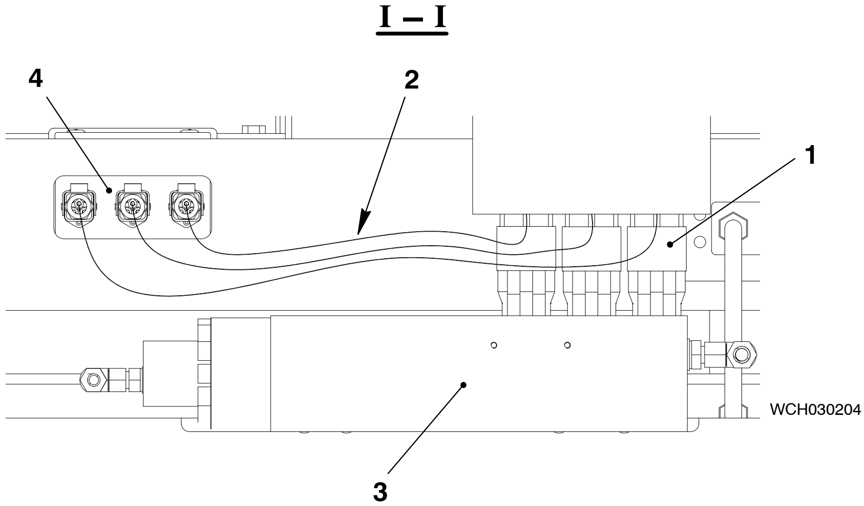


Fig. 3: Connection box E89.03

1 Fuel injection pipes
2 Heating cables
3 Flow limiter valve 10-5560_CX_2
4 Connection box E89.03 (Cyl. 3)

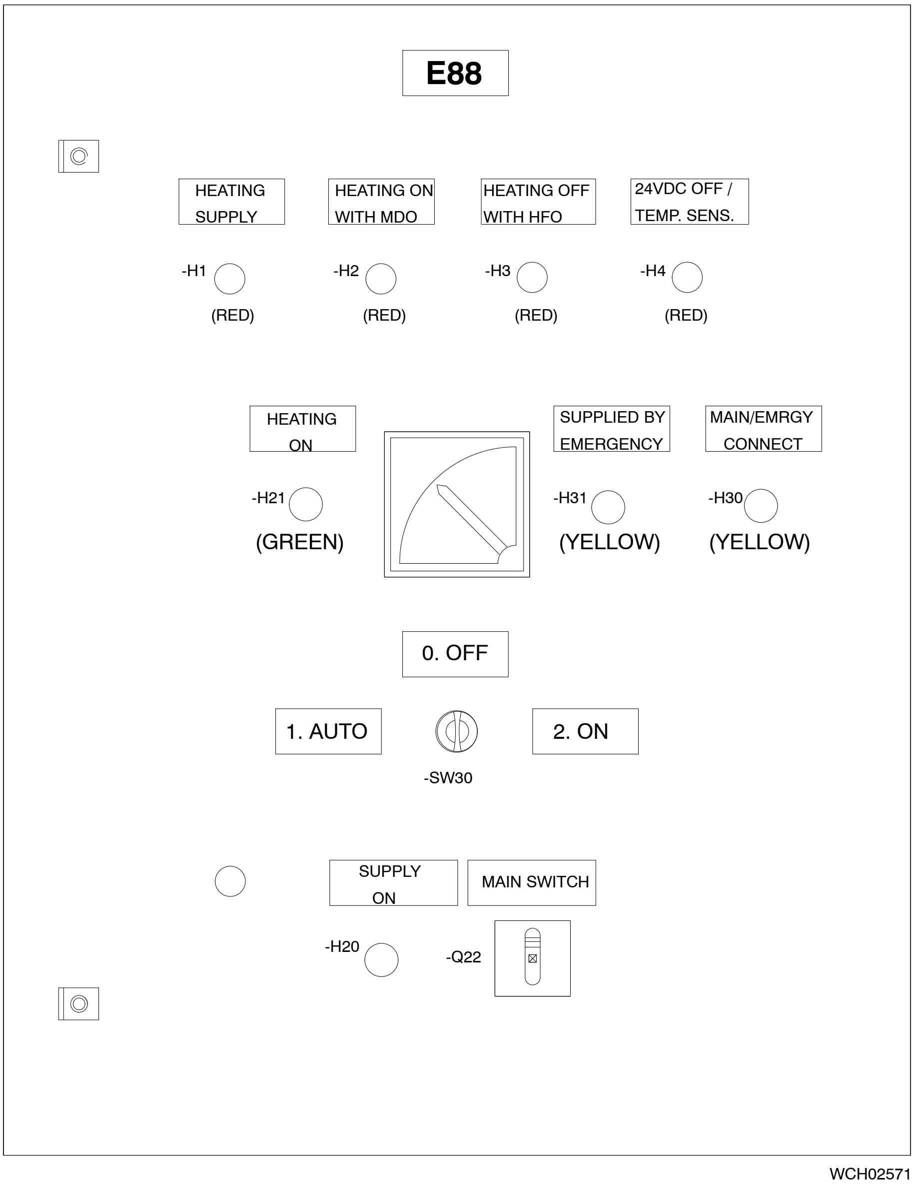


Fig. 4: Control box E88

Engine Monitoring Group 9

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Crank Angle Sensor Unit

1. General

The crank angle sensor unit is installed on the supply unit drive (7) at the driving end (see Fig. 1).

There are two crank angle systems that monitor the teeth on the intermediate wheel. The two sets of proximity sensors (2, 3 and 4, 5) operate independently to sense the teeth on the intermediate wheel (1).

Two more proximity sensors (10) and (11) are used to find the crank angle marks for TDC and BDC on the flywheel (8) (see Fig. 2).

All proximity sensors are connected to each CCM−20 (see 4002−1, paragraph 3.5 Engine Speed and Crank Angle Sensor.

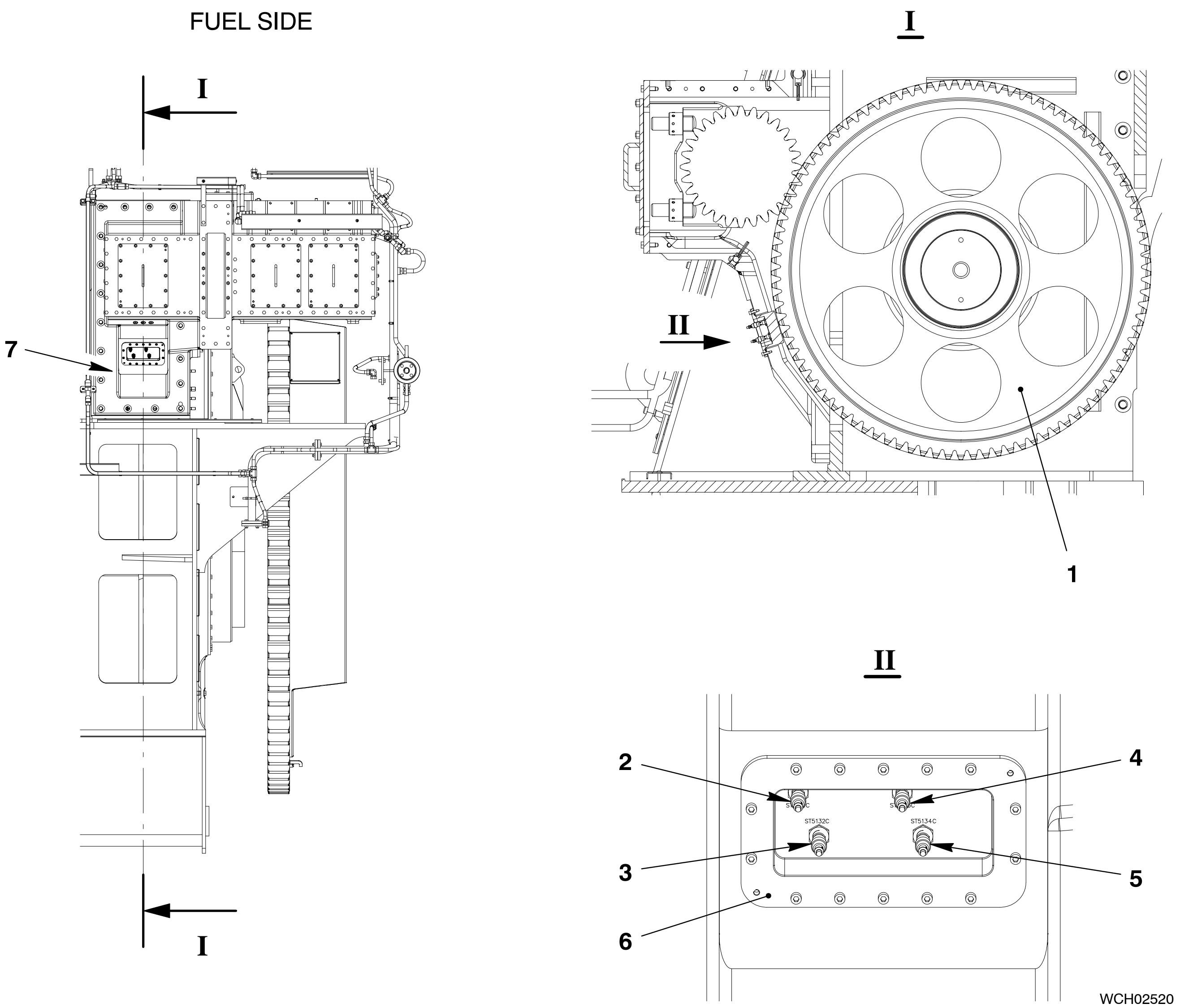

Fig. 1: Crank angle sensor unit

1 Intermediate wheel
2 Proximity sensor ST5131C
3 Proximity sensor ST5132C
4 Proximity sensor ST5133C
5 Proximity sensor ST5134C
6 Sensor adapter
7 Supply unit drive

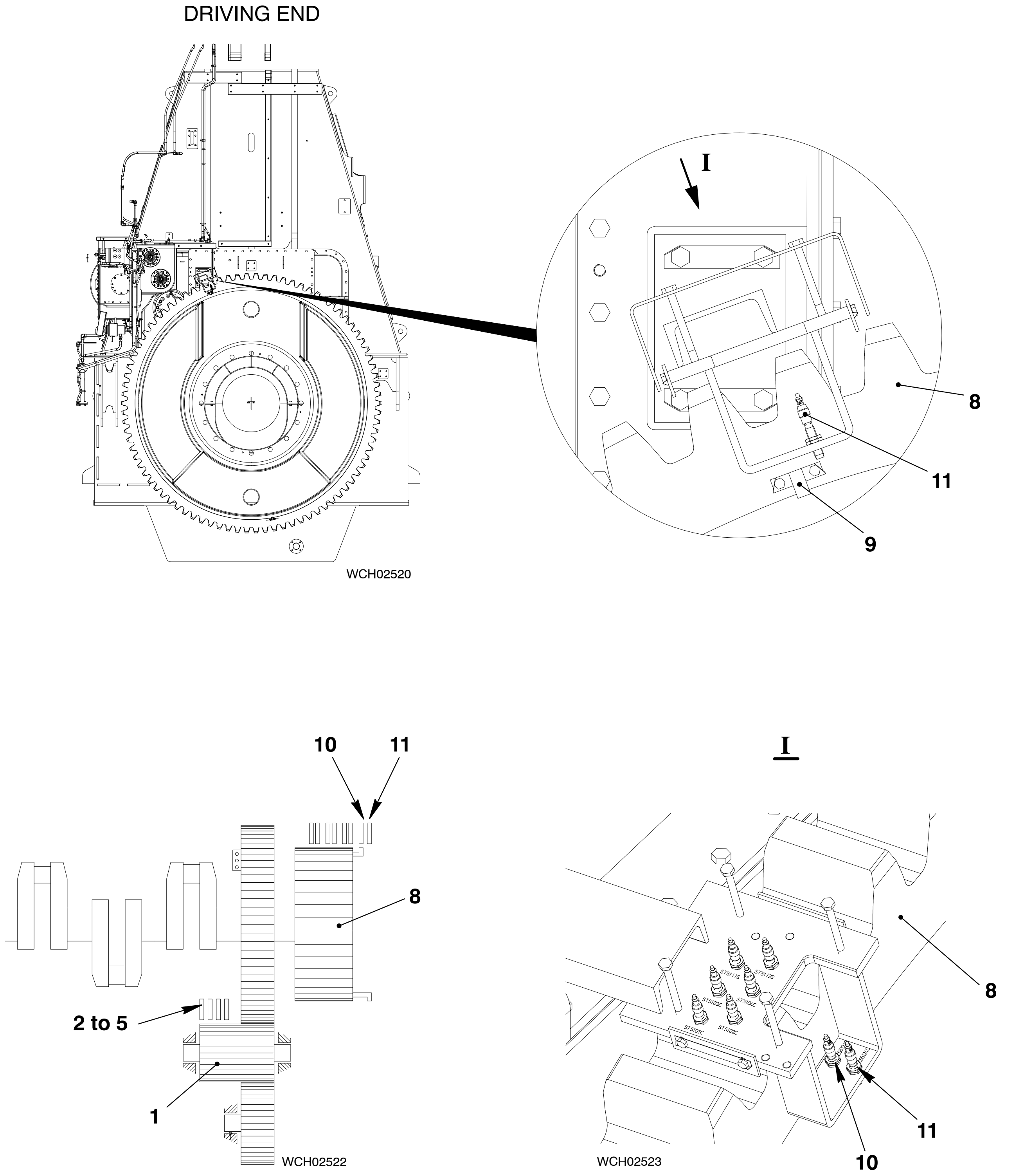

Fig. 2: Crank angle sensor unit

1	Intermediate wheel	8	Flywheel
2	Proximity sensor ST5131C	9	Crank angle mark
3	Proximity sensor ST5132C	10	Proximity sensor ZS5123C
4	Proximity sensor ST5133C	11	Proximity sensor ZS5124C
5	Proximity sensor ST5134C		

Intelligent Combustion Control

1. General

The Intelligent Combustion Control (ICC) permanently monitors and automatically controls the combustion process.

The ICC system adjusts the common injection time, which makes sure that the engine performance relates to the shop test results.

The ICC calculates the best engine control parameters for operation, which balances the compression and firing pressures in the engine (e.g. injection time offsets and exhaust valve closing time for each cylinder).

2. Function

The ICC, as part of the engine control system, adjusts the maximum peak firing pressure of the engine related to the shop test protocol and NO_x Technical File. All ICC modifications of the engine control parameters obey the IMO regulations and are related to the IMO certificate of the vessel.

The ICC keeps the pressure increase in the limits during the combustion process. As a result, the ICC system:

- Decreases the excessive wear of engine components
- Decreases the risk of an engine overload
- Prevents manual adjustment failures (only possible during open-loop control).

In the engine control system (ECS), it is possible to set to on or off each individual function of the ICC system (see 4002-2 Local Control Panel / Local Display Unit, paragraph 3).

The ICC adjusts the value of the firing pressure to its corrected set-point value. The system balances the firing pressure of all units and balances the compression pressure. The cylinder pressure and the firing pressure are balanced in an operation range that is more than the operation range of the auxiliary blowers (i.e. the auxiliary blowers are set to off). When all ICC functions are set to off, the engine operates in a conventional open-loop control mode.

Note: If there are large differences in the values (injection time or exhaust valve operation) for a cylinder that shows possible wear or damage, monitor the related cylinder. If necessary, replace the defective parts.

2.1 Pressure Transducers

The pressure transducer (1) (one for each cylinder) is installed on the cylinder cover (see Fig. 1).

The technology (Pressductor®) of the pressure transducers (1) uses a magneto-elastic measuring principle to measure the in-cylinder pressure. The permanently measured in-cylinder pressure of all cylinders gives the necessary data for the ICC system.

The pressure transducers (1) have a unique blow-through design. Usually, before the engine starts, the indicator valves (2) are open and the engine is in slow turning operation. Thus, possible combustion particles that remain (specially from HFO operation) are blown out of the pressure transducers (1). This function makes sure that the data is measured correctly and maintenance is decreased.

Note: For more data about slow turning, see 0220-1 Slow Turning.

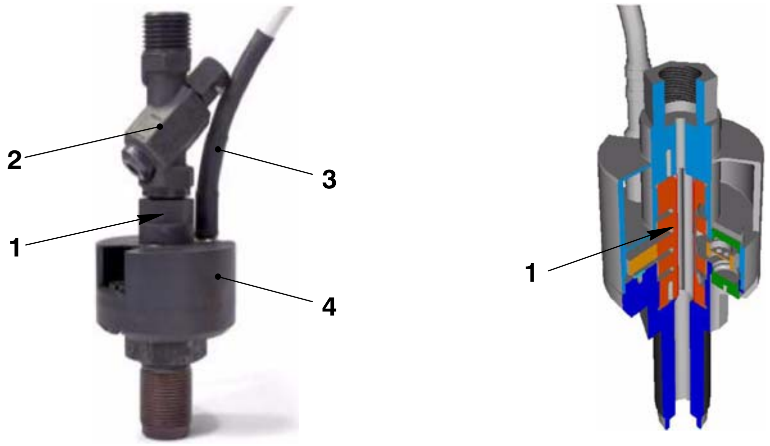

Fig. 1: Pressure Transducer

1 Pressure transducer	3 Cable
2 Indicator valve	4 Adapter piece

2.2 In-cylinder Pressure Evaluation

The compression pressure cannot be measured directly because of the combustion and fuel injection that can occur before TDC.

In the ICC system, the compression pressure of each cycle is calculated with the polynomial formula and the data of the piston position.

The peak firing pressure is the highest measured pressure value in the crank angle range between the start of the injection and approximately 20°CA after TDC (see Fig. 2).

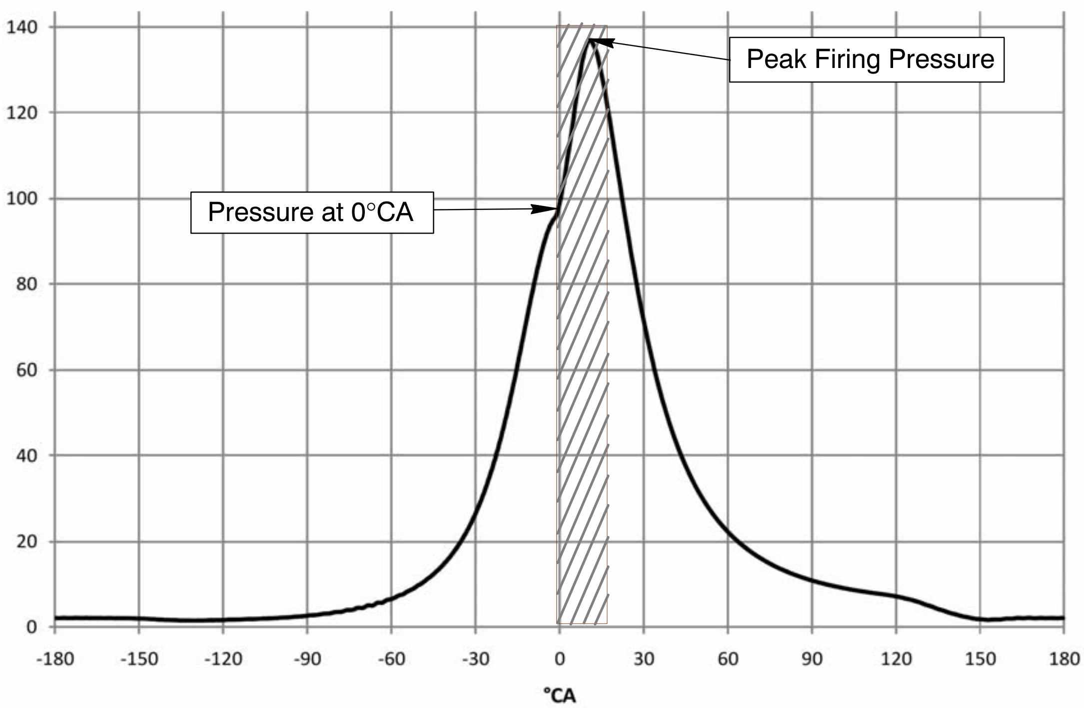

Fig. 2: Cylinder Pressure Trace of a Two-stroke Engine

The pressure increase is the difference between the firing pressure and the compression pressure (see Fig. 2). The ICC sets the pressure increase limit e.g. to 40 bar to prevent mechanical overload to the engine.

2.3 ICC - Installation and Control

The necessary firing pressure, referred to as the shop test performance, is continuously adjusted (a reverse ISO correction) to the conditions at each operation point of the engine. This makes sure that the firing pressure is always adjusted to the correct value, related to the engine design. Because of the ICC, you can use the maximum possible engine power without the risk of an overload.

The necessary temperature and pressure sensors are installed upstream of the turbocharger compressor inlet and in the scavenge air receiver. The sensors are connected to the IOM-10 (see Fig. 3).

The cylinder pressure data of each cylinder is taken as an analogue input signal from the pressure transducer into the ECS. For more data, see Fig. 3.

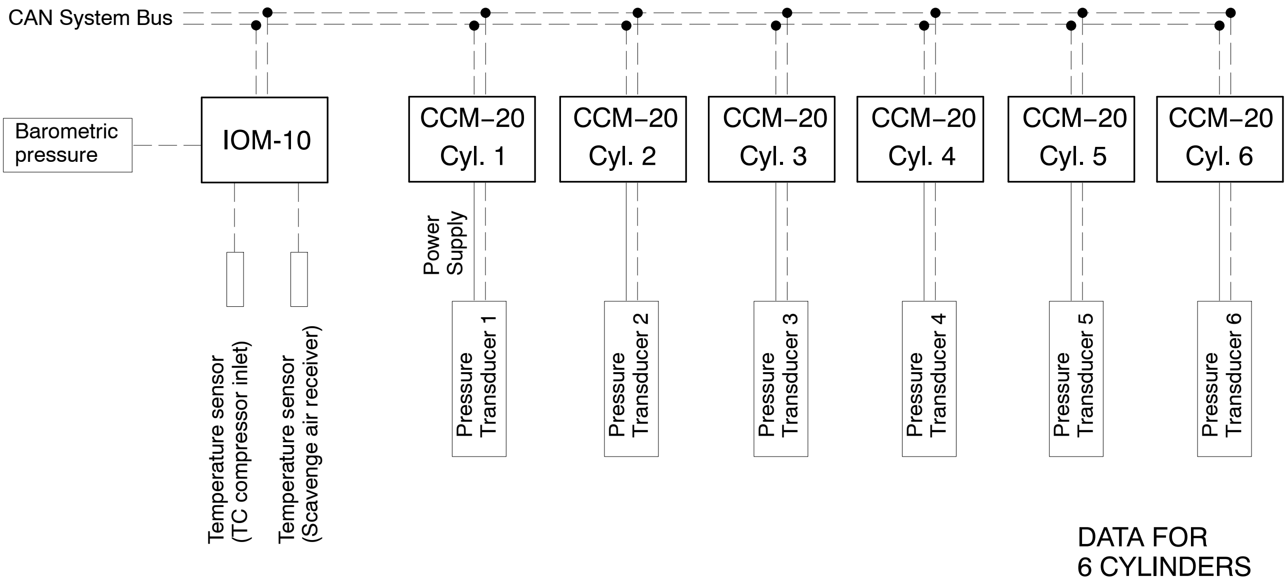

Fig. 3: Installation Schematic of the ICC System

The ECS control system filters the signals from the sensors and then transmits these signals to a controller. The measured value is adjusted to the correct set-point value and is related to the engine load. This real-time site correction and comparison is done for each engine cycle (see Fig. 4).

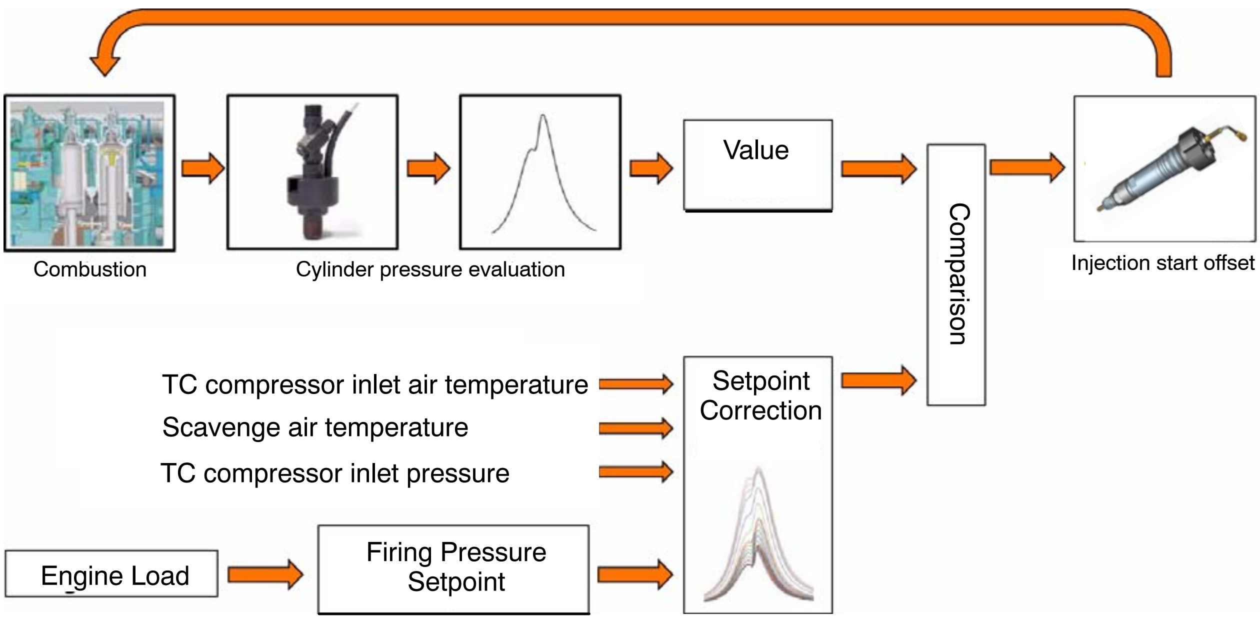

Fig. 4: Control schematic of the ICC System

Oil Mist Detector

1. General

The engine has an oil mist detector system. The system includes the sensors (2) and the control unit (1) on the engine (see Fig. 1).

A display unit (8) is installed in the control room (Fig. 2).

The sensors (2) are installed on the fuel side of the engine for:

- Each cylinder of the divided crankcase
- The supply unit drive
- The supply unit.

The oil mist detector system continuously monitors the concentration of oil mist in the crankcase, supply unit drive and the supply unit. If there is a high oil mist concentration, the oil mist detector activates an alarm.

Damage to the bearings is quickly found and explosions in the crankcase are prevented (see also 0460−1 Instructions about the Prevention of Crankcase Explosions).

2. Function

Each sensor (2) optically monitors the concentration of oil mist. Each sensor has a self-test function to make sure that there are no internal faults.

Data communication is between the control unit (1) and the display unit (8) (see Fig. 2).

The adjustments can be programmed in the display unit (8).

The menu-driven software has three user levels:

- User: Read-only data.
- Operator: Password-protected level for access to most adjustments and functions.
- Service: Password-protected level for authorized staff of the manufacturer and service personnel.

Note: Instructions that relate to adjustments, commissioning, troubleshooting, and maintenance are given in the related documentation of the manufacturer.

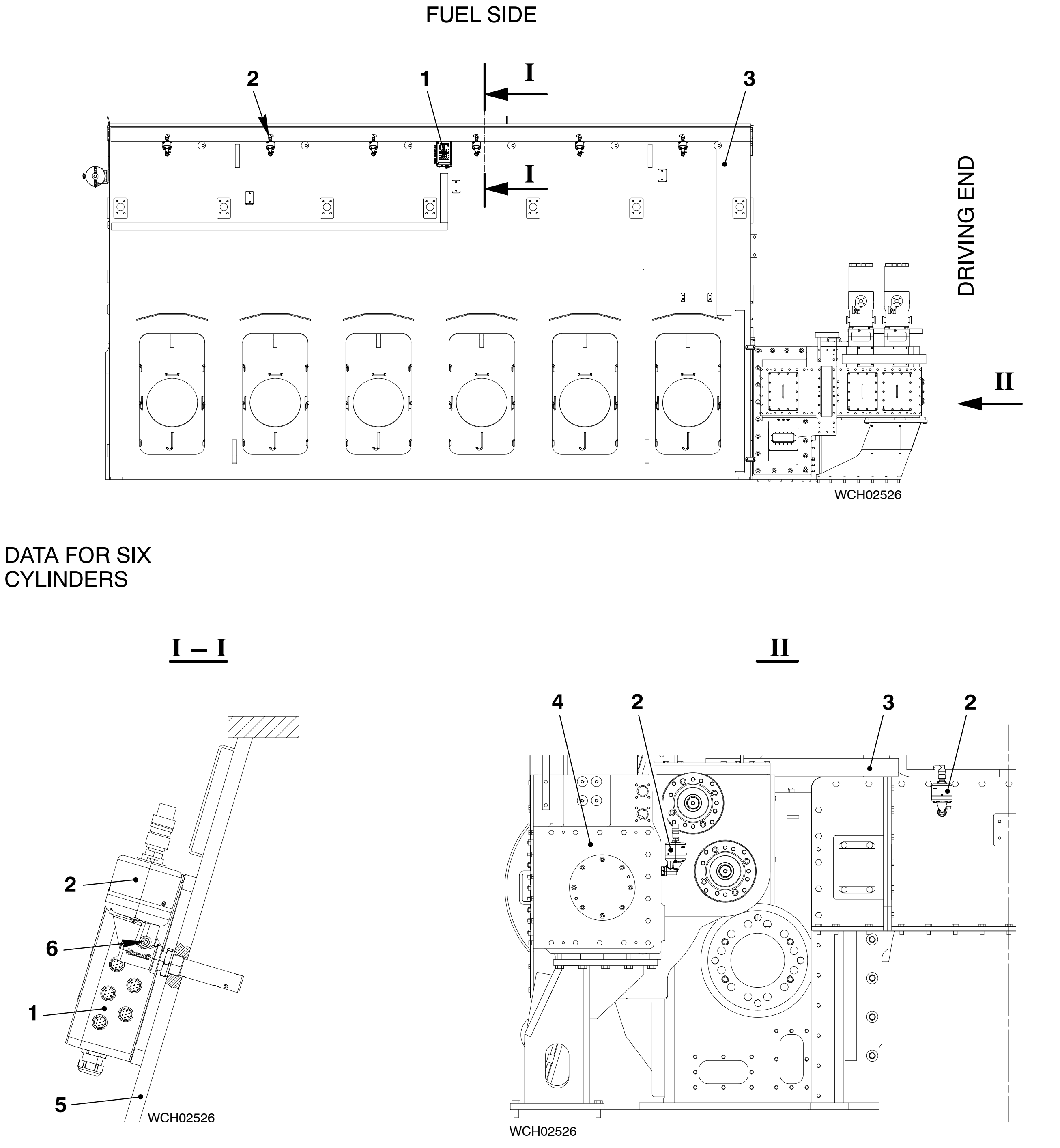

Fig. 1: Location of Sensors

1 Control unit E15.1
2 Sensor
3 Cable guide
4 Supply unit
5 Column
6 Test connection

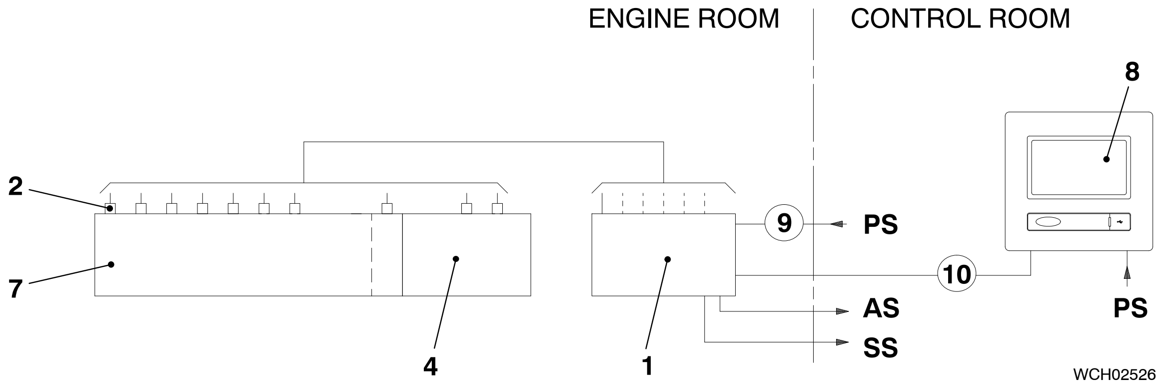

Fig. 2: Schematic Diagram

1	Control unit E15.1	9	Power cable
2	Sensor	10	Data cable
4	Supply unit	PS	Power supply
7	Crankcase and gear box	AS	to alarm system
8	Display unit	SS	to safety system

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Location of ECS Electronic Components

1. General

Most of the electronic components necessary for the engine control system (ECS) are installed on the engine.

The power supply box E85 (not shown) is installed near the engine.

2. Control boxes

Data about the most important control boxes and power supply boxes are given as follows:

2.1 E85

The E85 has the two 230 VAC power supplies for the CCM-20, MCM-11 and the LDU-20. The power supply box E85 also has circuit breakers to isolate the MCM-11 and each CCM-20.

2.2 E90

The E90 control box (10) is attached to the fuel side of the rail unit (1) (see Fig. 1). The control box E90 (shipyard interface box) contains the terminals that give communication to the external systems.

2.3 E25

The E25 local control box (4) is attached to the free end of the engine. The E25 has the local control panel, the LDU-20 and the main control module (MCM-11).

2.4 E95.01 to E95.0#

The control boxes E95.01 to E95.0# are attached to the related cylinders on the fuel side of the rail unit. Each control box has a CCM-20.

Note: The power supplies have redundancy. If it is necessary to isolate the ECS, make sure that each of the two power supplies are set to off (see also 4002-1 Engine Control System, paragraph 2.1).

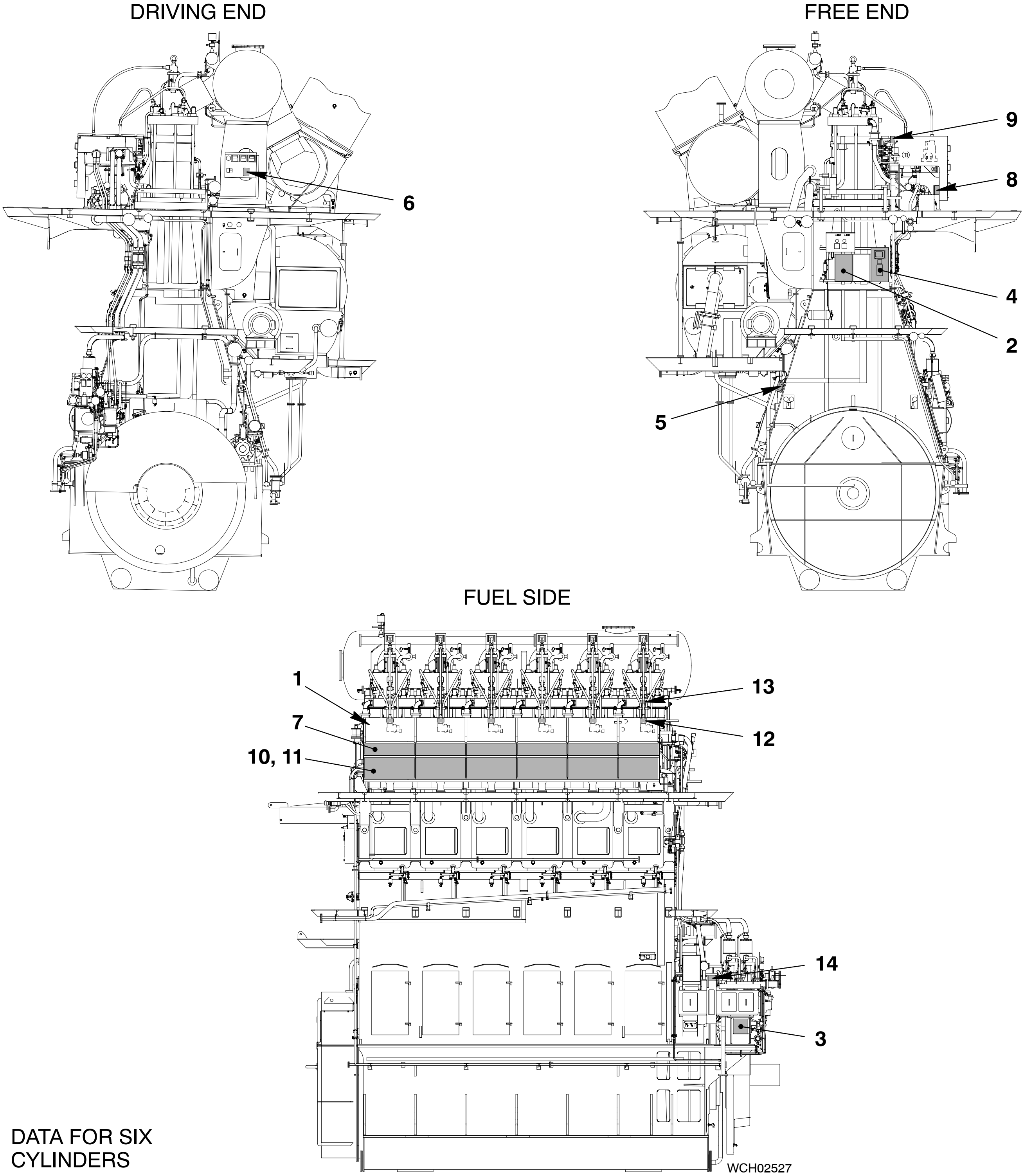

Fig. 1: ECS electronic components

1 Rail unit
2 Terminal box E10
3 Terminal box E20
4 Local control box E25
5 Terminal box E28
6 Terminal box E31 and E32
7 Terminal box E85.0 to E85.4
8 Terminal box E89
9 Terminal box E89.01 to E89.0x
10 Control box E90
11 Control box E95
12 Terminal box E95.41 to E95.4x
13 Terminal box E95.21 to E95.2x
14 Terminal box E98